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HABITAT MOSAIC AND UNDERSTORY BIRD COMMUNITIES IN MEXICAN CLOUD FOREST

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Declaration

I declare that this thesis has been composed solely by myself. The work and results reported within are my own, unless otherwise acknowledged.

Rafael Villegas-Patraca

August 2003, Edinburgh, UK

ABSTRACT

Cloud forest is one of the most threatened ecosystems in Mexico and is important for its high biological diversity and for the ecological services that it provides. The Mexican cloud forests (CF) have been fragmented as a result of anthropogenic activities and deforestation. The south of Mexico contains almost 30% of the country's cloud forest, only a small proportion of which is protected in nature reserves. Conservation effort needs to be focused on the ecological value of agroecosystems that surround nature reserves. The study areas are located in the south of Mexico. Two are in the El Triunfo biosphera reserve in la Sierra Madre de Chiapas, and one is located in the central Region Mountains of Veracruz. The coffee is cultivated in transitional areas between natural forest and adjoining land systems. Based on the type of management, the structure and vegetation, it is possible to distinguish five main coffee production systems: two traditional shaded *agroforests* (with native trees), one commercially oriented *polyspecific* shaded system (where several fruit trees are used as shade), and two "modern" systems shaded (*Inga*) and unshaded *monocultures* (sun coffee). This research attempts to explain the effects of cloud forest patches (natural forest and coffee plantations) on bird diversity.

Bird communities have been surveyed in 4 habitat types by point counts and mist-net techniques. The surveys were taken across a gradient from extensive primary and relatively undisturbed forest to intensive agricultural land uses (coffee plantations). Patterns of bird populations (species richness, abundance, density and community composition) and patch characteristics (size, altitudinal range, and topographic complexity) were analysed over this gradient.

Of a total of 4560 birds recorded in point counts, there were 294 species, 168 genera and 41 families. In the patches of CF, from a total of 256 bird species, 36 were migratory and 53 have some status of conservation. In the patches of coffee plantations from a total of 159 species, 49 were migratory and 52 were under some status of conservation. Forest habitats, including continuous and patch forests, and shade coffee plantations, are found to support the most species and individuals. Nearctic-Neotropical migratory species are most numerous in shade coffee. Bird communities in shade coffee (natural and Inga) are characterised by a higher proportion of frugivorous and nectarivorous species, than communities in native forests. Using mist-net techniques, a total of 105 species, 87 genera and 23 families of birds were captured in 1600 net/hours for all the habitats.

The size of forest patch is the main characteristic affecting forest interior and generalist species. Decreasing forest patch sizes appears to have unfavourable effects on forest generalist birds and positive effects on forest border species. The bird species most sensitive to forest fragmentation are those species restricted to the forest interior. The species richness and abundance demonstrate that many human-altered habitats are potentially valuable for birds. Further conservation efforts in tropical areas need to give more attention to the significance of agricultural lands as wildlife habitats.

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GLOSSARY

Backbone tree. The predominant canopy species in a shade-grown coffee farm

Beneficio. The mill that performs the processing of coffee cherries to produce green coffee beans

Biodiversity. The variety of life on earth and the interconnections among living things

Biogeography. The study of living systems and their distribution

Island Biogeography. The study of the relationship between island area and species number

Biosphere reserves. Established under UNESCO's Man in the Biosphere Program (MAB), biosphere reserves are a series of protected areas linked through a global network, intended to demonstrate the relationship between conservation and development

Biotic. Refers to the living components of the environment (such as plants, animals, and fungi) that affect ecological functions

Bird-friendly. The Smithsonian Migratory Bird Center has trademarked this term to describe environmentally sensitive coffee grown under defined criteria, including a shade spectrum or shade gradient. Among other things, the criteria state a minimum percentage of shade cover, exclude certain genera as backbone trees, and promote diversity by limiting the proportion of *Inga* trees in the canopy

Boundary. The line or zone formed by the edges of two adjacent ecosystems

Buffer zone. As it applies to coffee farming, a wide strip of vegetation along a stream to control erosion and runoff. Also, land that intercepts pesticide and fertilizer drift from non-organic fields

Census. A count of all individuals in a specified area over a specified time interval

CITES species. Species listed under the 1975 Convention on International Trade in Endangered Species (CITES), which is administered by the United Nations Environment Programme. Such species cannot be commercially traded as live specimens or wildlife products because they are endangered or threatened with extinction

Commercial polyculture. Similar to traditional polyculture, but some shade is removed to make room for more coffee shrubs; yields are higher, but some agrochemical inputs (fertilizers, pesticides) are usually needed; generally planted with a distinct backbone species, but more diverse than specialized shade (below)

Community. A characteristic group of plants and animals living and interacting with one another in a specific region under similar environmental conditions

Connectivity. A parameter of landscape function that measures the processes by which a set of populations are interconnected into a metapopulation

Corridor. Vegetation along road and rail reserves and verges, steep uncleared ridges, drain and canal sides, river and creek edges

Constant-effort mist netting. A capture method, standardised over space and time, used for counting numbers of birds captured in mist nets

Deforestation. The large-scale removal of trees from a habitat dominated by forest

Disturbance. Any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment (Turner, 1989)

Diversity. Typically used in relation to species, a single index that incorporates the number of species and relative abundance of species (Pielou, 1977; Wiens 1989)

Ecoregion. A geographically distinct area of land that is characterized by a distinctive climate, ecological features, and plant and animal communities

Ecosystem. A community of plants, animals, and microorganisms that are linked by energy and nutrient flows and that interact with each other and with the physical environment

Edge. Part of an ecosystem near the perimeter that is influenced by the environment of the adjacent ecosystem so that it differs in some characteristics from the centre of the ecosystem

Edge effect. Refers to changes in species composition, distribution and/or abundance found in the edge relative to the interior

Edge species. Species preferring the habitat created by the abutment of distinctive vegetation types

Endangered species. Species threatened with extinction

Endemic species. Species that naturally occurs in only one area or region

Epiphyte. Any plant that does not root in soil but rather uses another plant species for support.

Evenness. The uniformity of abundance between species in a community

Extinct. Refers to a species that no longer exists. Local extinction occurs when every member of a particular population has died. Global extinction occurs when every member of a species has died

Finca. Spanish for "estate," a specific coffee farm, either large or small

Forest fragmentation. Patchwork conversion and development of forest sites (usually the most accessible or most productive ones) that leave the remaining forest in stands of varying sizes and degrees of isolation (Harris, 1984)

Forest-interior species. Species that tend to avoid edge habitats and that require large tracts of forest habitat for nesting and foraging (Whitcomb *et al.*, 1981)

Fragmentation. The breaking up of large habitats into smaller, isolated chunks

Generalist. A species with broad food preferences, habitat preferences, or both (Ricklefs , 1979)

Gliricidia. A short deciduous tree, a legume, frequently used to supply shade for coffee plants, though not used as commonly as *Inga*

Guild. Two or more co-occurring species' populations that exploit the same type of resources in similar ways (Wiens, 1989; Simberloff and Dayan, 1991)

Habitat. The area in which an animal, plant, or microorganism lives and finds the nutrients, water, sunlight, shelter, living space, and other essentials it needs to survive

Habitat fragmentation. The alteration of a large habitat patch to create isolated or tenuously connected patches of the original habitat that are interspersed with an extensive mosaic of other habitat types (Wiens, 1989)

Habitat patches. Areas distinguished from their surroundings by environmental discontinuities (Wiens, 1976)

Habitat selection. Preference for certain habitats (Ricklefs, 1979)

Heterogeneity. The variety of qualities found in an environment (habitat patches) or a population (Ricklefs, 1979)

***Inga*.** One of a genus of commonly used shade tree. It is a legume which provides good shade, and is regularly planted as an overstory tree in structured shade coffee plantations throughout the Neotropics

Islands. Areas of vegetation which are unconnected to other native vegetation

Keystone species. A species whose abundance dramatically alters the structure and dynamics of ecological systems (Brown and Heske, 1990)

Landscape. The landforms of a region in the aggregate; the land surface and its associated habitats at scales of hectares to many square kilometers (for most vertebrates); a spatially heterogeneous area (Turner, 1989; Dunning *et al.*, 1992)

Landscape change. Alteration in the structure and function of the ecological mosaic of a landscape through time (Turner, 1989)

Landscape complementation. Changes in population caused by the relative distributions of habitat patches containing non-substitutable resources in a landscape. (Dunning *et al.,* 1992)

Landscape composition. The relative amounts of habitat types contained within a landscape (Dunning *et al.*, 1992)

Landscape ecology. Field of study that considers the development and dynamics of spatial heterogeneity, interactions and exchanges across heterogeneous landscapes, the influences of spatial heterogeneity on biotic and abiotic processes, and the management of spatial heterogeneity (Turner, 1989)

Local extinction. Disappearance of a population from a habitat patch or local area. Local extinctions can accumulate into regional extinctions and finally global extinction (Merriam and Wegner, 1992).

Matrix. The background land use or vegetation in a landscape: that ecosystem-type which is most extensive so that others appear as patches or corridors within it

Measurement bias. A systematic under- or overestimation of the true values due to a difference between the actual measurement and what one intends to measure (Gilbert, 1987)

Metapopulation. A collection or set of local populations living where discrete patches of the area are habitable and the intervening regions are not (Gilpin, 1987); basic demographic unit composed of a set of populations in different habitat patches linked by movement of individuals (Merriam and Wegner, 1992)

Migration. Regular, extensive, seasonal movements of birds between their breeding regions and their "wintering" regions (Welty, 1975)

Mountain-grown coffee. The more-favored arabica prefers higher altitudes, and the grading systems of some producing countries account for elevation. The term "high grown" is also used. Generally means coffee grown above 4,000 feet. Associated with a denser, harder, more flavorful bean because the fruits mature more slowly. High-elevation coffee is often shaded by near-constant cloud cover rather than a leafy canopy

Moult. Shed fur or feathers (for example, foxes moult their thick winter fur in summer, regrowing the fur over the summer in preparation for the following winter)

Natural Shade Coffee. The least intensified practice; coffee shrubs are planted in the existing forest with little alteration of native vegetation; also the least expensive practice, typically used by small family-owned farms that produce a modest crop of coffee. This is an increasingly rare practice and usually does involve some thinning of the canopy

NGO. Non-government organization. Any local, national, or international organization, profit or non-profit, whose members are persons not employed by a government

Neotropical migrant. A migratory bird in the Neotropical faunal region. The Neotropical Migratory Bird Conservation Program focuses primarily on species that nest in the Nearctic faunal region and winter in the Neotropical region (Stangel, 1992)

Organic. Produced by an approach that views the farm as an ecosystem. Emphasis is placed on recycling, composting, soil health, and biological activity with the goal of long-term protection of the farm environment. Synthetic chemicals are rigorously avoided

Organically-grown coffee Is not necessarily shade-grown, but it usually it is. This is because the trees of the canopy provide several necessities to the organic coffee farm, among them leaf litter (which acts as a fertilizer), resident wildlife species that control pests, and the retention of moisture

Remnant vegetation. Any patch of native vegetation around which most or all of the native vegetation has been removed. It may include corridors or islands of vegetation located on land with a variety of tenure

Patch. A non-linear habitat type that differs from the surrounding vegetation

Point count method. Count of contacts recorded by an observer from a fixed observation point and over a specified time interval (Ralph, 1981)

Polyculture. More managed than rustic coffee involving deliberate integration of beneficial plants (fruits, vegetables, nuts, medicinal plants, etc.), and resulting in greater species diversity than commercial polyculture; the crop diversification helps farmers in years when coffee prices are depressed; in many traditional indigenous systems there is no distinction between wild and domesticated plants and some plants are weeded, tolerated, or encouraged depending on household needs and the season

Population. A group of coexisting (conspecific) individuals that interbreed if they are sexually reproductive (Sinclair 1989)

Relative abundance. A percent measure or index of abundance of individuals of all species in a community (Ralph, 1981)

Resident. Inhabiting a given locality throughout the year, sedentary (Welty, 1975)

Shade-grown coffee, shade coffee. A term with no clear-cut definition, generally referring to coffee grown under a natural canopy and to farming practices nearer the "rustic" end of the shade spectrum

Sink habitat. Habitat in which reproduction is insufficient to balance local mortality Pulliam, 1988)

Sink population. A population that occupies habitat types in which reproductive output is inadequate to maintain local population levels. (Wiens and Rotenberry, 1981)

Slash and burn\agriculture. An agricultural system in which farmers periodically clear land for farming by cutting and burning patches of forest

Specialist. A species with narrow food preferences, habitat preferences, or both (Ricklefs, 1979)

Species. A group of actually or potentially interbreeding populations that are reproductively isolated from all other kinds of organisms (Ricklefs 1979)

Specialist species. A species that has a narrow ecological niche

Species-area relationship. A plot (often log-log) of the numbers of species of a particular taxon against area, such as islands or other biogeographic regions (Brown and Gibson, 1983)

Species richness. Number of species in a given area (Ralph, 1981)

Sun coffee or unshaded monoculture. Coffee grown without the canopy; the unshaded intensively-managed fields are highly productive if given the requisite agrochemical inputs

Sun coffee. Used to describe coffee that is not shade-grown, and generally used disparagingly—often neat rows of coffee beneath direct sun or scant shade, compared to the fuller canopy of a traditional farm

Survey. An enumeration or index of the number of individuals in an area from which inferences about the population can be made (Ralph, 1981)

Sustainable. For coffee agriculture and resource development, the term implies concern both for labourers' working conditions and for trading practices and land tenure systems that do not impoverish farmers—as well as sensitivity to the environment, minimization of pollution, and independence from non-renewable energy sources

Technified coffee. The word "technification" is a back-formation from the Spanish tecnificación. The practice of technification was spurred by the spread of coffee leaf rust to the New World in the 1970's; technification projects were assisted by the United States Agency for International Development (U.S.–AID). Technification goes beyond the intensive management of shade and shrubs to the application of agrochemical inputs and the introduction of higher-yielding, disease-resistant varieties of coffee that respond well to those inputs

Threatened species. "Threatened species" is a generic term for a plant or animal generally considered as vulnerable or endangered under various threatened species conservation laws. It is used to indicate that there is some level of threat as to the species viability in the wild

Trophic guilds. Groups of organisms that are similar in their nutritional requirements and feeding habits

Trophic. Pertaining to food or nutrition (Ricklefs, 1979)

Trophic structure. Organization of the community based on feeding relationships of populations (Ricklefs, 1979)

Variance. A statistical measure of the dispersion of a set of values about its mean (Ricklefs, 1979)

Acronyms

AICA	Area de Importancia para la Conservacion de Aves
CIB	Centro de Investigaciones Biologicas
CIPAMEX	Consejo para la Proteccion de la Aves.
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CONABIO	Comisión Nacional Para el Conocimiento y Uso De La Biodiversidad
CONOPAN	Comision Nacional de Obras en Parques Naturales
ETBR	El Triunfo Biosphere Reserve
IDESMAC	Instituto para el Desarrollo Sustentable de Mesoamerica
INMECAFE	Instituto Mexicano del Café
INEGI	Instituto Nacional de Estadistica Geografia e Informatica
IUCN	International Union for Conservation of Nature and Natural Resources
MAB	The Man and the Biosphere Programme
SARH	Secretaria de Agricultura y Recursos Hidraulicos.
SEDUE	Secretaria de Desarollo Urbano y Ecologia
SINAP	Sistema Nacional de Areas Naturales Protegidas

UNAM	Universidad Nacional Autonoma de Mexico.
UNESCO	United Nations Educational, Scientific and Cultural Organization
UTM	Universal Transverse Mercator

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CHAPTER 1

Introduction

1.1 General Introduction

Natural ecosystems in the tropics are being transformed rapidly as a result of human activities. This transformation of undisturbed tropical forest into an agricultural mosaic has meant the disappearance, fragmentation and isolation of local biological populations (Estrada *et al.,* 1993; 1994). As this trend continues, it has been pointed out that the role of agroecosystems in conserving biological diversity may become very important. Estimates reveal that managed agricultural, forest ecosystems and human settlements, cover approximately 95% of the terrestrial environment (Pimentel *et al.,* 1992). Given this situation, it is clear that biodiversity cannot be effectively conserved in protected areas alone (Moguel and Toledo, 1999). Structurally complex agricultural systems, especially those that include trees, are becoming increasingly important as a suitable habitat for many species (Greenberg, 1996; Greenberg *et al.,* 1997b; Vandermeer and Perfecto, 1997; Calvo and Blake, 1998).

At least 40% of the original tropical forests have been converted to other land uses. The loss of tropical broadleaved forests (Myers, 1980; Lanly, 1982) and the concurrent population declines of migratory land-birds that breed in temperate North America and over-winter in the tropics (Robbins *et al*., 1986) have been closely linked, in both the scientific and the popular literature. The conversion and fragmentation of moist tropical forests has been convincingly implicated in population declines of permanent resident tropical bird species (Willis, 1974; Lovejoy *et al.,* 1984; Thiollay, 1992), but impacts of tropical deforestation on migratory species that breed in North America are more open to doubt. The over-wintering period could be a time of intense selective pressure on neotropical migrants for a number of other reasons, such as mortality associated with stress from migratory flights, occupation of unfamiliar habitats by juvenile birds, and increased competition for food due to inflated densities of potential competitors (Morse, 1980).

The transformation of contiguously forested landscapes into landscapes comprising a mosaic and non-forest habitats causes changes in the population size of some bird species and alters the composition of bird communities (Robinson and Wilcove, 1994; Faaborgh *et al.,* 1993). The responses of birds to such habitat modification vary between species, with some forest bird species suffering from increased levels of nest predation and brood parasitism (Brittingham and Temple, 1983; Donovan *et al.*, 1995; Robinson *et al.*, 1995). Most investigations of landscape transformation have focused on large-scale fragmentation events and their effects on forest interior birds. However, the process of landscape fragmentation, typically begins with the creation of small internal openings within a forested landscape, a process called perforation (Forman, 1997). Such internal openings potentially have little overall effect on bird population and community composition because of wide spatial scale overlap with natural openings such as treefall gaps. Little information is available, however, on the effects of edge characteristics on forest bird populations (Annand and Thompson, 1997).

The recent tendency in agricultural extension services in some countries has been to recommend the cultivation of coffee without shade trees, in order to gain the highest possible yields (Beer, 1987), but there are few studies of the effect of this practice on the local fauna. This research is focusing on the effects of different kinds of coffee plantations on the understory bird communities in two regions of Mexico: Veracruz and Chiapas. In the central region of the state of Veracruz , coffee plantations are the most important economic activity. There are 49,000 ha which produce 49% of the coffee in the State (Marchal and Palma, 1985). However, there are few ecological studies in the region: one on birds (Aguilar- Ortiz, 1982), one on mammals (Gallina *et al.*, 1996) and the rest on vegetation (Jimenez Avila, 1979; Jimenez Avila and Correa Peña, 1980; Jimenez Avila and Gomez-Pompa, 1982;). With the recent decline in the international price of coffee, there is a tendency to convert these plantations to other crops such as sugar cane, and this change has had a negative effect on the bird fauna.

In Chiapas, the buffer zone of the El Triunfo biosphere reserve, located in La Sierra Madre of Chiapas, maintains one of the major areas of coffee production of Mexico. The buffer zone has a total area of 94 000 ha and over 30 000 ha are occupied by coffee plantations. In this region coffee plantation is the main economic activity for local people and it has a great importance at national level. Between 1999 to 2001 Chiapas produced 35% of the national coffee production. A few studies on birds have been made at El Triunfo biosphere reserve, some of them have mainly focused on key species such as the horned guan (*Oreophasis derbianus;* Andrle, 1967; Alvarez del Toro 1976; Gonzalez-Garcia, 1984, 1993, 1994), the quetzal (*Pharomachrus mocinno*; Avila and Hernandez, 1990, 1996), the azure-rumped tanager *(Tangara cabanisi*; Heath and Long, 1991) and the black penelopina (*Penelopina nigra*; Jimenez, 1993). Other research has involved bird communities and their ecological relationships, such as the study on frugivory and avian aspects in the cloud forest, or checklists of bird species such as that of Parker *et al.*(1976) who reported 88 bird species, mainly in cloud forest areas. The Natural History Institute in Chiapas has, during the last 10 years, made a compilation of 362 bird species over the whole of the biosphere reserve area. The last census done in the reserve, including a survey in the tropical rain forest, cloud forest and coffee plantations, reported 365 bird species (personal comunication, Tejeda, Avila and Cartas). However there is not enough information about the effect of habitat mosaic (including patches of coffee plantation and natural forest) on bird communities. In contrast to Veracruz, in Chiapas the coffee production has not declined in recent years.

1.2 Context of Research

1.2.1. Biodiversity Problems

The degradation of ecosystems throughout the world, but especially in tropical regions, has been widely reported and is now well documented. The loss of tropical forest cover can have far reaching effects including changes in regional climate patterns (especially rainfall), changes in biological productivity and acceleration in rates of soil erosion. In terms of biological diversity, the destruction of tropical forest causes extinction of vast numbers of species. Biodiversity loss is a biological problem, but the root causes of the problem include sociological and economic processes that operate on a global scale. An understanding of the phenomenon would require the investigation and clarification of both biological and social components, and international cooperation will be necessary to develop both scientific knowledge and successful management strategies (Jablonski, 1991).

The current loss of biodiversity has several causes, the direct destruction, conversion, or degradation of ecosystems results in the loss of entire assemblages of species. Over-exploitation, habitat disturbance, pollution, and the introduction of exotic species accelerate the loss of individual species within communities or ecosystems. Moreover, selective pressure arising directly and indirectly from human activities can result in the loss of genetic variability. Exploitation, habitat alteration, the presence of chemical toxins, or regional climate change may eliminate some genetically distinct parts of a population, yet not cause extinction of entire species (McNeely *et al.*, 1990; Soule, 1991).

However the most important single factor affecting biodiversity on all of ecosystems is the accelerated rate of habitat destruction, particularly in tropical forest. When an area of forest is cut and the land is converted to intensified use, such as agriculture, pasture or plantation forest, most of the species living in it cannot survive in the replacement system. When any habitat type is reduced to small patches, the organisms that depend on it are in greater danger of extinction and their populations are reduced in number, isolated, and subject to the highly altered impacts of sun, wind, water, soil conditions, others organisms, and human beings. These factors selectively affect small patches of any habitat and so reduce the biodiversity (Harris, 1984; Saunders *et al.*, 1991).

1.2.2. Deforestation

In many countries, especially in the developing countries of the Southern Hemisphere, systematic burning, grazing and cutting of forest-land is carried out in order to provide new land for agricultural or livestock purposes. It is usually done without studies of climate and topography and on lands where the nature of the soil physiographic characteristics or other physical attributes clearly indicate that the land involved is suitable only for forest. Although this practice may lead to a temporary increase in productivity, there are also many indications that in the long term there is usually a decrease in productivity per unit of surface and that erosion and irreversible soil deterioration often accompany this process. At the present rate of deforestation, an estimated 15% of all species could disappear within the next two decades. Many factors contribute to deforestation: timber production, clearance for agriculture, cutting for firewood and charcoal, fires, droughts, strip mining, pollution, urban development, and population pressures (Sandbukt, 1995; FAO 1988, quoted by Sharma, 1992).

As people seek land to cultivate, timber for fuel and raw materials for their industries, they turn to tropical forests which are being destroyed at an unprecedented rate. This loss and degradation is creating numerous economic, social, and ecological problems and it is the world's poorest people who are the most severely affected. Major repercussions of deforestation include: intensified seasonal flooding with resultant loss of lives and property; water shortages in dry seasons; accelerated erosion of agricultural lands; silting of rivers and coastal waters; the disappearance of plant and animal species; and local and regional climate modifications. In many tropical forests, the soils, terrain, temperature, patterns of rainfall and distribution of nutrients are in precarious balance, and neither trees nor grasses will grow again once extensive cutting disturbs them. Even in those places where re-growth is possible, extensive clearance destroys the ecological diversity from the original forest (FAO 1988, quoted by Sharma, 1992).

In the past, most forest losses were in the temperate forests of Europe, Asia and North America. In recent years, it is the tropical forests of Latin America, Asia and Africa that have been disappearing most rapidly. The rate of forest loss in 1987 was nearly 50% greater than in 1980. FAO has estimated that tropical forests are being removed at the rate of 7.3 million hectares per year. Brazil, with the largest remaining forest area, has experienced the most rapid losses (15 000 square kilometres of trees were cleared annually from 1978 to 1988, although in preceding years, the annual clearance was 250% greater). In 1990 it was estimated that each year, 16 to 20 million hectares of tropical forest have disappeared as trees are cut for timber and land is cleared for agricultural development (Rietbergen, 1993). On the basis of the current rates of deforestation, it is plausible that natural tropical forests will largely disappear over the next 100 years. Their conversion into vast expanses with little vegetative cover is not entirely improbable. These changes would imply extensive regional and global changes in climate (Whitmore, 1990).

Tropical forests are the world's richest biological zones and are estimated to contain as much as 40% of all the terrestrial species on the planet. In addition, tropical forests produce a significant proportion of the world's oxygen and provide a wide range of useful products (fuelwood, building materials, pulpwood, food, pharmaceuticals, resins, gums, dyes) of economic significance for both developing and developed countries. While tropical deforestation has been extensive over the past few decades, forest clearing is rarely complete and often not permanent, thus patches of primary, secondary, and managed forest remain in many agricultural landscapes (Myers, 1986; Peters, 1990; Poore and Sayer, 1991).

1.2.3. Forest Fragmentation

Habitat fragmentation can be characterised as a break up of a continuous landscape containing large patches into smaller, usually more numerous and less-connected patches. Much of the work that has sought to measure landscape pattern and habitat fragmentation comes out of the disciplines of conservation biology and, especially, landscape ecology. These disciplines are founded on the premise that landscape patterns strongly influence and are influenced by ecological processes (Forman and Gordon, 1986). Wilcox (1980) defines habitat fragmentation as including two components, the habitat destruction itself which is a requisite part of creating fragments, and the isolation which is the result.

Fragmentation exposes the forest organisms to an increased “edge effect”, bringing with it increased light levels, invasion by open country species, and dry winds (Schelhas and Greenberg, 1996). Fragmentation of the landscape produces a series of remnant vegetation patches surrounded by a matrix of different vegetation and land use. Two primary effects of this are an alteration of the microclimate within and surrounding the remnant and the isolation of each area from other remnant patches surrounding landscape. Thus in a fragmented landscape there are changes in the physical environment as well as biogeographic changes. All the remnants are exposed to these physical and geographic changes to a greater or less degree, but their effects are modified by the size, shape, and position in the landscape of individuals remnants (Saunders *et al.,* 1991). A forest patch may be too small to provide resources for animals with large home ranges. More often, a forest patch can support only small populations, which are prone to local extinction from a variety of factors, including stochastic variation in population size. Low population size introduces a number of potential additional problems related to the loss of genetic diversity. Sensitivity to fragmentation will vary considerably between species, depending on the degree of ecological specialisation, body size, and movements, patterns features that are poorly understood for most tropical organisms (Schelhas and Greenberg, 1996).

The most important cause of habitat fragmentation is more related to human consumption of resources than natural disturbance regimes. Consumption of resources has risen as human populations have grown. Inversely, the efficiency of resource use has decreased. The result has been increasing exploitation of natural resources. Through manipulation of ecosystems, humans have fragmented or completely lost important habitats for unknown numbers of species (Whitmore and Sayer 1992). Although large areas of the tropics have been converted to mosaics of fields, pastures, and forest patches, it needs to be recognised that it provides a wide range of benefits to rural people (Schelhas and Greenberg, 1996).

Reduction of forest patch area and isolation effects

Habitat fragmentation affects the flora and fauna of a given ecosystem by replacing a naturally occurring ecosystem with a human-dominated landscape which may be inhospitable to a certain number of the original species. However, in direct contrast to the ocean as a geographic barrier, the human landscape matrix is typically accessible to flora and fauna, in that they are able to disperse easily across it, if not reside within it (Keller and Anderson, 1992). On the other hand, the human landscape may directly contribute to the extinction of species within habitat islands by slanting the ecosystem balance in favour of species which are highly adaptable to changing conditions. For example, the increased amount of human-dominated landscape allows certain species to grow successfully, which can result in deterioration to species which depend exclusively on patch interior habitat. A frequently cited example is the parasitic brown-headed cowbird *(Molothrus ater)*, populations of which have increased dramatically since humans began altering the landscape on a large scale in North America. Brown-headed cowbirds are nest parasites, which by definition replace the eggs of another species with eggs of their own, allowing the other bird species to unknowingly incubate and raise their young. Their increased numbers have had negative effects on the reproductive success of many forest-dwelling songbirds (Mayfield, 1975).

In addition to swaying the ecosystem balance in favour of species which are highly adaptable, the loss of habitat associated with habitat fragmentation may simply cause interior species populations and ranges to decline. Saunders (1989) documented one example of how changing large expansive areas of intact habitat into fragmented islands affects avifauna. He researched changes in the avifauna of the wheatbelt of Western Australia as a result of fragmentation. He showed that 41% of the birds native to the region have decreased in range or abundance since the 1900's and indicated that almost all of these changes resulted directly from habitat fragmentation and the decline in abundance of native vegetation. Although some species have increased in abundance, he noted that many more species have been adversely affected than have benefited. Importantly, the species that typically increase in abundance or range when habitat fragmentation occurs are those which are known for being adaptable. In other words, their resource needs can be met by a variety of conditions, and thus often benefit by human activities by reducing their competition with other species. Because of this, those species which benefit by human activities are not the ones we necessarily need to manage or protect. Instead, we need to protect those species which are adapted solely for survival in the rapidly disappearing unfragmented habitat (Harris, 1984).

The tendency for inbreeding and loss of genetic variability, which results from isolating subpopulations of plants and animals from each other as a result of habitat fragmentation, exists in both tropical and temperate communities. If the distance between the fragments is too large and a species is unable to disperse across the area in between, the population is essentially divided. Inbreeding may result if the subpopulation in a given fragment is small. This has not been directly documented, but the potential exists (Harvey and Lyles, 1986). Loss of genetic variability can occur even without inbreeding, however, and the resultant homozygosity in certain genes can lead to an evolutionary dead end for a species (Soule, 1986). In order to increase exchange between fragments, many wildlife managers employ the use of corridors which interconnect two or more habitat islands. According to the research of MacClintock *et al.* (1977) corridors enhance species richness of breeding birds, and increase the travel of seed-dispersing wildlife (Harris, 1984). Corridors may constrain the loss of genetic variability and allow dispersal of species between fragments, but the diminishing of native ecosystems into fragments continues. This decrease in size of native ecosystems can only be detrimental to the species that depend on them for survival.

Effects on species diversity

Studies on edge effects suggest that species composition and abundance patterns will change in fragmented landscapes. For example birds characteristic of forest interior habitats may be unable to maintain their population in landscapes where edge is abundant. Instead, the landscape may gradually become dominated by edge-adapted species not in great need of conservation (Blake, 1991). Species composition is altered in fragmented landscapes because some species are more vulnerable than others to reduced area, increased isolation, edge effects, and other factors that accompany the fragmentation process. Species loss from fragmented habitats, then, may follow a predictable and deterministic sequence (Patterson, 1987; Blake 1991). In studying habitat patches of various sizes, a pattern of nested subsets in the distribution of species is often observed. Nested subsets is a biogeographic pattern in which larger habitats contain the same subset of species found in smaller habitats but with added new species to that subset. These species, those only present in large areas, are generally the most vulnerable to fragmentation.

Distribution of bird species among woodlots in agricultural landscapes is typically non-random; the species found in small woodlots are also found in the larger patches. A similar non-random pattern, would be where all species occupy large patches but many of the species are absent from small patches. Studies of birds on the wheat-belt of Western of Australia have documented the loss of many species in small habitat remnants since isolation (Saunders, 1989). Such results support previous suggestions that, although a collection of small sites may be a refuge of more species, large sites are that, although a collection of small sites may be a refuge of more species, large sites are needed to maintain populations of species sensitive to human disturbance. Nested species distribution patterns do not always have a direct explanation. There can be other reasons for nested subsets besides a predictable sequence of extinction as habitats are progressively fragmented.

Tropical communities are often more susceptible to loss of biological diversity than temperate communities, because tropical species are typically found in lower densities, are less widely distributed, and often have weaker dispersal capabilities (Wilcove *et al.,* 1986). Many tropical species have evolved complex mutualisms, plant-pollinator, plant-seed disperser, and parasite-host relationships in which local extinction of one of the species involved inevitably leads to the extinction of the other. The cassowary (*Casuarius casuarius*), an Australian rainforest frugivore, is extremely susceptible to local extinction by habitat fragmentation because its habitat requirement for large contiguous rainforest areas is compounded by its unique plant-seed disperser mutualism. This bird wanders nomadically in search of episodic fruiting events. The cassowary serves as one of only a few dispersers of very large seeds, many of which need to be scarified (digested) before they will germinate. The extinction of cassowaries from rainforest fragments will inevitably lead to the extinction of the trees or plants which rely on them as a seed scarifier/disperser (Laurance, 1991). Besides being home to extinction-prone species, tropical communities are liable to destruction and fragmentation because of their physical location, overlapping the geographical borders of third world countries. In these countries, citizens often rely on the revenue raised from rainforest timber or cattle raised on cleared rainforest land for survival. This constant pressure on rainforest communities leads to excessive habitat fragmentation. Small isolated fragments result, leading to an altered ecosystem balance. On the tropical island of Java, where almost the entire original habitat remaining exists in reserves, ecologists Thiollay and Meyburg (1988) assessed the status of all the raptors found in the rainforest habitat. Nearly all the raptors were extremely rare outside the reserves, as expected. They also found that the larger a reserve was, the denser the raptor populations within the reserve. Lovejoy *et al.* (1986) found a similar phenomenon with Amazonian birds in the Biological Dynamics of Forest Fragments Project (formerly Minimum

Critical Size of Ecosystems) in Brazil. The primary goal of the BDFF project is to discover how rainforest communities respond after an intact ecosystem is split into different size fragments. They found a cluster effect, in which the abundance of birds in a forest fragment increased significantly directly after deforestation of the adjacent area. The increased number of birds was attributed to the migration of birds from the newly clear-cut area to the forest fragment. This crowding effect decreased with increasing size of a forest fragment.

1.2.4. Edge effects

One of the most obvious features of fragmented landscapes is the increase in forest edge. In continuous forest, habitat edges are rare, typically limited to small internal clearings created by landslides, river meanders, or other natural disturbances (Laurance, 1997). But in a heavily fragmented landscape, forest edges become a major feature. The margins of forest fragments are usually abrupt, delineating a sudden transition from forest to pastures, crops, or other modified habitat. Researchers are becoming convinced that edge effects often have a major impact on the ecology of fragmented tropical forest. Edge effects can be classified into physical and biotic phenomena (Kapos *et al.,* 1997). In rainforest, physical edge effects can include elevated wind turbulence and temperature variability, lateral light penetration, and reduced humidity, all of which result from the close proximity of a harsh external climate in the surrounding matrix. Biotic effects include the proliferation of secondary vegetation along forest margins, invasion of weedy or generalist plants and animals, alteration of ecological processes such as nutrient cycling and energy flows, and a myriad other ecological changes (Murcia, 1995). The ecological consequences of edge effects in fragments can be grouped into three types: 1) abiotic effects, involving changes in the environmental conditions that result from proximity to a structurally dissimilar matrix; 2) direct biological effects, which involve changes in the abundance and distribution of species caused directly by the physical conditions near the edge and determined by physiological tolerances of species to the conditions on and near the edge; and 3) indirect biological effects, which involve changes in species interactions, such as predation, brood parasitism, competition, herbivory, and biotic pollination and seed dispersal.

The size of a fragment and the amount of edge are linked. Abrupt edges often result from fragmenting an ecosystem, in contrast to the more gradual natural ecotones. Edges have positive impacts on many species of plants and animals; the typical species which benefit are those which do not require human protection and management because they can easily meet their resource needs outside of the intact ecosystem. Edge has typically been associated with an increase in species richness; however researchers are increasingly documenting how the edge effects are negatively affecting the native biota. Harris (1984) points out that although the number of species may be higher in edge than in the adjacent interior habitat, species diversity usually is not. Diversity takes into account not only the number of species, but the relative abundance and dominance of the species present. Another potentially adverse effect of edge is that it inherently reduces the size of the habitat (eg. forest interior) because of the many physical changes which occur where an edge is bordering on a human-dominated area. Most documented cases of edge effects are from forest edges. In addition to the abundant growth of shade-intolerant vegetation at a forest edge in response to the increase in available light, a "seed rain" bombards the forest interior, often from introduced exotics. The increased exposure to wind causes a higher rate of treefalls, tree mortality, and temperature and humidity are quite different at the edge than in the forest interior (Lovejoy *et al.*, 1986; Laurance 1991). These physical changes necessarily impact on the biota of the habitat.

Several authors have suggested that the abundance of birds decreases near an artificial edge due to decreased nest success. Nest success near the edge decreases because of the increase in generalist predators and brood parasites (Mayfield, 1975; Andren and Angelstam, 1988). Populations of brown-headed cowbirds, a brood parasite, have increased as a direct result of human activity. These birds have had a negative impact on the nesting success of forest songbirds in North America that nest near the forest edge (Mayfield, 1975). Studies show that while vegetational changes may extend from 10-30 m into a forest, faunal effects may extend 300-600 m into a fragment (Wilcove *et al.*, 1986). This is important considering that although generalist predators such as grackles, racoons, cowbirds, and chipmunks may concentrate their activity near the edge, they certainly also can frequent the forest interior, often to the detriment of those species which rely exclusively on forest interior.

In order to reduce the penetration of far edge effects into a natural habitat, Harris (1984) proposed a system of long-rotation islands, in which an old-growth centre is surrounded by various age stands of timber. This system provides some edge for those species which benefit from it, while minimising the amount of edge between the old-growth centre stand and the surrounding stands. In general terms, the creation of edge and the reduction in area of intact ecosystems are obvious results of habitat fragmentation on the landscape. But it is not clear how these factors affect the flora and fauna of a given region. These factors may positively affect some species and negatively affect others. For that reason it is important to continue the research on the effects of edge creation to enhance understanding of how habitat fragmentation affects flora and fauna of various habitat types.

1.2.5. Island biogeography

The creation of habitat "islands" in a human-dominated landscape has been termed insularisation by Wilcox (1980). Habitat islands are often compared to oceanic islands, and several scientists have extended the theory of island biogeography (MacArthur and Wilson, 1967) to these mainland islands. Island biogeography predicts the number of species that should occur on a given "island" based on immigration and extinction rates. Species mobility, distance from a colonising source, and surplus population at the source determine rates of immigration, whereas rates of extinction depend on island size, population dynamics and biological characteristics of the species involved. This theory predicts a dynamic equilibrium number of species on an island, which is ultimately determined by the competing factors of immigration and extinction. Island biogeography can be applied to landscape fragmentation as a model of how small habitat islands can be before adversely affecting the biological diversity of the original habitat (Harris, 1984). This theory is thus very important in the design of nature reserves, as it provides a quantitative guideline for reserve size and connectivity between neighbouring reserves, based on the ecological characteristics of a given region (Diamond, *et al.* 1987). However, island biogeography does not address the influence of edge on the number of species in a given island.

As human destruction of remaining natural habitats accelerates, biologists have felt that most existing wildlife refuges are too small to avoid the extinction of numerous species (Diamond, *et al.* 1987). However, because there has not been a firm basis for even approximately predicting the extinction in refuges, decision makers have had difficulty convincing government planners faced with conflicting land use pressure of the need for large refuges. In recent years many researchers have recognised that a understanding of extinction might be obtained from island biogeography, since refuges of natural habitat in a sea of human altered environments behave as islands for species dependent on natural habitat. In terms for conservation strategy many researchers have concluded that some large refuges are essential to minimise extinction rates and to ensure certain species any chance of survival at all.

Conservation strategy must focus on species and habitats threatened by human activities, such as the understory bird species that inhabit patches of natural forest surrounded by coffee plantations. On the basis of these issues, the present research analyses the effects of increasing forest disturbance and bird populations with a view to quantifying the impact and suggestion how such knowledge can be utilised to improve management and conservation.

1.3 Aims

The specific objective of this research project was to investigate and compare the effects of cloud forest conversion on the understory bird communities in different types of coffee plantation. The research was carried out in two areas in Southern Mexico (central Veracruz and Chiapas in "El Triunfo" biosphere reserve) where coffee production is one of the most important activities. A mosaic of different habitats such as cloud forest, natural shade coffee, Inga shade coffee and sun coffee were surveyed in both study areas. The detailed objectives were:

1) To describe and compare the composition of the understory bird communities occurring in the cloud forest and in the different types of coffee plantation (natural shade coffee, Inga shade coffee and sun coffee) at both study sites. This is achieved by identifying the understory bird species detected and assessing the bird species richness in each of the four surveyed habitats.

2) To assess the composition of the understory bird community occurring in the four different habitats, in terms of distribution of species by trophic guilds, dietary specialisation, trophic-behavioural guilds, use of forest strata, level of restriction to cloud forest and its interior, distribution range, endemicity, resident/migratory status, level of rarity, and conservation status.

3) To determine patterns of distribution of migratory, and resident (adult and juveniles) birds in the four different habitats.

4) To evaluate the effects of patches size, altitudinal range, and canopy complexity on the understory bird community in the four different habitats.

5) To determine the effects of habitat mosaic on understory bird species, focusing on the habitat preferences (in cloud forest, natural shade coffee, Inga shade coffee and sun coffee). This should permit the identification of habitats that are unique in terms of their species composition and/or their contribution to the conservation of species diversity. In fauna, this information helps to improve management and land use policy.

1.4 Structure of the thesis

In the first chapter the background issues like the effects of deforestation, forest fragmentation are explained. The nature of the coffee productivity and its effects on forest fragmentation and biodiversity in Mexico is examined in chapter 2. In chapter 3 the unique characteristic, importance and current situation of cloud forest for conservation is assessed, this leads to a discussion of protected areas in Mexico and it the particular role played by the cloud forest. Chapter 4 goes into the methodology utilised in the research, and the characteristic of the three study sites selected, in Chiapas and Veracruz, giving details of the procedure in the field and of the data analysis. Chapters 5 and 6 examine the results of the survey in the field and Chapter 7 put these findings together. The thesis ends with Chapter 8 with the conclusion and recommendations for conservation and management.

CHAPTER 2

Coffee Situation

2.1 Introduction

During the past 15 to 20 years the coffee production in northern Latin America has been redefined by changes associated with the ecological, social and economic sustainability of coffee (Table 2.1). Only recently has it been reported that coffee is profoundly affecting migratory bird diversity and other ecological indicators of environmental health. From Colombia to Mexico, the industrial transformation of the coffee sector threatens the traditional coffee agroecosystem through loss of biodiversity, habitat fragmentation, pesticide poisoning and soil erosion. In the simplest terms, the change is from natural vegetation to shade coffee and then to sun coffee. The region has some of the highest levels of biodiversity on the global-level that are maintained to a surprisingly high degree within the traditional coffee system. Changing the structure and management of this system may cause problems for the region's overall environmental health, as well as for the livelihoods of small growers and rural communities. Coffee management choices in the future will profoundly affect conservation objectives in countries throughout the Western Hemisphere. One example is El Salvador, where coffee plantations represent about 60 percent of the nation's remaining forested area (Komar, 1998).

The transformation involves switching from the traditional, canopy-covered coffee plantation with a mixed plant community in the overstory, to a virtual monoculture of coffee that may include moderate to sparse shade cover of a single species, or, in some cases, no shade at all. The route from the shade into the sun usually runs in parallel with new fertiliser-responsive varieties of coffee and an array of agrochemicals. Of the 2.8 million hectares (6.9 million acres) planted to coffee in Mexico, Colombia, Central America and the Caribbean through the early 1990s, 1.1

million hectares (about 40 percent) have been converted to sun coffee or "technified". While the changes have occurred too recently to be evaluated in terms of total impact upon the region, the overall land and food security of small producers is sure to be affected by the transformation to more intensified production (Moguel and Toledo, 1996).

Table 2.1 Coffee production since 1950 in Northern Latin America (thousands of metric tons).

COUNTRY	**1950***	**1960_**	**1970†**	**1980**	**1990**	**1950-1990% CHANGE**
World Total	2222	4268	4262	5039	6282	183
Mexico	63	157	182	228	440	598
Central America	189	341	428	605	680	260
Costa Rica	23	59	82	106	151	557
El Salvador	74	114	139	183	156	111
Guatemala	57	108	125	179	202	254
Honduras	13	28	39	71	118	807
Nicaragua	19	27	38	59	43	126
Panama	3	5	5	7	10	233
Caribbean	107	136	123	134	139	30
Cuba	31	37	29	21	27	-13
Dominican Rep.	27	44	44	58	59	119
Haiti	35	35	31	39	37	6
Jamaica	3	2	2	2	1	-66
Puerto Rico	10	15	12	12	13	30
Trinidad/Tobago	1	3	3	2	2	100
Colombia	352	468	483	740	845	140
Northern Latin American Total	711	1102	1214	1707	2104	196

*1948-52 average; _1961-65 average; †1969-71 average
Source: FAO Production Yearbook (various years)

Some countries have embraced the transformation of their coffee sector much more heartily than others. Costa Rica and Colombia, for instance, display relatively high levels of technified coffee plantation. Although producers in some areas have recently begun to re-introduce and increase shade levels, the overall trend in the past two decades has been one of shade removal or reduction, resulting in landscape transformations with long-term ramifications for conservation and environmental protection. Interestingly, recent years have seen an increased awareness of the environmental and social links to coffee growing on the part of producers, marketers and consumers. Producer organisations throughout northern Latin America, usually formed into peasant co-operatives, are beginning to address environmental aspects of coffee-growing by maintaining a mixed shade cover (Table 2.2). Marketing strategies based on organic coffee and on social justice and fair commodity prices paid to farmers are emerging in many countries. Consumers are now faced with a growing array of coffees produced beneath a variety of systems, but they seldom realise the distinction being made between the methods of production (Moguel and Toledo, 1996; Wunderle, 1999).

Table 2.2 Number of farms and small coffee producers in Latin America.

COUNTRY	NUMBER OF FARMS	NUMBER OF SMALL FARMS	SMALL FARMS AS PERCENTAGE
Guatemala	43 352	34 000	78
El Salvador	43 779	34 569	79
Honduras	38 800	37 881	98
Nicaragua	17 483	14 924	85
Costa Rica	65 000	55 250	85
Panama	30 742	29 000	94
Central America	239 156	205 624	(average) 86
Colombia	302 945	223 574	73
Mexico	280 333	274 835	98

* Note: "small" defined as farms under 10 ha. In Central America and Mexico, and under 12 ha. in Colombia

* Source: USAID/ROCAP, 1981; Colombian Coffee Federation document, 1991; INMECAFE Coffee Census, 1992

2.2 Conservation of forest ecosystems

Deforestation trends are serious throughout the coffee-producing lands of Latin America. Seven of the ten countries in the world with the highest deforestation rates are in Latin America and the Caribbean. These seven include Jamaica, Haiti, Costa Rica, Paraguay, Ecuador, Guatemala and Mexico. In a number of areas, tropical forest ecosystems have disappeared or are on a path to elimination in the near-term. By the late 1980s, for example, only an estimated one-quarter of the primary moist tropical forest in Colombia remained (Pimentel *et al.*, 1992).

Remarkable biodiversity values are at risk. Latin American tropical forests are critical in the protection of water quality and wildlife species, as well as economically as reservoirs of germplasm with multiple applications for food, medicine, and industrial products. The region's threatened natural heritage transcends national boundaries. For instance, neotropical migratory birds that winter in northern Latin America constitute 60 to 80 percent of the bird species that inhabit forests throughout the eastern U.S. and Canada; neotropical migrants also constitute a large percentage of bird species in the forests of the Pacific Northwest. Birds numbering hundreds of millions and representing more than 120 species migrate annually through or to the part of the Central American isthmus composed of Costa Rica and Panama (Moguel and Toledo, 1996).

Traditional shade coffee production has been shown to be highly beneficial to biodiversity conservation in tropical forest ecosystems. In northern Latin America, traditional coffee covers very significant areas with closed canopy, agro-forestry systems having high species diversity. As an illustration, biologists from the Smithsonian Migratory Bird Centre conducted research in the southern Mexican State of Chiapas. This research found that traditionally-managed coffee and cacao (cocoa) plantations support at least 180 species of birds, an amount significantly greater than bird numbers found on other agricultural lands and exceeded only by undisturbed tropical forest. The attraction of industrial sun coffee for birds falls well short of that of the traditional shade systems. For example, studies in Colombia and Mexico have identified over 90 percent fewer bird species in sun-grown plantations than in shade coffee (Greenberg, 1996).

Shade coffee also provides an essential habitat for diverse communities of other tropical forest species. Findings by The University of Michigan biologist Ivette Perfecto and colleagues suggest from research in Costa Rica, that the local species diversity of beetles, ants, wasps and spiders on a single tree species (*Erythrina poeppigiana*) in shade coffee plantations, approximates to the arthropod diversity levels on single tree species sampled in undisturbed tropical forest (Perfecto and Snelling1995). Additional recent studies on tropical forest ecology have been conducted by scientists from Mexico's National University and Chicago's Lincoln Park Zoo. The work of these researchers in Veracruz, Mexico, has shown that shaded agricultural plantations, as compared to unshaded agricultural landscapes, feature a richer diversity of small mammals such as opossums, squirrels and mice. Bats, which are important dispersers of seeds and pollinators of many tree species as well as natural predators of insects, are also present in such systems. Comparing forest habitats on several agricultural lands, these same researchers found that habitats designated as "mixed plantation" (cacao, coffee, bananas, and citrus) and "coffee" (coffee with shade trees) jointly contained 74% of the species richness.

Traditional coffee is often integral to agro-forestry systems in which tree species are cultivated together with the coffee and other agricultural commodities. Where geographic and market conditions are favourable, economic returns can be achieved through sustained-yield timber production in association with coffee. For example, research in Costa Rica has shown that timber harvesting from the precious hardwood species *Cordia alliadora* can occur with no significant damage to growing coffee crops. Agro-forestry systems, including those involving coffee, have potential to enhance the economic and ecological stability of poor rural areas in northern Latin America. By providing an alternative to deforestation, traditional coffee systems constitute an important check against greenhouse gas emissions, which contribute to global warming.

Several studies have found that shade coffee agroecosystems provide suitable habitats for a large number of species (Perfecto *et al,*. 1996). The conservation value of coffee plantations comes into prominence when it is realised that Neartic migrants use these habitats during the winter (Greenberg, 1996; Vandermeer and Perfecto, 1997). Most of the studies have supported the importance of coffee plantation for the conservation of forest birds (Aguilar-Ortiz, 1982; Vaninni, 1994; Wunderle and Latta, 1994, 1996; Greenberg *et al.,* 1997a, 1997b; Calvo and Blake, 1998). A further study has examined landscape variables in relation to bird populations and coffee plantations (Parrish and Petit, 1996). A very few studies have focused on other groups such as mammals (Estrada *et al.,* 1993, 1994; Gallina *et al.,* 1996), and invertebrates (Nestel *et al.,* 1993; Perfecto and Snelling, 1995).

In summary, there has been a recent tendency in northern Latin America to replace traditional shaded coffee plantations with technified "sun coffee", where coffee plants grow with no shade and with the use of insecticides (Rice and Ward, 1996). This simplified agroecosystem does not support high biological diversity levels as do the traditional plantations (Gallina *et al.,* 1996; Greenberg *et al.,* 1997a). However, simply to classify coffee plantations as shaded or not shaded is not satisfactory since there are a variety of shade management techniques, so different plantations are not equivalent, this consequently may affect bird populations differently (Greenberg *et al.,* 1997a; Calvo and Blake 1998).

2.3 Geographic distribution of coffee-growing areas

The humidity and thermal requirements of coffee crops dictate that in Mexico, coffee plantations are cultivated within a specific elevation range on the coastal slopes of the central and southern mountains. These elevation limits vary by region, however, according to geographic orientation Mexican coffee is cultivated on both the Atlantic and the Pacific coastal slopes, which differ markedly in terms of climate. In general terms, the Atlantic slopes are wetter than their Pacific counterparts because the Atlantic slopes are under the influence of the trade of winds that bring humidity almost all the year round from the Gulf of Mexico (from North to East). In contrast, Pacific slopes have a monsoon-type regime, with humid air currents flowing towards the mainland during half the year and dry air flowing seaward during the next 6 months. Consequently, Pacific slopes are generally humid, and interior slopes are dry. These climatic features are a key factor influencing vegetational differences on the respective slopes: tropical rain forests and cloud forests dominate on the Atlantic side, tropical dry forests and pine oak forests on the Pacific.

Situated generally between 600 and 1300 m elevation, the coffee fields are located in a biogeographic and ecologically strategic altitudinal belt in which tropical and temperate elements overlap and the four main types of Mexican forests come into contact. Therefore, depending on their geographic orientation, coffee fields support various types of vegetation. An ecogeographical analysis of the 356 coffee growing municipalities conducted by Moguel (1995) showed that coffee areas located on the Atlantic slopes correspond mainly to regions originally covered by tropical rain forests (50-76% of the total). By contrast those on Pacific slopes (in Nayarit Colima, and Guerrero) are cultivated where tropical dry forests dominate (45-83% of the total area). Coffee in cloud forests areas is important in Hidalgo and Chiapas but less notably in Puebla, Veracruz, Guerrero, and Oaxaca. Coffee in pine oak forests is important in Puebla and Guerrero (Table 2.3).

Table 2.3 Percentage of tropical and temperate forests displaced or affected by coffee plantations in the nine Mexican states producing coffee (Moguel and Toledo 1996).

STATES	RAIN	DRY	CLOUD	PINE-OAK
Gulf of Mexico slopes				
San Luis Potosi	76	14	4	6
Puebla	51.5	1	7	40.5
Hidalgo	47	--	24	29
Veracruz	68.5	18.5	7	6
Pacific slopes				
Nayarit	--	82.5	--	17.5
Colima	--	83	--	17
Guerrero	--	45	5	50
Both slopes				
Oaxaca	76	14	4	6
Chiapas	54.5	12	15.3	18

2.4 Traditional coffee plantations and conservation of priority areas

Biodiversity will not be conserved effectively in natural areas alone. There are only just under 7 000 nationally protected areas in the world, covering some 650 million ha, which represent less than 5 % of the earth's land surface (Ryan, 1992). The rest of the earth environment is affected by human activities in one way or another, including agriculture and urbanisation. About 75% of the earth ecosystems are manipulated to obtain products used by humans (Pimentel, 1992). Consequently it is necessary to complement the system of natural reserves with a matrix of areas managed according to ecological principles for the conservation of biological diversity (Harris, 1984; Pimentel, 1992).

Studies of biological diversity have focused mainly on undisturbed ecosystems, with less attention given to changes in biodiversity which may occur in managed or agricultural ecosystems. Landscape structure, field areas and polycultures appear to increase the biodiversity of traditional agroecosystems (Altieri *et al.*, 1987; Oldfield and Alcorn, 1987; Toledo, 1990). Thus, there is increasing evidence that the mosaic structure of landscape maintains and even in some respect improves biodiversity (Oldfield and Alcorn, 1991, 1994; Gonzalez-Bernaldez, 1991; Brown and Brown, 1992; Reichhardt *et al.*, 1994; Toledo *et al.*, 1994).

The confirmed capacity of traditional shaded coffee fields to accommodate high biodiversity, plus the strategic location of coffee-growing areas, suggest that these systems can play an important conservation role. In Central and Southern Mexico, species richness is concentrated in lowland habitats, whereas endemic species with limited geographic ranges, and species that are rare or locally distributed are found in mountain habitats (Peterson *et al.*, 1993). This altitudinal pattern is found in all the main biological groups: flowering plants, mammals, birds, reptiles, and butterflies.

Demonstrations can be given of an extensive overlap between coffee growing areas and several regions with high numbers of species and endemics. For instance, of the 155 regions regarded by CONABIO (Comision Nacional para el Estudio y Uso de la Biodiversidad) as crucial to the conservation of Mexico's biodiversity, 14 overlap with or are near various coffee growing areas. Based on this information and other criteria, 14 main coffee regions in Mexico can be identified as *hot spots* for conservation. With the exception of portions of the Sierra North of Puebla and the Region of Soconusco in Chiapas, where sun coffee has been planted in large tracts, traditional shaded fields still dominate these regions.

In regions where deforestation has drastically affected original forests, traditional coffee systems can act as a refuge for many species. This function could be decisive in those biogeographically important areas where habitats have been severely transformed, as in the region of Soconusco in Chiapas. In other cases, coffee fields can operate as conservation sites complementary to or even independent of biosphere reserves and other protected areas (Los Tuxtlas, Selva Lacandona, El Triunfo, Manantlan). Finally, from a landscape perspective, traditional coffee fields can contribute to preserving regional ecological processes because, for example, coffee areas maintain forested portions as part of an entire watershed.

2.5 Birds in coffee systems

Because Mexico is located in the transition zone between North and South America, the country has quite a mixture of the avian species typical to each continent. Out of some 9 000 species in the world, 769 breed in Mexico, and an additional 257 are found as migrants or accidentals. Compare this to the combined number of species in the Canada and the United States - less than 800 - even though Mexico has only 11 percent of its northern neighbour's land area.

The importance of traditional tropical agroforestry in the conservation of bird diversity has been demonstrated in empirical studies (Borrero 1986; Andrade and Rubio, 1994; Thiollay, 1995). The shaded traditionally-managed coffee plantations of Mexico constitute an appropriate habitat for a large number of both resident and migratory bird species. Although the role played by traditional coffee agroforests in bird conservation has been pointed out by several authors (Terborgh, 1989; Willie, 1994), there are still few studies reporting data for Mexican sites. The Smithsonian Migratory Centre is currently carrying out a detailed research project on this topic (Greenberg, 1994).

It appears that there is a spectrum of bird diversity, having its extremes in the traditional shaded coffee plantations on the one hand and the technified, sun-grown coffee plantations on the other. Specifically, 136 and 184 bird species were recorded in traditional coffee fields of Central of Veracruz and Soconusco, Chiapas, respectively (Aguilar-Ortiz, 1982; Martinez and Peters, 1996). At the same time 104 and 107 species were present in a commercial polyculture with several or a few canopy species

(Greenberg *et al.*, in press), 50 species in monogeneric shaded coffee, and between 6 and 12 species in a sun-grown monoculture (Martinez and Peters, 1996). In general, birds inhabiting shaded coffee agroforests represent a mixture of forest species (particularly those in the canopy) and the second-growth species (Greenberg, 1993). Birds are attracted to coffee agroforests not only for the coffee cherries but also for several other foods, including fruits, nectar, and insects. However, because coffee plantations are normally found adjacent to original or mature forests, it is difficult to determine the ability of the plantation alone to support reproducing bird populations. Therefore, it is useful to assess whether the connectivity or isolation of the shaded coffee patches might be a key factors in determining the maintenance of bird species diversity. Martinez and Peters (1996) found 184 species of birds in traditional coffee fields located alongside a tropical forest, in contrast to 82 species in a similar coffee plantation isolated from any forest remnants.

According to Borrero (1986), Greenberg (1994) and Terborgh (1989) of all agricultural systems in the Neotropics, shade coffee plantations have some of the highest numbers of individuals and species of migratory birds. For these reasons the Mexican territory is the most significant winter destination of those migrants considered potentially endangered species (Terbogh 1989). Most of the coffee growing areas coincide with the winter habitat of migrants. Shade coffee plantations play an important role as dry season refuges for both migrants and local species.

2.6 The situation in Mexico

In the context of wordwide coffee production, Mexico is ranked fourth in terms of volume, fifth in amount of land, and ninth in yield performance. Mexico is, in addition, the world's first country to export organic coffee, accounting for one-fifth of the total volume. Coffee is also an important agricultural export commodity for the country, ranking fifth nationally in terms of harvested area. According to the coffee census of the "Instituto Mexicano del Café" (INMECAFE), the state agency responsible for the trade and production of coffee in Mexico that was dismantled in 1990, coffee was being produced by 1989 in about 4 300 localities, and was cultivated in 357 municipalities and 12 states. The main coffee producing states in Mexico in decreasing order of importance, are Chiapas, Oaxaca, Veracruz, Puebla, Hidalgo, Guerrero, and San Luis Potosi.

In Mexico, coffee is cultivated in a variety of settings, altitudes ranging from 300 to almost 2 000 m above sea level and in areas exhibiting a wide range of climates, soils, and vegetation types. Coffee production is most successful between 600 and 1 200 m, on relatively steep slopes, and in the transitional zone between tropical and temperate ecotones. It is estimated that there are approximately 20 000 coffee producers (INEGI, 1992), with a total of 1.5 million people economically involved in the cultivation of coffee (Nolasco, 1985). In 1989 the cultivated areas covered 700 000 ha (census of INMECAFE) and over 850 000 ha in 1991, according to the last National Agricultural Census (Censo Nacional Agropecuario y Ejidal). Ninety percent of the coffee growers worked smallholdings covering less than 5 ha and 70% worked more than 2 ha (Santoyo *et al.*, 1995).

There are five main coffee production systems in Mexico, distinguished according to management level, vegetational and structural complexity: 1) traditional rustic or mountain, 2) traditional polyculture, 3) commercial polyculture, 4) shaded monoculture and 5) unshaded monoculture (Figure 2.1; Fuentes-Flores, 1979; Nolasco, 1985). The traditional rustic or mountain coffee system substitutes coffee bushes for the plants growing on the floor of the forests. This system removes only the lower strata of the forest; as a result the original tree cover is maintained, under which coffee bushes are inserted. In Mexico this type of management may be observed in relatively isolated areas, where local communities typically have introduced coffee into the native forest ecosystems. The traditional polyculture system is a shaded coffee plantation that involves the most advanced stage of manipulation of the native forest ecosystem. As in the previous case, coffee is introduced under the cover of the original forest, but in a different way. Coffee is grown alongside numerous useful plant species, forming a sophisticated system of managing both native and introduced species, for instance either by favouring the growth of or eliminating certain tree species. The result is a larger area of coffee with a great variety of arboreal, shrub-like, and herbaceous species, both wild and cultivated. In this system, coffee plantations reach maximum vegetational and architectural complexity and the highest useful diversity. Commercial products include coffee and an array of products for market and local subsistence, such as foodstuffs, medicines, and raw materials.

The commercial polyculture system involves the complete removal of the original forest canopy trees and the introduction of a set of shade trees appropriate for coffee cultivation. Rather than the original trees, the forest cover of this cultivation type comprises tree species that provide shade (such as many leguminous plants which add nitrogen to the soil) or are useful commercially, such as the non-native trees rubber (*Castilla elastica*), pepper (*Pimienta dioca*), cedar (*Cedrela odorata*), jiniquil (*Inga* spp), chalahuite (*Inga* spp), and colorin (*Erythrina* spp). These trees make up the arboreal cover of polyculture plots where coffee, citrus fruits, bananas, and others cash crops are grown. This system has a better coffee yield and makes use of agrochemical products fairly frequently; production is directed exclusively to the market. The unshaded monoculture system (sun grown coffee) has no tree cover at all, and the coffee bushes are exposed to direct sunlight. This approach represents a system that is totally agricultural and has lost the agroforestal character displayed in the previous systems. Converted into a specialised plantation, this coffee-producing system requires high inputs of chemical fertilisers and pesticides, the use of machinery, and an intensive work force throughout the yearly cycle. However, the highest yields are obtained under this system (Moguel and Toledo, 1996; Inmecafe , 1984).

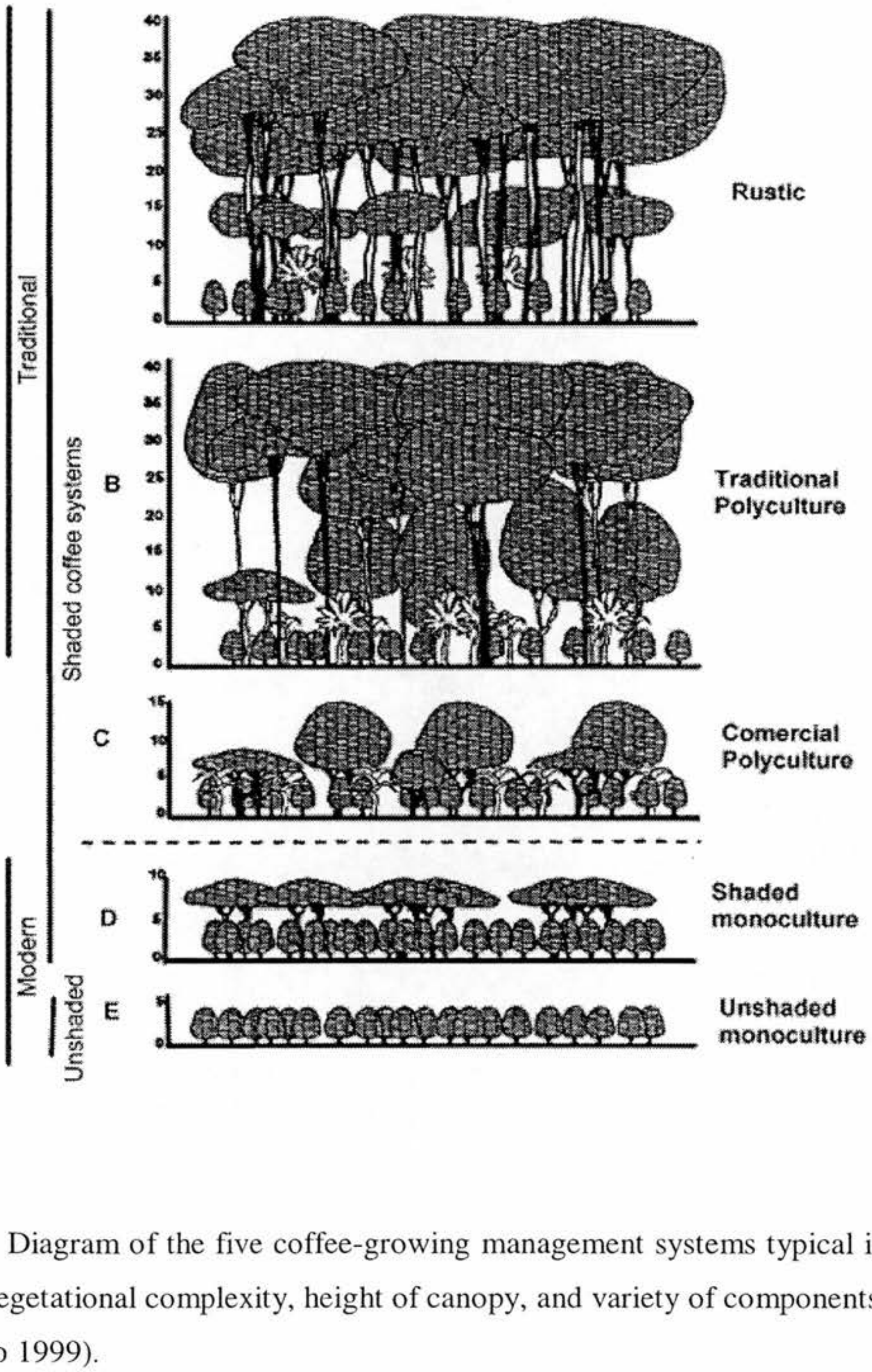


Figure 2.1 Diagram of the five coffee-growing management systems typical in Mexico, showing vegetational complexity, height of canopy, and variety of components. (Moguel and Toledo 1999).

2.7 Shade grown coffee

2.7.1. Early and recent history

Coffee was first cultivated in Ethiopia. Its wild ancestors were small understory species, which grew as the bottom tier of a four-tiered tropical highland forest. Even when domesticated, coffee shrubs require ample shade, the temperature fluctuations of direct sunlight weaken the shrubs and make them more susceptible to disease. Most Western Hemisphere coffee is descended from a Javanese seedling brought to the Caribbean in 1721. This seedling was a descendant of the coffee shrubs in the forests of Ethiopia. In Latin America, farmers were able to duplicate successfully the three and four tiered forest habitat, as they found climatic conditions along the equator almost identical to those in Africa.

However, in 1970 windborne spores of African coffee rust landed in Brazil and began to spread northwards, triggering panic in the Latin American coffee industry. Coffee producers went to the dwindling forests of Southwestern Ethiopia, coffee's evolutionary home, and found wild varieties that were resistant to 27 of the 33 known types of the rust ("*la roya*"). They returned to South America and crossbred it commercially. Governments also reacted to "*la roya*" by technifying coffee plantations, removing shade trees, introducing new varieties, and boosting chemical use. Ironically, "*la roya*" has not spread as feared, probably because the cool temperatures and the dry seasons in most Latin American highlands limits its growth. This "technifying" of coffee producing regions has had a tremendous impact on the rainforest canopy and on the lives of the people who live there.

Because coffee is a seasonal crop, farmers were able to grow other crops under the canopy to assist them in their survival during the non-coffee crop season. In the shade grown coffee the canopy provides the necessary moisture and filtered light for growing, not only coffee, but other crops as well. Bananas, cocoa, mangoes, vegetables and timber woods for fuel serve to sustain the lives of the local population (Perfecto and Snelling , 1995; Moguel and Toledo ,1996).

2.7.2. Benefits of shade grown coffee

Traditional, shade coffee plantations often produce more than coffee. It is common among small farms for the household to extract useful products such as firewood, construction materials, fence posts and fruits, in addition to the coffee harvested each year. For peasant producers living precarious livelihoods from year to year, such "non-coffee" products provide the family with items that can either be used directly, or traded locally for cash or other necessities. Income from selective harvesting of timber derived from shade trees can be substantial. In studies based on Costa Rican practices, timber stands of *Cordia alliodora*, used as shade in densities of 120-290 trees per hectare, have been shown to produce a sustainable output of 6-15 cubic meters per hectare per year of commercial wood. Timber output such as this can help provide income security for small farmers; for instance, timber harvests from shaded cacao plantations saved Costa Rican producers through several years of tough financial times in the early 1980s, when plant disease decimated cacao production.

This habitat is a complex mixture of biodiversity: abundant flora and fauna support one another in their quest for survival. The shade canopy serves as shelter for hundreds of species of migratory songbirds, and the rich insect life provide fuel for the continuance of avian migration. When coffee plantations are "technified" various situations arise, for example, biodiversity suffers greatly for the new-style modernised coffee estates. It was found that 94% fewer bird species inhabit the sun-grown plantations than the traditional or shade plantations. Studies show that the recent sharp decline in the number of migratory birds is at least partially attributable to the replacement of shade-coffee with sun-coffee. In Colombia 70% of the coffee-growing area is now "technified"; in Costa Rica 40% and in Mexico 17% (Pimentel *et al* , 1992; Greenberg, 1996).

In contrast to shade grown coffee, the sun grown coffee depends on the use of chemical fertilisers and pesticides. Farmers are often not instructed in the proper and safe ways to use these chemicals or in the methods of protecting themselves. As a result, there has been an increase in instances of water poisoning through the contamination of ground water and aquifers by chemicals such as chlordane (banned in the U.S.), a highly toxic insecticide that persists for years in the environment. In one documented case in 1987, more than 200 people became sick from drinking water contaminated with agricultural pesticides and fertilisers in the western Mexican State of Jalisco. Endosulfan, another highly toxic insecticide, has also contributed to on increase in cases of human poisoning. Increased nitrogen fertiliser applications have gone together with the widespread removal of shade cover from Central American coffee plantations. In high concentrations, nitrates can cause infant methemoglobinemia ("blue-baby syndrome"), a potentially fatal condition that impedes oxygen transport in the baby's bloodstream. Other human health concerns surrounding nitrate contamination of groundwater include suspected links between nitrates and certain cancers, birth defects, hypertension, and developmental problems in children. It is important to mention that chemicals, which are banned in the United States, are sold by the tons to Latin American producers for sun-grown coffee crops (Moguel and Toledo, 1996).

A number of non-profit organisations, including Oxfam and Equal Exchange, have tried to promote direct trade with co-operatives of small farms, which use traditional methods, instead to the large producers. This means that the farm workers are now able to earn a just wage. Labour laws have been enacted in these co-operatives to prohibit children from working in the fields. Women, who traditionally "helped" their husbands for no wage can now enjoy equal pay (Parra *et al.*, 1996).

2.7.3. Organic shade grown coffee

Shade grown coffee is raised "organically", since the habitat itself excludes the use of fertilisers and pesticides. Additionally, small farms and co-operatives cannot afford the cost of these chemicals. Organic coffee growers are typically organised into local co-operatives that are affiliated with, and bound by the standards of, international certification programmes. The largest of such programme is the "Organic Crop Improvement Association" (OCIA), which as of late 1995 claimed more than one million certified hectares (2.5 million acres) and 30,000 grower-members world-wide.

Soil building practices (which often help reduce the waste stream pollutants of water supplies) are key OCIA requirements for certified organic farms. The OCIA standards permit certification only of fields or plantations where no synthetic pesticides or fertilisers have been applied during the preceding three years.

Other organisations have been instrumental in setting up schools and health clinics, on site, for the farm workers and their families. Other organisations, such as FINCA, have set up village banking systems, enabling farmers families, especially women, to finance "micro-businesses" which bring about more sustainability to their communities (Jimenez Avila and Gomez-Pompa, 1982).

2.8 Ecological and biological implications of coffee systems in Mexico

The five coffee production systems discussed represent a gradient from the most traditional, low-input, vegetationally and structurally diverse systems to the least diverse and most intensive, technified and modern systems. The five designs can be divided first in terms of the use of trees as shade, separating shaded systems from the unshaded (sun) coffee system. This division also makes for a basic management contrast: agroforestry versus the agricultural system. A second criterion distinguishes polycultures from monocultures. The last two systems (shaded and unshaded monocultures) contrast sharply with the polyculture where coffee is grown under a canopy of several tree species and has as neighbours various cultivated species (such as citrus, bananas and plantains).

Whereas shaded, multilayered coffee plantations can be considered traditional managed systems, a final distinction must be made between shaded polycultures with non-original or non-native trees (commercial polycultures), which are generally owned by small-scale peasants, and coffee plantations in which the original forests are transformed into managed forests by indigenous peasants. The commercial polyculture system is a less diversified design, directed mainly to the production of cash crops under a multispecific canopy of introduced trees. Thus, although the two traditional systems are both agroforests, where coffee and other crops are introduced into the native forest, commercial polycultures are artificial forests created through the complete manipulation of the arboreal species. Consequently, traditional agroforests contain average canopy heights of 20-30 m. whereas commercial polycultures generally house a planted canopy (commonly of legume trees) of no more than 15 m.

The architectural, vegetational, and structural complexity of these five systems and their corresponding systemic and ecophysiological features have different ecological consequences, not only on a microenvironmental scale (Jimenez Avila, 1981; Jimenez Avila and Gomez-Pompa, 1982; Nestel, 1995) but also on the scale of the regional ecosystem. For instance, the presence or absence of shade in the coffee plantation is not only the most significant difference in terms of the ecology and economy of coffee systems (Beer 1987), but is also a key factor in the maintenance of the landscape equilibrium of the region. 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, decrease of soil micro-organism abundance and diversity, and decreased soil fertility. In addition, a diverse shade forest creates more habitats for both 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 various degrees ecological and biological processes such as hydrologic balance, soil quality, forest cover, and biological diversity.

CHAPTER 3

Cloud Forest and Protected Areas

3.1 Cloud forest

Tropical cloud forest occurs on a global scale within a wide range of annual and seasonal rainfall regimes i.e. 500-10,000mm/year (Hamilton *et al.*, 1993). There is also significant variation in the altitudinal position of this mountain vegetation belt. For large, inland mountain systems, cloud forest may typically be found between 2,000-3,500m, whereas in coastal and insular mountains this zone may descend to 100 m (Challenger, 1998).

Cloud forest has been classified by several authors and the nomenclature include: tropical montane forest, montane rain-forest, dwarf forest, elfin woodland, evergreen cloud forest, pine-oak liquidambar forest, mesophilous montane forest and lower montane wet forest (Labastille and Pool, 1978; Rzedowski, 1986; Vázquez-García, 1993). These forest types can be defined both by distinctive plant associations and by the altitudinal limits within which they lie (Grubb, 1971). This high variability between cloud forest has been shown in the literature and as a consequence, this kind of forest needs to be studied in specific areas, in order to obtain the quantitative data necessary for making reasonably accurate projections. Several approaches have been used to categorise types of cloud forests, most of them related to changes in the forest height, structure, and composition, mainly as a consequence of temperature decrease. Several authors have shown diverse approaches and methodologies to assess vegetation pattern (Davis and Goetz, 1990; Michaelsen *et al.*, 1994) and dynamics (Akashi and Mueller-Dumbois, 1995; Cole and Taylor, 1995), which can be useful in determining changes and processes in cloud forest at different scales. However, only few studies (Kitayama *et al.*, 1995) have dealt with the dynamics and variability of particular cloud forests in relation to their environment, which might be crucial for understanding the processes and factors involved in the succession and regeneration of specific forests.

3.1.1. Characteristics of Cloud Forest

In America, these forests occur on tropical mountains and highlands in the northern neotropics, from northern Mexico (Miranda and Sharp, 1950) to South America and the Caribbean islands (Labastille and Pool, 1978), at elevations from 800 – 1,200 m to 2,500-2,800 m or more. Their distribution has a discontinuous pattern (Vázquez-García, 1993), but in spite of their limited total area, they are of great importance for biodiversity (Hietz and Hietz-Seifert, 1995).

Many tropical and subtropical cloud forests are limited to altitudinal zones where humid air masses rise along mountain slopes resulting in cloud formation and high levels of precipitation, air humidity and mist frequency (Hietz and Hietz-Seifert, 1995). The cloud cover at the vegetation level influences the atmospheric interaction through reduced solar radiation and vapour deficit, canopy wetting, and general suppression of evapo-transpiration. The net precipitation is significantly enhanced through direct canopy interception of cloud water (horizontal precipitation or cloud stripping) and low water use by the vegetation. The overall mean annual precipitation (fog plus rainfall) in these forest is usually from 1,000 to 2,500 mm, and humidity is normally near to saturation point (Hamilton *et al.*, 1993).

The topography is usually extremely precipitous with slopes often of 40 to 50 degrees and the soils are normally volcanic (Labastille and Pool, 1978). The tropical cloud forest in Middle America is a naturally fragmented ecosystem owing to the geological history of the region. As a result of its historical fragmentation, cloud forests hold high levels of endemicity and offer the possibility of studying the important biogeographic and ecological processes which underpin the spatial and temporal dynamics of this ecosystem (Hernández-Baños *et al.*, 1995). Fragmentation of the cloud forest in the region, however, has increased considerably due to human activities and settlements, threatening its prevalence (Escalona *et al.*, 1995; Vázquez-García, 1995).

The tropical cloud forest is composed of forest ecosystems of distinctive floristic and structured form. In comparison with lower latitude tropical moist forest, the stand characteristics generally include reduced tree stature and increased stem density. Canopy trees usually exhibit contorted trunks and branches; dense compact crowns; and small, thick and hard leaves. Cloud forest is also characterised by having a high proportion of biomass as epiphytes (bryophytes, lichens and ferns) and a corresponding reduction in woody climbers. Soils are wet and frequently waterlogged and highly organic in the form of humus and peat in surface horizons. Biodiversity in terms of tree species of herbs, shrubs and epiphytes can be relatively high (considering the small area extent) when compared with richness of tree species in lowland rain forest.

3.1.2. Importance of the cloud forest

Much of value of cloud forest is related to their unique characteristics of biodiversity and endemism and the functions that they provide. Many cloud forest areas serve as habitats for endangered species, which are being marginalised by the transformation and destruction of ecosystems at lower elevations. Furthermore, the hydrological role of cloud forest through their water stripping function makes them increasingly valuable in terms of water resources in a way that is quite distinct from other forests or types of land use (Stadtmuller, 1987). Leaves and branches of tree crowns intercept wind-driven cloud moisture, which drips to the ground, resulting in the addition of water to the hydrological system. As a result these forests play an important role in watershed protection by maintaining ground cover, thus minimising soil erosion and providing a regular and controlled supply of water to communities living downstream.

Cloud forests may also provide a valuable range of other services to local populations living in or adjacent to the forest such as a source of fuelwood and small dimension timber, and supply a range of non-wood forest products including honey and medicinal plants (Stadtmuller, 1987).

3.1.3. Current situation of the Cloud Forest

Tropical cloud forests are disappearing at an alarming rate and, in view of their extreme ecological and environmental importance, all the efforts should focus on preserving most of what remains. Conservation of the biodiversity of the species of these ecosystems probably relies on the stability of the whole system and this fact is of particular concern in this type of forest because of the high frequency of endemic species (Gentry, 1995).

Over the last decades man's influence on cloud forest has increased dramatically rates (Monasterio, 1987). These forests are at the top of the list of the world's most threatened ecosystems, and it is widely believed that the majority of those which remain are small areas or remnant patches of their original extent (Doumenge *et al.*, 1995; Scatena, 1995). Moreover, their potential for use seems to be very restricted, especially because of the high vulnerability to soil erosion and because of the role of vegetation in the water balance of the watersheds (Wuetrich, 1993). In many tropical upland regions of Mexico, past deforestation trends have given rise to landscape mosaics made up of patches of primary and secondary forest, agroforest land, shrub land, pastureland, tree plantation, and cropland (Kappelle *et al.,* 1995; Figure 3.1).

Despite their considerable value, these fragile habitats are under increasing threat from a wide range of sources. In particular, human population pressures have forced the conversion of more marginal and previously less accessible areas for both subsistence and cash crops. Many areas are under pressure from encroachment by livestock or have already been cleared to provide new grazing land. In many areas the exploitation of fuelwood and non-wood forest products has reached unsustainable levels resulting in irreversible damage to the forest habitat. The same is true for hunting or capture of fauna (for sport, subsistence or commercial trade), tourism, recreation and new road building projects (Doumenge *et al.*, 1995). In fact, it has been reported that cloud forests have higher deforestation rates than the tropical forest biome as a whole (Doumenge *et al.*, 1995). Inappropriate use of the resources of these ecosystems might have several consequences. For example, cloud forest can be significant water collectors by means of fog interception (Bruijnzeel and Proctor, 1995; Juvik and Nullet, 1995) which produces and increases water availability down slope. Consequently, forest clearing should be carefully considered because it might lead to important water shortages, removing of the forest vegetation probably increases the risks of flooding and soil erosion due to the role of these forests as water flow regulators (Peñafiel, 1995). The timber exploitation might be economically unsustainable because of the slow turnover of the cloud forest trees due to their very slow growth. Moreover, logging will be very destructive and very expensive due to topographic and logistical limitations, while significant nutrient losses may occur as a consequence of some management practices in which soil and vegetation, the main nutrient flow regulators, are severely affected (Weaver *et al.*, 1996).

3.1.4. Mexican cloud forest

In Mexico, Leopold (1950) estimated that these forests originally covered about 0.5% of the country, with a discontinuous distribution along the major mountain ranges. They are generally called mesophilous montane forest ("*bosque mesófilo de montaña*"; Rzedowski, 1978), although this term is applied to any humid, broadleaved montane forest, and does not require high cloud frequency (Hietz and Hietz-Seifert, 1995). The climate is temperate and wet, mean annual precipitation is never below 1,000 mm and there are only between 0 to 4 dry months per year, but the humidity remains constant because of the frequent fogs. This vegetation is usually found in depressions and hillsides at different latitudes from 1,000 to 2,000 m (Rzedowski, 1986).

Cloud forests in Mexico and northern Central America are characterised by the mixture of temperate and tropical elements in their canopy layer. Contrary to cloud forests further south, the canopy is composed of mainly temperate tree genera (*Quercus, Liquidambar, Ostrya, Fagus, Alnus, Carpinus,* etc.), whereas their herb and epiphyte communities comprise many tropical elements (Figure 3.2; Rzedowski, 1986). In general, destruction of the cloud forest is a response to the intense, uncontrolled search for new agricultural lands, and pressure imposed by populations at lower elevations

(Labastille and Pool, 1978). In Mexico this forest type has suffered severe degradation and fragmentation, as a result of human activities such as agriculture, cattle, grazing by livestock and selective cutting of trees for timber or fuelwood.

The Mexican cloud forest is one of the most threatened ecosystems in the country, but at the same time, contributes highly to its biological diversity (Flores-Villela and Gerez 1994; Gómez-Pompa *et al.*, 1995). The South of Mexico holds almost a 60% of the cloud forests of the country (Flores-Villela and Gerez, 1994) and represents an important biogeographic unit (Vázquez-García, 1995; Hernández-Baños *et al.*, 1995; Stattersfield *et al.*, 1998), because of the occurrence of endemic species such as the bearded wood-partridge (*Dendrortyx barbatus*), horned guan (*Oreophasis derbianus*), and blue tangara (*Tangara cabanisi*). This region is also significant because of its bird species richness, and as an important area for altitudinal and latitudinal migratory birds (Escalona *et al.*, 1995).

Figure 3.1 Mexican cloud forest in the study area of Barranca Grande in Veracruz.

Based on analysis of patterns of distribution, diversity and endemism of bird faunas, Hernández-Baños *et al.* (1995) defined biogeographic regions of the humid montane forest (cloud forest and humid pine-oak forest) in Middle America. This allowed them to identify regions of humid montane forest that require conservation action. Such regions were eastern Mexico north of the Isthmus of Tehuantepec, the southern Sierra Madre, and interior Oaxaca, all of which remain practically unprotected. Once priority regions for conservation of humid montane forest have been identified, it is fundamental to define areas for conservation at a local scale. The definition of such areas has to be guided, among other aspects, by landscape studies. Conservation of the Mexican cloud forest is very important because it does not have a wide distribution and is rich in diversity of species. Studies on the impact caused by forest use is necessary in order to provide guidelines for its conservation and sustainable management.

Figure 3.2 Mexican cloud forest in the study area of Custepec at the Biosphere Reserve in Chiapas.

3.2 Protected areas in Mexico

Mexico is the third largest country in Latin America after Brazil and Argentina, ranking fourth in the world after Indonesia, Brazil and Colombia in terms of biodiversity (Toledo, 1988). Mexico is among the top ten countries in the world for the number of restricted-range bird species and endemic bird areas it supports (ICBP, 1992). It has the highest diversity of reptiles in the world, the second greatest mammal diversity and holds 8.7% of the world amphibian species, 11% of reptile, bird and mammal species and 14% of fish species. Furthermore, 32% of Mexico's terrestrial vertebrates and 40-50% of her plant species are endemic (Alcérreca *et al.*, 1988; Flores-Villela and Gerez, 1988). This biological richness results from great habitat variation and diverse ecological regions, complex topography, climate, geology and geographical location. The different ecosystems range from deserts to rain forests and mangrove swamps. In addition, Mexico bridges two major biogeographic realms, the Nearctic and the Neotropical, which provide exchanges between elements of northern temperate and tropical origins (Rzedowski, 1978).

The protected areas in Mexico play an important role in the conservation of this high biodiversity. However these areas cover a small percentage of the different ecosystems that need be protected in the short term. There appear to be discrepancies in the definitions and number of established protected areas, according to some authors (Vargas, 1984; Flores-Villela and Geréz; 1988). At present there are 15 legally defined categories of protected area, such as biosphere reserve, nature reserve, national park, national monument, protected landscape and managed resource protected area (WCMC, 2000). By 1969 there were 40 protected areas covering 795 760 ha, of which 34 were national parks (649 778 ha) and six were special biosphere reserves (145 982 ha; SEDUE, 1989). However, Vargas (1984 and pers. comm., 1992) reports 46 national parks only for the same period. By 1992 the total number of protected areas administered by SEDUE (Secretaría de Desarrollo Urbano y Ecologia) had increased to 68 (SEDUE, 1989). Although 20% of national territory is protected, these protected areas have not functioned in practice (Jardel, 1990).

There are a number of problems facing protected areas, they include lack of clear objectives, absence of scientific research and management plans, appropriate legal support and management resources; irregularities in land tenure and pressure from settlements in and around protected areas; and lack of public awareness (Alcérreca *et al.*, 1988; SEDUE, 1989). Up to the early 1980s, property rights had been left undefined in 60% of national parks (Vargas, 1984). The majority of protected areas have been established on communal land or *ejidos*. This has led to conflicts between nature conservation and local utilisation (Jardel, 1990). The legal situation is further complicated when the limits of protected areas are confused or erroneous, as is frequently the case in existing decrees (Alcérreca *et al.*, 1988). The main threats to protected areas are deforestation, over-population around the area, over-grazing and erosion. For example in 1970 it was reported that 69.1% of the national parks had human settlements, containing 73,715 people (Vargas, 1984). Activities, such as the expansion of agriculture have resulted in loss of soil, exhaustion of watercourses and pollution around and inside the protected areas (Alcérreca *et al.*, 1988; SEDUE, 1989).

Until recently, the majority of existing protected areas have represented temperate ecosystems. The national system of natural protected areas (SINAP, *Sistema Nacional de Areas Naturales Protegida*) has intended to include areas representative of all the ecosystems found in the country (SEDUE, 1989). The montane broad-leaved forest, coastal wetlands, dry tropical forest, arid zones and the cloud forest are conservation priorities in terms of biological diversity, ecological value and vulnerability (E. Jardel, pers. comm., 1999).

There are currently twelve established Biosphere Reserves in Mexico: Calakmul (in the state of Campeche), Isla Contoy, and Sian Ka'an (in the state of Quintana Roo), Islas del Golfo de California and Vizcaino (in the state of Baja California), Manantlan (in the states of Colima and Jalisco), Mapimi (In state of Chihuahua), Michilia (in state of Durango), El Cielo (in state of Tamaulipas), and two in the state of Chiapas: El Triunfo, and Montes Azules (Figure 3.3, UNESCO\ ROSTLAC 1997).

Two of the study sites in the present research (Cuxtepec and La Chilana) are located inside a biosphere reserve in Chiapas (El Triunfo), while the study site in Veracruz is located on private land. Unfortunately, the cloud forest of central Veracruz is poorly represented within the natural protected areas scheme, and in some places anthropogenic fragmentation of this ecosystem has been severe, as a result of cattle grazing, coffee, sugar, corn and other plantations, and clearance for paper pulp production.

Figure 3.3 Distribution of biosphere reserves in Mexico according to UNESCO (UNESCO, 1997).

3.2.1. History of protected areas in Mexico

In practice, nature conservation began during the Prehispanic era (before 1521). The most notable example is the Maya civilisation, which based its development on a balanced agricultural-forestry system, that involved the strict protection of numerous areas, and provided "rest" periods for exploited areas (Gómez-Pompa, 1987; Gómez-Pompa and Kaus, 1990). This early commitment to resource protection was also shown by Nezahualcóyotl, who planted forested areas in Chapultepec, Molino de las Flores, El Contador, and in the botanical gardens and zoological parks established by the Emperor Moctezuma II in the 16th century (Vargas, 1984; SEDUE, 1989). The Spanish conquest of Mexico destroyed or modified patterns of traditional resource use. Rapid demographic growth and the intensive exploitation of natural resources has meant that many areas are left in a natural state only in inaccessible locations, or tracts remaining under indigenous control (Alcérreca *et al.*, 1988).

The first legal definition of a protected natural area appeared in the Forestry Law in 1926, although this definition was rather ambiguous as it allowed the establishment of both forest and tourist areas. However, prior to this Law, the declaration of national parks or reserves was carried out by means of presidential decrees for individual areas. By this means, the first protected area, the first forest reserve (*Reserva Forestal*) and the first national park (*parque nacional*) were created in 1876, and 1917, respectively (SEDUE, 1989). A great increase in the number of protected areas was brought about by President Lázaro Cárdenas (1934-1940). Under his presidency, 40 national parks and seven reserves (58% of the present day system) were created, and major improvements were made in administration (Vargas, 1984; Alcérreca *et al.*, 1988; SEDUE, 1989). The 1942 Forestry Law made more detailed provision for the protection of national parks and their resources (Vargas, 1984). In addition, the of Regulation for National and International Parks (*Reglamento de Parques Nacionales e Internacionales*) was approved in the same year and provided the clearest concept on national parks to date (SEDUE, 1989; Vargas, 1984).

Since the 1940's significant clarification to protected areas has been installed. In 1944, further regulations to the 1942 Forestry Law were published, providing some measures for wildlife protection. The 1948 Forestry Law provided some control of forest exploitation and the regulation for the establishment of protected forestry zones. The Federal Hunting Law (*Ley Federal de Caza*) in 1952, made provision for the establishment of wild faunal refuges (Vargas, 1984), and between 1950-1980, a policy of creating "*vedas forestales*" (hunting reserves) was carried out. These were declared over large areas of the country, but the scheme was a failure and caused serious over-exploitation of resources and corruption (Vargas, 1990).

The current Forestry Law was promulgated in 1960, and it provided the establishment of national parks for public use within suitable forested areas by the Federal Executive (SEDUE, 1989). In 1973, the National Commission of Works in Natural Parks (*Comisión Nacional de Obras en Parques Naturales,* CONOPAN) was created within the erstwhile Ministry of Public Works (*Secretaría de Obras Públicas*). CONOPAN promoted the unlegislated concept of "natural parks" (*Parques Naturales*) which caused increased confusion within the existing system (SEDUE, 1989) and in 1976 CONOPAN was dissolved. The protected areas thrived again under the presidency of José Lopez Portillo (1976-1982), during this period nine new national parks and 20 new reserves (*reservas*) were declared (SEDUE, 1989). In 1977 the first two national biosphere reserves, Michilía and Mapimí, were created (Alcérreca *et al.*, 1988), and a third, Montes Azules, was declared the following year (SEDUE, 1989).

In the late 1960s, up to present, national biosphere reserves are the only protected areas to have been selected using biological criteria and they are also the only ones which fulfil the minimum management requirements for conservation (E. Jardel, pers. comm., 1999). The biosphere reserves are the ideal type of protected area as they adapt well to the socio-economic conditions (Halffter, 1984; 1991; Jardel *et al.*, 1992). The Biosphere reserve programme was conceived by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as one solution to the seemingly overwhelming environmental pressures confronting the world.

The reserves would conserve samples of the world's ecosystems such as a tropical forest, prairie grassland, coral reef, river system, or desert. In 1971 the Man and the Biosphere Programme (MAB) was started with the intention to test and outline how humans can strike a balance among the apparently conflicting issues of conserving biological diversity, promoting economic and social development, and maintaining associated cultural values. Scientists from 83 nations supervise the MAB programme involving over 325 reserves, including 6 in the Mexico. Individual Biosphere Reserves remain under the sovereign jurisdiction of the countries in which they are situated. A proposed reserve is nominated by its national government and must meet a minimum set of criteria. In each country, a resident committee defines and organises national projects while working groups and expert panels coordinate core programme and scientific methodology.

The MAB model is a simple concept for accomplishing sustained use. A reserve is usually composed of three main parts: 1) a central "core" area which serves as a refugium for plant and animal communities and their genetic resources. A core area has secure legal protection and permits scientific research on how biological diversity can be sustained; 2) a "buffer zone" surrounding the core area which may include experimental research and rehabilitation, and accommodate education, tourism and recreational facilities. Manipulative management practices are permitted to enhance production while conserving natural processes; and 3) a "transition" area surrounding the other zones where concepts developed in the reserve are applied to achieve sustainable balances between the use of natural resources to meet human needs and their conservation for the future of the entire region. Although the reserves are conceived as a series of concentric rings, the three zones can be implemented in many different ways to accommodate regional geographic conditions and constraints. Since the early 1980s, U. S. MAB has nominated multi-site Biosphere Reserves to strengthen regional cooperation in implementing reserve concepts (Jardel 1999).

Prior to the 1980s, in Mexico national biosphere reserves were established by individual presidential decrees (Vargas, 1984). In addition, the Fisheries Ministry has established aquatic faunal refuges by virtue of the Fisheries Legislation (1972 and 1986). Similarly, there are a few protected areas that have been established by virtue of other laws, i.e. the Federal Hunting Law, the Fisheries Legislation, state decrees and other government agencies (Vargas, 1984). In 1982, The Ministry for Urban Development and Ecology (SEDUE) was created. Within the SEDUE, the Sub-secretariat of Ecology (*Subsecretaría de Ecología*) was also created and in 1986 the national system of natural protected areas *(Sistema Nacional de Areas Naturales Protegidas*, SINAP) was established as a part of the National Programme for Ecology. The SINAP has been an instrument to ensure the preservation, rational use and value of the natural and cultural resources, determining their management and priorities (SEDUE, 1989).

The experimental forestry plots (*campos experimentales forestales*, CEFs) and the experimental biological stations (*estaciones experimentales de biología*, EEBs, administered by the Secretariat of Agriculture and Water Resources (*Secretaría de Agricultura y Recursos Hidráulicos,* SARH) and the National University of Mexico (*Universidad Nacional Autónoma de México*, UNAM), respectively, appeared around 1961. Although these two types of experimental areas were set up mainly for research, they also provided some degree of environmental protection (Vargas, 1984).

In the past, the system of protected areas has in fact been unable to protect adequately the natural richness of the country, due to lack of legislation and resources for management (Vargas, 1984; Alcérreca *et al.*, 1988; WCMC, 1998). This has been compounded by the fact that many of the existing decrees have not been carried out. Moreover, ambiguity over management arises, since areas designated as national parks often remain in private ownership (Halffter, 1992; Jardel *et al.*, 1992). As regards international activities, in 1940 Mexico signed the convention on The Protection of Nature and Wildlife Preservation in the Western Hemisphere (*Convención sobre la Protección de la Flora, de la Fauna y de las Bellezas Escénicas Naturales de los Países de América*); in 1984 it became a signatory to the Convention concerning the World Cultural and Natural Heritage (World Heritage Convention), in 1986 the Convention on Wetlands of International Importance especially as Waterfowl Habitat and participates in the Unesco Man and the Biosphere Programme with six internationally recognised biosphere reserves. It also signed the Convention on the Protection and Development of the Marine Environment of the Wider Caribbean Region (Cartagena Convention; IUCN, 1985), the Convention concerning with the Cooperation in Combating Oils Spills in the Wider Caribbean Region on 24 March 1983, the second Protocol concerning Specially Protected Areas and Wildlife (SPAW) in June 1991, and through SEDUE Mexico participates in the FAO Latin American Network Programme (*Red Latinoamericana de Cooperación Técnica en Parques Nacionales, Otras Areas Protegidas, Flora y Fauna Silvestres*).

As a corollary, in 1901, the Central Board for Forests and Woods (*Junta Central de Bosques y Arbolados*) was created through a Presidential Decree as the first body responsible for protected areas (Vargas, 1984). From 1910 to 1912 they were covered by the Forest Department (*Departamento de Bosques*); from 1914 to 1920 they were the responsibility of the Department of Forests, Hunting and Fishing (*Departamento de Bosques, Caza y Pesca*), and from 1932 to 1934 this responsibility was placed on the General Directorate of Forestry, Hunting and Fishing (*Dirección General Forestal y de Caza y Pesca*) (Vargas, pers. comm., 1992). Between 1934 and 1939, with the creation of a large number of new protected areas, special institutes were created for the administration of these areas. The first was the Forests and National Parks Office (*Oficina de Bosques y Parques Nacionales*). This Office was then raised to the status of a department, the Department of National and International Parks (*Departamento de Parques Nacionales e Internacionales*). Between 1940 and 1951, the Department of Reserves and National Parks (*Departamento de Reservas y Parques Nacionales*) dealt with protected areas within the General Directorate of Forestry and Hunting. There were a great number of changes between 1951 and 1972, and the responsibility for protected areas was shifted between numerous government departments. The short-lived National Commission for Works in Natural Parks (*Comisión Nacional de Obras en Parques Naturales*, CONOPAN) was created in 1973, but dissolved three years later due to its incompatibility with existing administrative bodies.

From 1976 to 1982, five government agencies were responsible for protected area management: the Ministry of Agriculture and Water Resources (*Secretaría de Agricultura y Recursos Hidráulicos*), the Ministry of Human Settlements and Public

Works (*Secretaría de Asentamientos Humanos y Obras Públicas*), the Government of the Federal District (*Gobernación del Distrito Federal*), the Ministry of Tourism (*Secretaría de Turismo*) and the Ministry of Fisheries (*Secretaría de Pesca;* Pérez-Gil and Jaramillo, 1992). Within SEDUE, the Ministry of Ecology was responsible for protected areas through the General Directorate for Ecological Conservation of Natural Resources (*Dirección General de Conservación Ecológica de los Recursos Naturales*; DGCERN), created in 1985. DGCERN was formed by the amalgamation of the former General Directorate of Reserves and Ecological Protected Areas (*Dirección General de Parques, Reservas y Areas Ecológicas Protegidas,* DGPRAEP) and the General Directorate for Wild Flora and Fauna (*Dirección General de Flora y Fauna Silvestres*; Alcérreca *et al.*, 1988). The administration of protected areas was the responsibility of SEDUE, although this responsibility could also be delegated to states and municipalities. Management may also be contracted to NGOs in certain cases. In May 1992, SEDUE was dissolved and its functions taken over by the new Ministry for Social Development (SEDESOL, Pérez-Gil and Jaramillo, 1992).

In 1972 Dr Miguel Alvarez del Toro and several institutions at state level decreed by El Triunfo as a natural area and ecological typical of cloud forests of Chiapas estate (Diario Oficial de la Nacion, 1972). However this decree did not identify an exact location, limits and management plan. Finally El Triunfo biosphere reserve was established in 1990 (Diario Oficial de la Federación, 1990). The reserve has an area of 119,177 ha. Around 21% (25,719 ha) corresponds to the core zone, and is divided in five polygons located in national lands; 89% corresponds (93,458 ha) to the buffer zone where a private, communal and *ejidos* lands can be founded. The reserve was incorporated into the biosphere reserve international net of UNESCO in 1993.

CHAPTER 4

Study Site and Methodology

4.1 Introduction

The first steps in the field research were to select representative "forest patches" for study; to identify "census points" and “mist net” sites within these patches; and to establish a "study site" around each point. The selection of appropriate census points was a critical component of this research. The most important criterion for suitable census points was that each point had to contain a sufficient understory for bird habitat. Almost any representative patches containing relatively mature forest and shade coffee plantations would have been acceptable for both regions. The research methodology can be divided into three phases. The first phase relates to finding good sites for point counting, and for this phase, a characterisation of the agroecosystems and forest community structure was developed. The second phase was the selection of appropriate sites for the mist nets, which proved to be a difficult task especially in high elevation areas within the cloud mountain forest. The last phase was the spatial and data analysis of the two areas, the results of which, at both local and regional levels, were used in an attempt to build a conceptual model of the spatial relationships within and between El Triunfo Biosphere Reserve (Chiapas) and in the area of Barranca Grande (centre of Veracruz).

4.2 Study sites

The fieldwork was carried out in two different regions of southern Mexico, located in the states of Chiapas and Veracruz. In the cloud forest of Chiapas the fieldwork was more difficult than in Veracruz because of the damage caused by the hurricane Mitch. However, finding areas similar to those in Chiapas, with large areas of continuous forest, presented difficulties in Veracruz because of the high fragmentation level of the forest in the state.

4.2.1. Chiapas

"El Triunfo Biosphere Reserve" (ETBR) is located in the state of Chiapas, in southeast Mexico (Figures 4.1 and 4.2). The reserve lies on the Sierra Madre of Chiapas, a mountain range that runs parallel to the Pacific coast, and it is considered to be the most important cloud forest reserve in Mexico. This reserve has great conservation value due to the great diversity and number of its endemic species (Mulleried, 1957; Tejeda Cruz *et al.*, 1997). The ETBR is located in a topographically complex region characterized by steep mountains and valleys, with strong and pronounced slopes (> 60°). The reserve is divided into two slopes: the Gulf of Mexico slope in the north and the Pacific slope to the south. It has an altitudinal range from 450 masl on the Pacific slope to 2,750 masl at the highest peak (Mulleried, 1957). The reserve extends over 119,177 ha, 21% (25,719 ha) corresponds to core zones, split into five polygonal areas located in nationally-owned land. The remaining 79% (93,458 ha) is the buffer zone, where there are *ejidos* (communal lands) and private properties (Tejeda Cruz *et al.*, 1997). In this buffer zone exist 43 *ejidos*, 162 private properties, 1 national area, and a communal land. The population is 14,217 inhabitants living in 210 localities (INEGI, 1990). However, in the coffee harvest season, there is a great increase in population due to a temporary immigration of workers from different parts of Chiapas and Guatemala. These temporary workers are hired both by *finca* owners and by *ejidatarios* (IHN, 1988). The selected areas are located in the core zone (zone 3 and 4) and in the coffee *fincas* named Custepec and Chilana belonging to the buffer zone.

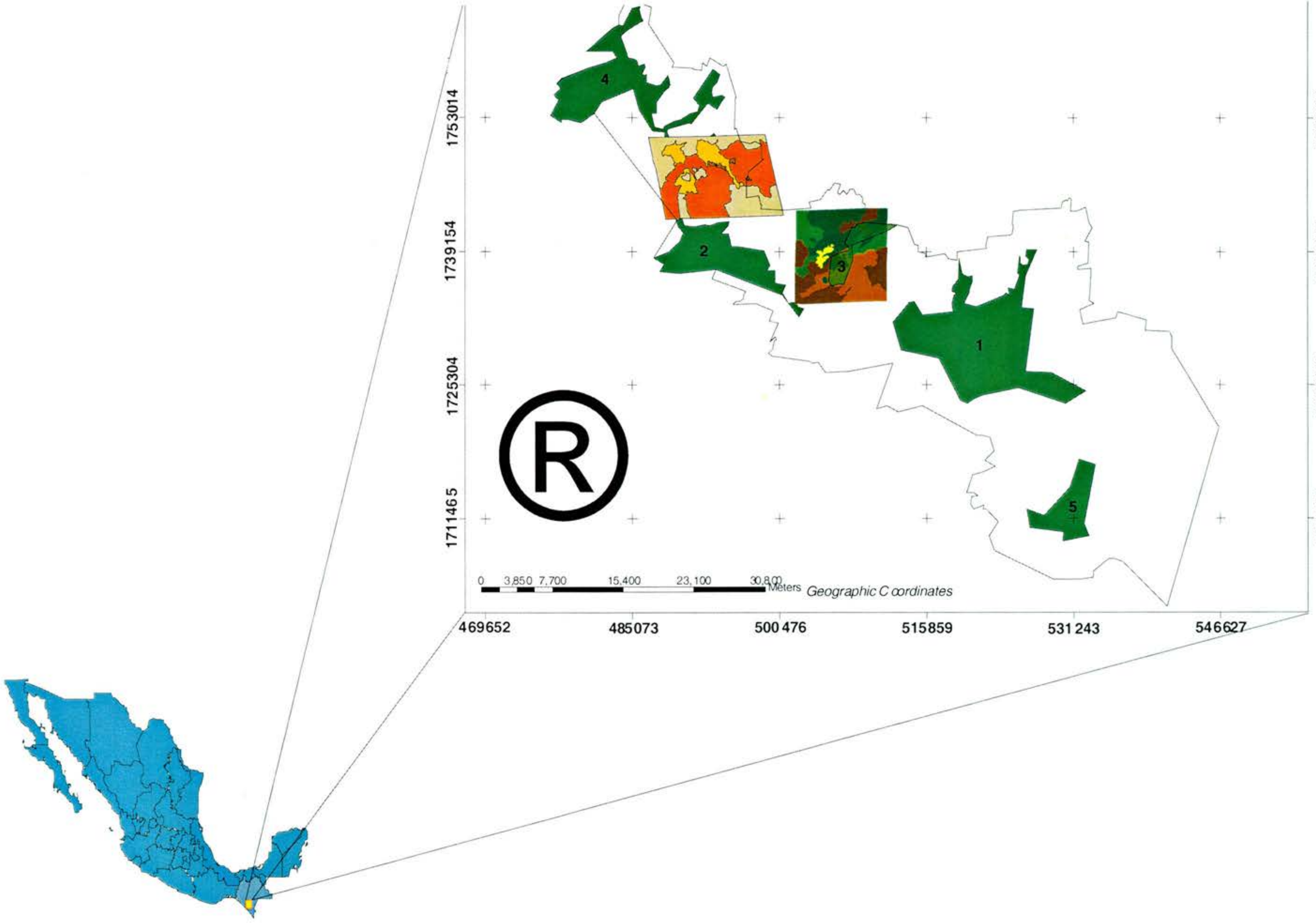


Figure 4.1 Map of location of Custepec and La Chilana at El Triunfo Biosphere Reserve. The projection shows the shape of the Biosphere Reserve with the five core zones (in green) and the two study areas (Custepec and La Chilana).

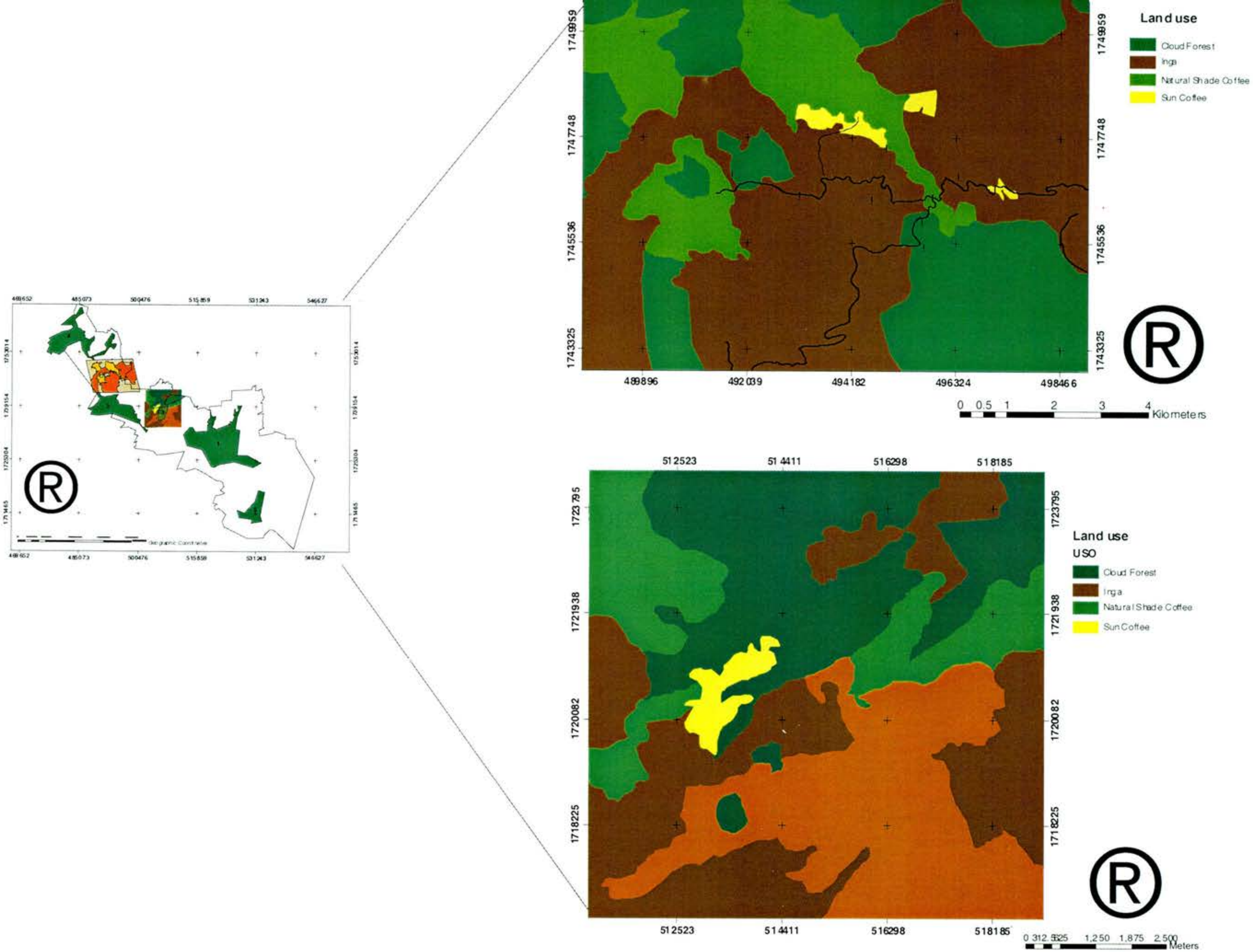


Figure 4.2 Land use map of Custepec and La Chilana, showing the different habitat used in this study.

According to the classification of Koeppen modified by García (1987), there are three climatic types: Am(w), Aw2(w) and C(m)(w) that correspond to semi-hot humid, hot humid and temperate sub-humid with summer rain, respectively. Average temperatures range from 14 to 30 °C, with a minimum during the winter of - 4 °C. The annual precipitation ranges from 1 000 to 4 500 mm (SPP, 1981). As a result of its topography and geological history, the ETBR (El Triunfo Biosphere Reserve) area is considered a Pleistocene refuge (Toledo, 1982). The geological material is predominantly granite of igneous origin from the Palaeozoic and Quaternary periods. Rocks are mainly igneous, with some sedimentary, calcareous and limonite material (Mulleried, 1957). The reserve area contains five groups of soils, principally lithosols and Cambisols, and in smaller proportions Regosols, Phaeozems, Acrisols, Fluvisols and Luvisols. Soils are generally shallow with a high susceptibility to the erosion (INEGI, 1993).

The ETBR contains 10 of the 19 vegetation types defined according to the Breedlove classification (1973). Among the most important are the evergreen cloud scrub, evergreen cloud forest, mountain rainforest, and low mountain rainforest. The topographic characteristics and the vegetation cover of the medium and high part of the Sierra Madre de Chiapas work as an enormous sponge that captures water from the rain and mist. This water generates a great number of streams and rivers that supply rural populations, urban centres, agricultural zones and irrigation districts, on both slopes (INEGI, 1993). In fact this capture of water and recharge of the water table are the most important ecological services offered by this forested area because they maintain the freshwater flow to the wetlands in two large productive zones: the Coast of the Pacific (Soconusco) and the Central Chiapas Depression (The Frailesca). In the same way, the area is important in atmospheric carbon capture. This geographical region also operates as a biological corridor. Many of the plants and animals that are found in Guatemala and Oaxaca are also in this mountain range, therefore it is considered as part of the middle-American corridor (Vásquez-García, 1993).

The ETBR has the largest fragment of mountain cloud forest in Chiapas and one of the largest in Mexico. The vegetation type is characterised by having a high diversity of plants; it has been reported as the cloud forest with the highest tree diversity in Mexico and Central America (Vásquez-García, 1993). The Pacific slope, covered by tropical rainforest is also the largest remnant of this ecosystem on the Chiapas Pacific side and its species composition is different from the tropical rainforest bordering on the Gulf of Mexico (Miranda 1957, 1975). The area contains a high diversity and an elevated number of endemic plant species such as: *Anthurium ovandense*, *Vriesa ovandensis, Zamia soconuscensis*, *Ceratozamia matudae*, *Monstera siltepeca*, *Buchosia matudai*, *Pleurothalis matudiana*, *Rodenletia ovandensis* and *Anthurium rzedoskii*. At a national scale 59 % of the Cycada, 47% of Aracea, 20% of the palms and more than 50% of ferns species reported to Mexico are found in this zone. Despite the earlier surveys, the flora inventory is incomplete (it is estimated that only 40% has been complete), 751 plant species have been recorded in the reserve Core Zone I (Long and Heath, 1991) and 777 in Core Zone II (Matuda, 1950). The structure of the arboreal strata in the Core Zone I is similar to forests in Guatemala and Panama.

The fauna of the Reserve represents 22% of the fauna of Mexico, and 43% of Chiapas. Concerning avifauna, the ETBR is the habitat for 390 bird species (Tejeda-Cruz *et al*., 1997). This represents more than 35% of the reported birds for Mexico, and therefore it is considered an Area of Importance for the Conservation of the Birds (AICA) by the CIPA-MEX (Consejo para la proteccion de las aves en Mexico; Arizmendi, 1997). Within its avifauna are 75 neotropical migrants; furthermore there are 7 species in danger of extinction such as the pavón (*Oreophasis derbianus*) and the quetzal (*Pharomachrus mocinno*); 29 threatened species such as the azure-rumped tanager (*Tangara cabanisi*); 7 species with special protection; and 54 rare species, according to criteria of the Mexican Law (Mexican Official Norm). Due to its great quantity of endemic species, the Sierra Madre of Chiapas, including the ETBR, is classified as an Endemic Bird Area by BirdLife International. There are also 3 bird species endemic to highlands of Chiapas and Guatemala; 19 species with distributions restricted to the highlands of north Central America; and one species endemic to the Chiapas coast (*Campylorhynchus chiapensis*).

Mammals are represented by 116 species; this places the ETBR as the second national protected area in mammal diversity (Ceballos, com. pers.), almost 20 % (23 spp) of these mammals are considered of economic importance, 3 are endemic to Chiapas State and 6 have some type of protection according to IUCN, CITES and SEDESOL (Espinoza *et al.*, unpublished data). Amphibians and reptiles of the ETBR have not been studied in detail, collections have been accomplished solely in core zones 1 and 5 (Fig 4.1) with a total of 85 registered species (22 of amphibians and 63 reptiles). One of the outstanding features of the amphibian and reptile fauna is the high level of endemism, 7 species are endemic to Mexico and among those 5 are exclusively endemic to Chiapas (Espinoza *et al.,* unpublished data).

Like most tropical forests, the ETBR is subjected to land use pressure by local people. In the region the predominant land use is agriculture. Coffee production is the most important economic activity in the area, and this is reflected in land use patterns, coffee plantations covering most of the agricultural land, followed by maize and beans. Camedora palm leaf gathering is another important economic activity, this extractive activity is done mainly in primary forest stands. Cattle-raising is very localized, the only area with extensive cattle-ranching is Pijijiapan Municipality, in particular San Antonio communal lands and neighbouring *ejidos.* Cattle-raising is practised elsewhere at a very small scale. The reserve buffer zone is strongly marginalized. Educational services are provided by the government only at a basic level in most of the *ejidos* and in the big coffee *fincas.* The Public services are limited to electric energy supply and health care in the most important *ejidos* (IHN, 1988).

The importance of coffee in the area as the main economic activity is reflected in the fact that more than 80% of the buffer zone inhabitants work in activities related to coffee production. According to Moguel and Toledo (1999), coffee production systems at ETBR can be classified as follows: "rustic", which maintains the original tree layer; traditional polyculture, where original tree species are maintained, but coffee is grown alongside many useful plant species; and shaded monoculture, where leguminous tree species are extensively used to provide shade for coffee bushes. This particular situation in the area affords a great opportunity to evaluate the role of coffee agroecosystems on biodiversity conservation. This information may be used later to promote the best management option in terms of conservation.

4.2.2. Veracruz

In Veracruz state the study area was located in Barranca Grande which is situated in the municipality of Cosautlan de Carvajal in the central region of Veracruz (Figures 4.3 and 4.4). The area is located between 19° 21' N and 97 ° 22' and 97 ° 04' W. The elevation of the study area varies between 920 and 1780 m. This municipality covers an area of 711 km^2, and grouped together with 8 other municipalities, represents the most important area for coffee production in the state.

According to the classification of Koeppen modified by García (1987) there are two climate types: C(m)(w) or temperate sub-humid with summer rains and Am(w) that corresponds to semi-hot humid. Temperature ranges from 10 to 25 °C, with a mean of 19.4 °C and a minimum during the winter of - 6 °C. This region is considered as one of the rainiest in the country with an annual rainfall range from 1 500 to 4 800 mm; the average annual precipitation in the study area is 2 082 mm (SPP, 1981). In Barranca Grande area soils are generally of little depth, with high susceptibility to erosion. This area shows four groups of soils, Cambisols, Acrisols, Luvisols and Fluvisols (INEGI, 1993). The geological parent material is predominantly volcanic from the Pleistocene with some igneous (granite), and some sedimentary, calcareous and limonite (Jimenez, 1979).

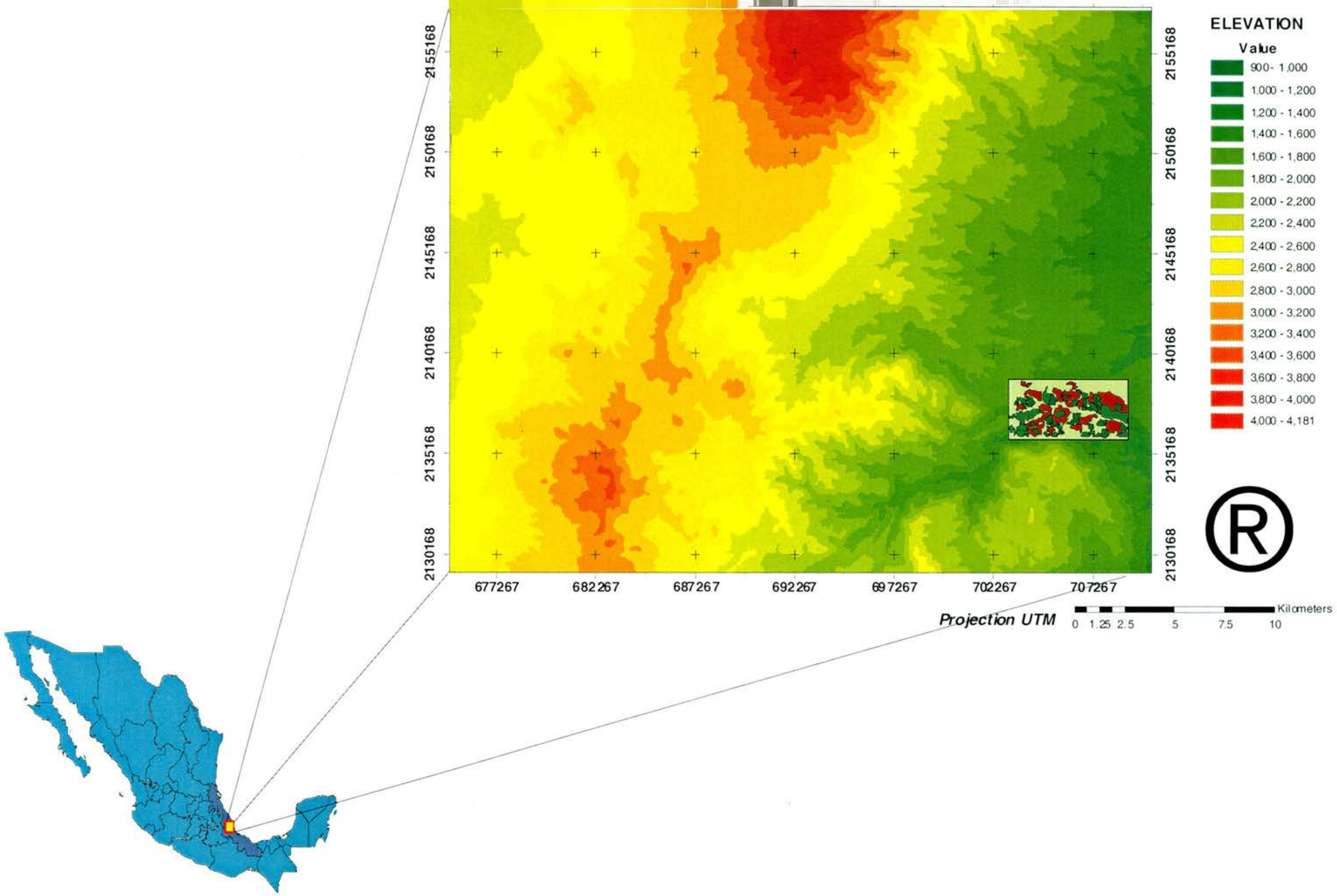


Figure 4.3 Map of location of Barranca Grande at Veracruz state. The small square shows the extension of the study site.

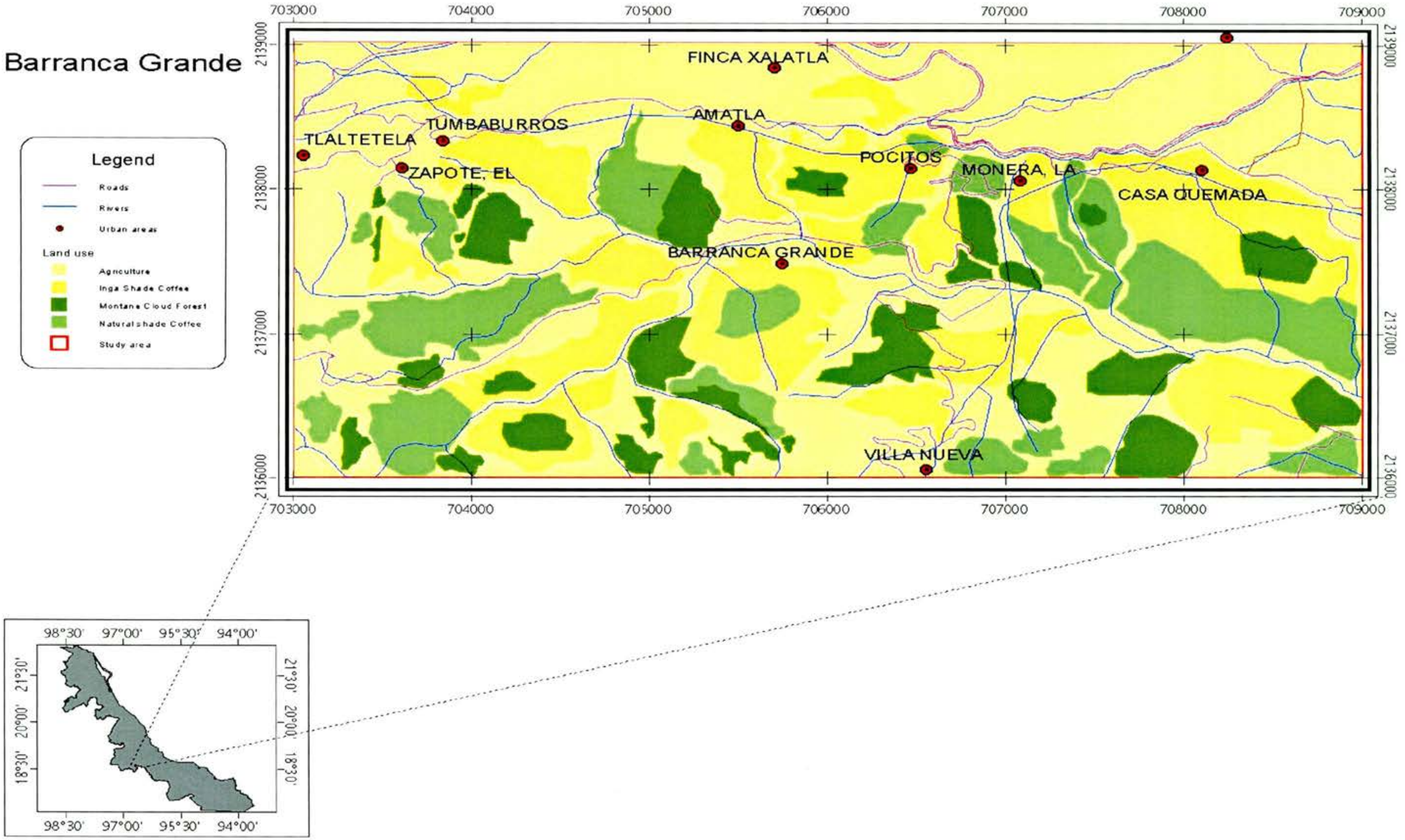


Figure 4.4 Location of Barranca Grande in Veracruz state. Map of land use showing the different habitats used in this study.

The largest patches of cloud forest in the central region of Veracruz are located in Barranca Grande and they are also amongst the largest in Veracruz State. This vegetation type is characterised by having a high diversity of plants. At a national scale, about 32 % of Aracea, 10 % of the palms and 30 % of ferns reported from Mexico, are found in this zone. The floral inventory is almost complete (it is estimated 90% has been done), with 593 plant species registered in the study area (Jimenez, 1979). Three strata of the vegetation structure are found: arboreal, herbs and shrubs. The fauna of Barranca Grande represents 13% of the fauna of Mexico, and 34% of Veracruz. Concerning avifauna, cloud forest is the habitat of 154 birds species (Aguilar et al., 1992), and this represents more than 20% of the reported birds for Mexico, therefore it is also considered an Area of Importance for the Conservation of the Birds (AICA) by CIPA-MEX (Arizmendi, 1997). Within its avifauna are 96 neotropical migrants and according to the criteria of the Mexican Law (Mexican Official Norm) this area holds 3 species in danger of extinction, such as *Dactylortyx thoracicus*; 19 threatened species, 5 species with special protection and 37 rare species.

The mammals are represented by 107 species; from this total 18 are considered of economic importance, 4 have some type of protection according to IUCN, CITES and SEDESOL, and 2 are endemic to Veracruz State (Jimenez, 1979). The amphibians and reptiles have not been studied in detail. A total of 69 species have been recorded (17 of amphibians and 52 reptiles). One of the outstanding features of the amphibian and reptile fauna is the high number of endemic species, seven species are endemic to Mexico, among those two are exclusively from Veracruz (Espinoza *et al.*, unpublished data).

In the study area exist 32 *ejidos*, 231 private properties, and an area of communal land. The population is 167,217 inhabitants living in 314 localities (INEGI, 1990). However, as in the other study areas in the coffee and sugar harvest season, there is a great increase in population due to a temporary immigration of workers from different parts of Veracruz. These temporary workers are hired both by *finca* owners and by *ejidatarios* (IHN, 1988). The predominant land use is agriculture. Sugar production is one of the most important economic activities in the area, however coffee plantations cover most of the agricultural land, followed by maize and fruit trees. Cattle-raising is practised in Barranca Grande on a small scale in comparison with the agriculture.

4.3 The fieldwork approach

In Chiapas, the research was located in the coffee *fincas* "La Chilana" and "Custepec", both sites located in the "El Triunfo Biosphere Reserve". The reconnaissance work in the area turned out to be very difficult. It was expected to start in October 1998, however, because of the damage caused by Hurricane Mitch the field sites had to be changed. As a result the fieldwork started in January 1999, after the roads and trails were passable, and finished in November of the same year. In Barranca Grande (in Veracruz) the entrance to the study site was easier than in Chiapas, the roads were more accessible and the communities were close to the coffee plantations. However the landscape of the plantations was as difficult as in Chiapas with very steep canyons. In Barranca Grande the fieldwork was carried out from October 1999 to May 2000.

In Chiapas, communication with the ETBR office provided personal contacts with local landowners and residents, which helped to give a general overview of the local land and forestry management practices, as well of regional social problems affecting land use. This procedure was important in view of the recent history of confrontation between local people, the landowners, and the environmental authorities ("El Triunfo" Biosphere Reserve personnel, and Secretaria del Medio Ambiente Recursos Naturales y Pesca SEMARNAP). Contact with these local people and institutions was very important in the development of this research, in providing them with a convincing explanation of the objectives, goals and timetable for the research project, in order to get understanding and support from local communities. The field team in Chiapas included two local farmers with great experience and knowledge of the area. They were also very helpful in the identification of tree species (by local names), for the security of all the team, and as well for establishing personal contact with other local people. The team also included a field technician as an assistant, whose tasks were bird survey and botanical samples. Local people were also employed, mainly to help with the demarcation of plots and collecting botanical samples. In the case of Veracruz the support of local authorities, landowners and the "Instituto de Ecologia" was vital in the development of the research. The team included 2 fieldwork assistants and help from members of the Herbarium of the "Instituto de Ecologia" for tree identification.

Firstly, the forest patches were located on topographic maps and aerial photographs, at scales of 1:250 000 and 1:50 000 (Instituto Nacional de Estadistica y Geografia, INEGI). A ground survey of the region by driving roads or walking trails was also necessary to confirm the precise siting of the patches. A requirement of the field methodology was the selection of a number of forest patches, surrounded by agroecosystem habitats such as shade coffee plantations. A preliminary task was therefore the location and selection of a number of forest patches over a range of sizes. Large forested tracts were better for this kind of study, but in certain situations smaller sizes were acceptable - for instance very limited cloud forest patches, riparian strips, or remote and inaccessible areas. Non-forested portions such as sun coffee were also included. In many cases discrete forest patches were difficult to define, especially in areas where a patchwork of forest stands were interconnected by corridors. For research purposes, these areas were considered as part of one large contiguous forest patch.

In each one of the study sites (in Chiapas and Veracruz) the research was carried out in 4 different habitats: Inga plantation (Inga), sun coffe (SC), natural shade coffee (NSC) and cloud forest (CF). In Veracruz the only site, with their respective 4 habitats, was Barranca Grande. In contrast in Chiapas, the fieldwork was carried out in two coffee *fincas:* Custepec (core zone 3) and La Chilana (core zone 4). In each *finca* the habitat corresponding to the cloud forest was located in the core zone, whereas the plantation habitats (Inga, SC and NSC) were located in the buffer area. The methods used at the study sites to assess the bird population in each one of the habitats consisted of point counts and mist nets. The structure of the methodology is illustrated in Figure 4.5.

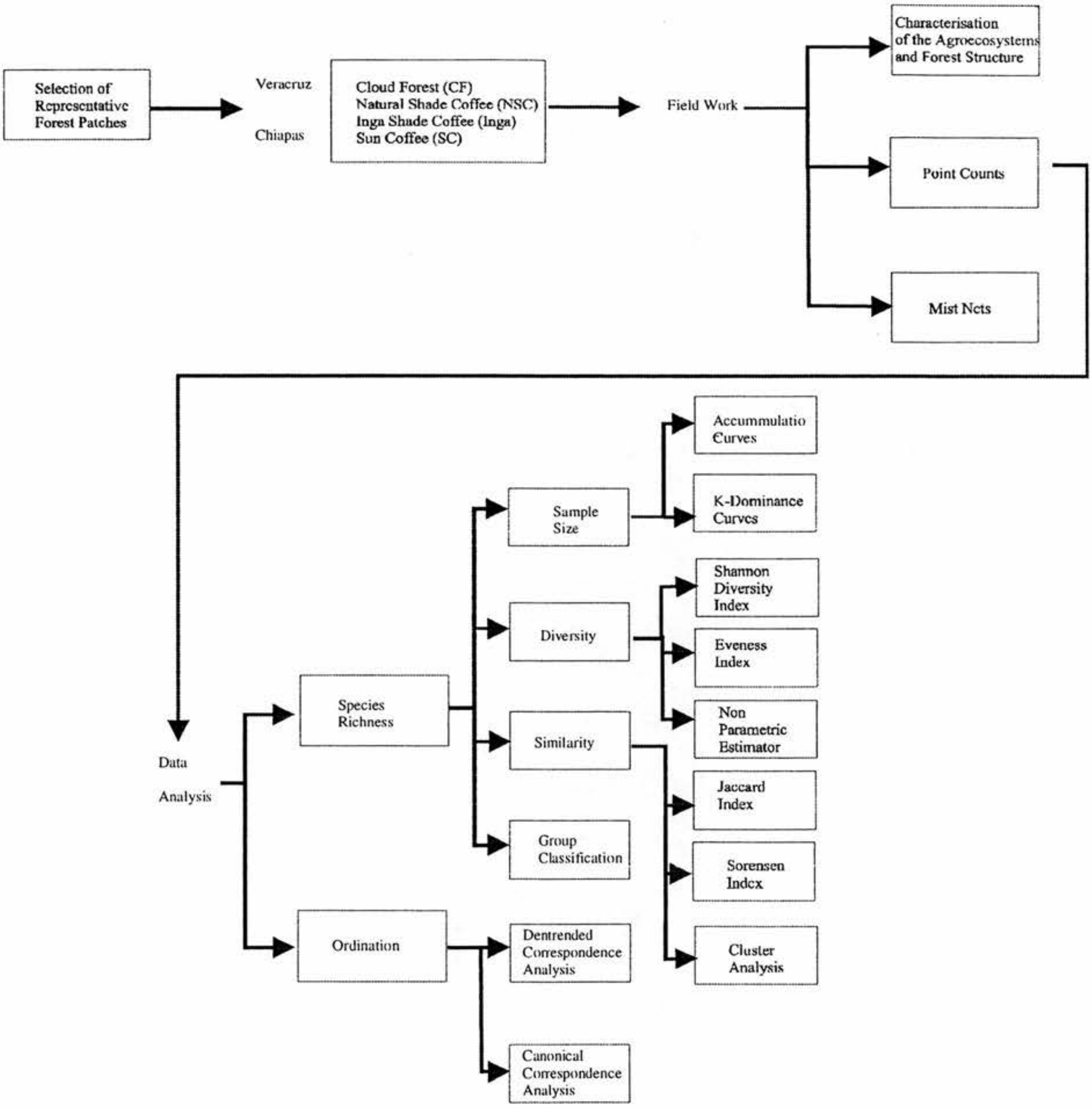


Figure 4.5 Schematic view of the methodological structure.

4.4 Point Counts

The assessment of population size needs to be an integral part of any monitoring programme. Various methods have been employed and thoroughly tested (Ralph and Scott, 1981). Abundance of birds has long been used to measure habitat suitability but is often retrospective, giving trends without any possibility of determining causation, and can even be misleading (van Horne, 1983). It is desirable to use a method that allows the researcher to census as many points as possible in the time available, thus gaining as many independent data points as possible. Consequently it is much better, statistically, to census five points in a 10-day interval, than to count at one point five times. The further apart each of the five points are, the more likely it will be that the data can be extrapolated to a larger region. The point count is probably the best for most surveys and has been adopted as the standard method for monitoring (Koskimies and Vaisanen 1991; Ralph et. al 1993 and others). For the purposes of this research, the sampling was extended over a 4-5 month period, using repeated point sites over the study area.

Point counts of birds are the most widely used quantitative method and involve an observer recording birds from a single point for a standardised period of time. In many countries point counts are the main method of monitoring the population changes of breeding landbirds. With this method it is possible to study the annual changes of bird populations at fixed points, differences in species composition between habitats, and the abundance patterns of species. The point count method is probably the most efficient and data-rich method of counting birds. This method is preferred in forested habitats or difficult terrain. Point counts involve an observer standing in one spot and recording all the birds seen or heard at either a fixed distance, or an unlimited distance. This method can be conducted once or many times at a given point. The North American Breeding Bird Survey of the U.S.D.I. Fish and Wildlife Service is using this method. The point count method applied to landbirds does not provide reliable data on waterfowl; some landbirds also pose problems, as they are either particularly quiet, or particularly loud, or nocturnal, or flocking. If these species are of particular interest, the method may need to be modified to accommodate them (Koskimies and Vaisanen 1991).

In each forest patch, one or more census points were selected according to the following criteria: the habitat at each census point had to be representative of the entire study site; each census point had to be within the forest or agroecosystem patch, and 10 m distance from the edge of the forest; and all points were at least 200 metres apart from any of the others, in order to reduce the chances of counting the same birds at more than one point. Data from point counts were used to estimate: 1) mean relative abundance and its variance, 2) differences between relative abundance for populations in different habitats or regions, 3) population tendencies and 4) species richness. Point count data are often a reasonable surrogate for total population size for all these population parameters.

The census points were spread over several forest and agroecosystem patches rather than putting all of them in the same continuous forest. They were located in the field using a compass and pacing the distance. A Navigator Global Positioning System (GPS) was available on all the field visits and the UTM of each point was recorded, this equipment was very important in locating census points maps and aerial photographs from the field. However it proved to be of little value in dense forest cover and mountain conditions, which blocked the satellite signal. Approximate coordinates were obtained only in more open areas at a number of reference points, which made it easier to locate the forest sampling census plots on the map. Aspect was obtained from a compass, while slope was measured by means of a Haga clinometer. Once the points were located, they were marked by tying flagging tape (brightly coloured plastic ribbon) to an easily visible tree trunk or branch. Each census point that was identified and marked became the centre of a 50-meter circular study site. All the census counts and subsequent observations of behaviour were taken within this study site, and various characteristics of the vegetation were also described within the 50-meter circle. The census points selected were representative of the vegetation density of the study sites.

Censuses were conducted by two teams of two persons each between dawn and 12:30 am. Censuses were not conducted if it was raining heavily or excessively windy. Observers were trained and tested prior to the initiation of fieldwork to minimise observer variability; and they were also regularly rotated throughout the study area to minimise observer bias. At each census point, the observer, date, time, temperature, and topographic quadrangle were recorded. Cloud cover, wind, stream noise, and overall noise were assigned a rating of 0-4. All data were recorded on standardised data sheet. Bird censuses were conducted using a variable circular plot point count method (Reynolds *et al.*, 1980). Counts were taken over a 10-minute interval by a single observer. All birds detected were plotted on data sheets and the distance from the observer to the bird was estimated. Visual observations and additive bird measurements during the period were recorded for each site.

Point counts were placed systematically within treatments. The number of point counts for each habitat varied between places according to the availability and area of habitat. In Chiapas there were 60 in cloud forest, 65 in natural shade coffee, 60 in Inga shade coffee and 45 in sun coffee, given a total of 230 sites a grand total of 2760 point count censuses was conducted. All Inga shade point count lines were placed in an altitudinal range from 900 to 1,300 masl. Cloud forest point counts are found between 1,600 and 2,300 masl. Natural shade and sun coffee point count lines occupied an altitudinal range from 500 to 1,200 masl.

The number of samples and timing of censuses was evenly distributed across the four habitat types. The difference in sample number was largely a reflection of the local availability of each of the four habitats studied. All the habitats were placed within the boundaries of core zone 3 (Custepec) and 4 (La Chilana), where a large cloud forests stand is found. Coffee points were placed in large private *fincas* on the Atlantic slope. Those areas show a very patchy distribution, because production units are small, creating a mosaic of forest, coffee plantations and other land uses.

In Veracruz, from October 1999 to May 2000, 50 point counts were placed in cloud forest, 60 in natural shade coffee, 75 in Inga shade coffee (combined with several kind of tropical fruit trees) and 40 in sun coffee, giving a total of 225 sampling points. This was about the same number of samples for the census that was possible to have across the four habitat types in Chiapas. It was not possible to distribute the number of samples of censuses evenly across the four habitat types. As in Chiapas, the difference in sample number is largely a reflection of the local availability of each of the four habitats studied. In several small and medium sized patches across one part of the highlands Central Veracruz, the areas belong to private farmers and landowners, and no protected area exists in the region. This was the main problem in locating continuous areas of cloud forest. Inga, natural and sun coffee points were placed mainly in three medium-sized private *fincas* on areas with a difficult landscape (habitats with numerous steep sided slopes). The number of recorded point counts totalled 1,800 over 8 months. The altitudinal range varied between 1,200 and 2,500 masl for the four types of habitats.

4.5 Mist Nets and Banding

The capture of birds in nets can give the researchers an insight into the health and demographics of the population of the birds being studied. The sex ratio of a population can be used to assess the species differential survivorship from the previous year and the ability of the population to increase. The mist net capture rate gives a measure of the number surviving during the previous winter, and the marking of individuals gives an insight into the degree of dispersal between different habitats and into the survivorship between years (e.g. Peach *et al.*, 1991). Measures of body size such as wing length, can give a measure of individual fitness. Mist nets have been used for a long period to capture birds. Recently they have been used to monitor populations. Although some researchers have used them to assess population size, for most species (e.g. Karr, 1981), censuses are the best method for this, because netting provides relatively fewer data points per unit time. Netting, however, is the method of choice to provide information about a range of attributes of the population, for instance, age and sex ratios and physiological condition. Over the years numerous aids have been developed for field workers, with an emphasis on capture techniques and data-taking (e.g., Baldwin, 1931; Bub, 1991; Lincoln, 1947; Lincoln and Baldwin, 1929; Lockley and Russell, 1953; McClure, 1984). Austin introduced mist nets to North American biologists in 1947 (Keyes and Grue, 1982), and he, Low (1957), and Bleiz (1957) were pioneers in their use. The procedure detailed below is essentially identical to the "Constant Effort Sites"

(CES) Scheme of the British Trust for Ornithology (Baillie *et al.*,1986). The standards of operation are also identical to those of the Monitoring Avian Productivity and Survivorship Programme (MAPS) (De Sante, 1992). In these studies it is suggested that a series of mist net arrays, as is used in the British programme at 10 to 12 day intervals during the breeding season, coupled with point count censuses. These data provide an index of adult population size and changes at each station. The proportion of young birds in the catch will provide a measure of post-fledgling productivity. Finally, between-year recaptures can provide a sensitive measure of adult survivorship and recruitment. With these data, managers have information on the possible causes of landbird decline or their remedies. The monitoring of populations with mist nets is no more complicated than other techniques, but placement and operation need to be carried out uniformly.

4.5.1. Net Specifications and Maintenance

A variety of net types exist, but for this research the same type of net was used throughout all the study. A black colour was used in all habitats and the net mesh was either 30 mm or 36 mm in diameter when stretched. Nets of 12 m were preferred because larger nets catch more thrush-sized birds, but smaller birds can become more severely tangled. However in some areas a half-net of 6 m was used. Some nets had to be replaced when they faded badly or were degraded by the sun so that it would break very readily. Two fingers were gently put into the net to test the durability. Nets also sustained damage from branches, misuse, large birds, and from the rare occasions when a badly tangled bird had to be cut out of the netting.

The nets were not operated in rain, strong winds, or extreme heat. When these conditions occurred with the nets already open, they were closed, because the precipitation would be heavy enough for the birds' feathers to become so wet as to lose their insulation. Strong winds can cause severe tangling. In general, a steady wind of more than 10 mph or occasional gusts to more than 15 mph needed to be watched carefully for their effect on netted birds, and the nets were closed when it was necessary. Finally, in situations with excessive heat and direct sunlight with little wind, netted birds can quickly overheat and die. On such hot days, birds did not remain in an exposed net for more than 15 minutes.

4.5.2. Net location and placement

In this research a capture station of about 25 ha (in an area of more than 200 ha) was developed in order to monitor populations and demographic parameters. Ten net locations were placed in sites with high capture rates, such as along streams, near a spring, and other areas where vegetation was dense. The field team was split in two groups of two people, because usually this number of people can set up and monitor an array of 8-12 mist nets quite easily. Ten nets were taken as an appropriate number. Distance between nets was 20 m, and this was a very important factor because of the effect of net dispersion on the precision of data from capture-recapture analyses. In order to increase the probability of capturing a bird banded in the previous months, it was important to place the nets as far apart as possible, thus intersecting the maximum number of territories. However, in tropical areas it is critical that nets are close enough to be visited in a maximum of 10-15 minutes walking time. Nets were placed at the same location and orientation for all 10-day intervals in each month. Although few problems arise during the field work from placement of mist net points in areas of relatively high human impact, capture arrays had to be located with more care. In some areas nets were left in place (but closed) between capture days if the chance of encounter by visitors was extremely low. In most areas, it was advisable to rig the nets to allow easy removal at the close of a day's effort. Baiting, artificial water or taped vocalisations were not used at any time to attract birds to the nets.

The best locations for the nets were at the edge of a habitat. In this case it was appropriate to include the boundary between secondary vegetation and continuous forest, riparian areas and brushy portions of wooded areas but not with any kind of agroecosystem. The previous observation of birds (point counts) played an important role in the identification of an appropriate net site. In order to operate the nets properly, the trammels (the horizontal shelf strings that support the net) were stretched horizontally. When operated, the netting material should not be stretched apart to its full extent, but should allow some slack between the trammel lines; otherwise birds will bounce off the taut net.

Ten nets of 2.5 and 3 metres above the ground were used by site, in some sites it was preferable to stack nets one above the other when there was a great abundance of birds. Even the canopy-dwelling species invariably spend at least some time at lower levels, whether to nest, to take water, or forage. For the nets, the following simple method of putting them in place was used: 1) all the vegetation was cleared from a net lane 2 m wide, to prevent vegetation from becoming entangled in the net, 2) a piece of 1-m by 3/8-inch steel reinforcing bar was driven into the ground with a small hand-held sledgehammer at one end of the net lane on a slight backwards angle to the net, and 3) a 5-foot section of sawn 10-foot, 0.5-inch or larger, galvanised steel conduit was inserted over the rebar. All these steps were repeated at the other end of the net lane. When a net was closed it had to be spun to keep it from unravelling. The most effective way of achieving this was between two people from both ends simultaneously, leaving the topmost trammel separated from the others on the pole, and spinning the net on the lower trammels into a tight roll. After this the top trammel was pulled down atop the roll to keep it from unravelling. This allowed the net to be opened much more quickly than if the net had been spun around all the trammel lines. In order to roll up the net, all the support cords were keep together and centred on the axle as the net was rolled up to allow easy unrolling later. A rubber band was used to hold the loops in place at the end of the rolled net. In some places poles and rebar were hidden under vegetation near the net location to save set-up time. Nets were also commonly put into cloth bags.

4.5.3. Net Hours

The same schedule was operated from month to month, so as to allow direct comparisons. A standard "net" is considered to be 12 m long and 2.5 m high. For calculating effort, one standard mist net operated for one hour was a "net-hour." Two nets stacked atop one another were not considered as two nets. Although a single net location, if it was operated for one hour, they represented a total of two net-hours. Although there are methods of compensating for varying number of nets operate in different time periods (Ralph, 1976), these are best implemented during migratory periods when there is a high turnover of individuals between days. During the breeding season, when populations are more stable, it was best to operate nets on as regular a schedule as possible. This included the number of nets, the number of hours, the time of day, the number of days, and the number of days between operations.

The data are recorded on a daily basis was as follows: 1) basic information: state, region, station, year, operator(s), month and day; 2) number of nets, this number is usually one, but if stacked nets were used, they were reported as the same location); 3) opening and closing times, using the 24-hour clock, to record the time of starting to open and the time of starting to close the nets; 4) hours open, the number of hours open was calculated to the nearest hour (e.g., 5 hours, 50 minutes is 6.0 hours; 5) number of net-hours, calculated by the number of nets multiplied by the hours open; and 6) the total net-hours which is the total number of net-hours for each day.

Nets were opened within 15 minutes of local sunrise and operated for a minimum of 5, and in some cases 10 hours per day. Nets were checked every 25 minutes (more often in inclement or very hot weather) and invariably more than once each hour. That is, the net rounds were begun no longer than 30 minutes after the start of the previous round. Nets were opened in the same order each day, and closed in the same order that they were opened in. Each station was operated once per 10-day monitoring interval throughout the field season.

4.5.4. Removing birds from nets: body grasp method

For this study the method of body grasp was used for extracting birds from mist nets. This method is used by most netters, it was derived from the ideas of Shreve (1965), and was later modified and augmented by Ralph (1967, 1988). This technique is essential, providing the most secure and careful method to ensure the life and health of the birds was a primary concern.

This method was used to catch birds. Some stations have recently used this method, and it has been found to surpass other methods in ease of learning, reduced injury to the birds, and speed of removal. About 9 out of 10 birds can be removed by this method. The first steps of the method were to find out from which side of the net the bird entered and find the opening of the pocket caused by the weight of the bird. After this could be three choices: 1) if the bird's body was accessible, without any netting in the way, and the net was free of the back and head, the bird could be put into the bander's grip, with the palm against its back, the index and middle fingers on either side of the neck, the left wing held with the thumb, and the other fingers curled around the body and the right wing; 2) if the net was tangled around the head and wing, the fingers were slipped over the body and under the wings. This involved the thumb around the breast and the fingers over the bird's back, and down over its sides and under the wings and carefully around the curve of the body; and 3) if the body was too tangled to be available for a body grasp, there are some alternative methods depending of how the bird body was tangled. When the body was firmly secured, the body was backed out of the net to expose at least the bend of one of the wings. Then, the net was removed from the wings. Net threads were flicked from the bend of the wings working from the underside. In general the thumb was placed under the thread(s) on the underside of the wing and the forefinger was placed on the outer bend of the wing as a fulcrum to flick the thread over. Often at this stage it was helpful to pull gently on the exposed portions of the still tangled threads in order to free them or to see where they were caught. When one wing was free, the fingers were slipped over the now-exposed wing, securing it against the bird's body. Then, the remaining loops were pulled from around the neck, working from the back of the head forwards, in the manner of removing a T-shirt. The net was removed from the other wing, as above and the bird was gradually put into the "bander's grip." After, the bird was pulled up and away from the net, and it would usually free its own feet in an effort to fly. The heel joint was straightened out, the bird's toes had a tendency to relax, so that the netting was more easily removed. If the bird was clutching the net firmly, the feet was freed by freeing the opposable toe (the "thumb") by sliding the threads over it and lifting it away from the other toes; with the fingers, straightening the other three toes out; and sliding the netting over the toes with repeated strokes.

This method was very easy on the bird, because the only firm contact was on the sides of the neck. It was also a time saver, because feet untangle themselves. The method worked best with a recently caught bird that had had little time to entangle itself, but was applicable to most birds. Once the birds were removed from the nets (each individual separately) they were placed in a small cloth bag, and transported to the processing site. For each site a central processing area was implemented because this was better for the birds rather than to process item at each net as they were captured. When the processing became delayed, it was always preferred to have the birds out of the nets and stored in bags. The bags were made from opaque cloth, and sewn so that the seams were on the outside. The bags were hanging from hooks or branches to prevent them from being stepped on, and they were kept out of direct sunlight. The birds were released at the processing site except for females (indicated by a brood patch) and dependent juveniles (indicated by a frizzy appearance and a growing tail). They were released at the point of capture. Recaptures provided the most important data in constant-effort mist netting. When a bird showed stressed behaviour and had to be released without complete processing, the following measure were regarded as the priorities: 1) band number (if it was a recapture), 2) species; 3) age (usually involving skulling, or diagnostic plumage characters), 4) new band number (if the bird was previously unbanded), 5) sex, and 6) other measurements or data.

4.6 Data collection

At each net place, the location and vegetation description was filled out. The location information on the first three lines of the form was vital to the data base management. In addition to date, time, and location, it was imperative that the species were accurately identified. It was also vital that the age and the sex of the birds were determined when this was possible (by determining the amount of skull pneumatization, as essentially all analyses that depend upon accurate ageing can be made with above 99 percent confidence). All the above information was recorded for each individual captured or recaptured.

Age and sex determinations were generally complicated by the highly variable nature of size, plumage, and moult patterns for each species. A certain percentage of individuals were not reliably aged, or sexed. Birds in breeding condition (adults) the extent of juvenal plumage and molt, and the wing chord were also recorded. The guide of Pyle *et al.* (1987) was used for identification.

4.6.1. Age Classes

The age class system used by the U.S. Fish and Wildlife Service and Canadian Wildlife Service was also used in this study. The system is based primarily on the calendar year. Below are the age designation, the alpha code used by the Services, and a definition of the age class as follow: 1) Unknown (U or 0): age cannot be determined with absolute confidence; 2) hatching year (HY or H): a young bird incapable of sustained flight; 3) second year (SY or S): a bird in its juvenile or first basic plumage during its first calendar year (i.e., from its fledging until December 31 of the year that it fledged); 4) after hatching year (AHY or A): a bird in its second calendar year (i.e., January 1 of the year following fledging through December 31 of the same year); 5) after second year (ASY or O): a bird in at least its second calendar year; and 6) an adult in at least its third calendar year (ATY) (i.e., a bird in at least the year following its first breeding season and second prebasic molt).

4.6.2. Data Entry

If particular data were not collected, the columns were left blank. If a band was lost or destroyed, an indication of this was written in the code column and also in the species column. Only the records for one band size or for the recaptured birds were placed on any one sheet. A new banding sheet was always started for new series of bands or every month. The sheet were broken down into the following categories:

1) Heading material, the following information was given: state code, region code, band size ("R" for recaptures, entered on a separate sheet), page number (for each band size), and month of banding or capture.
2) Recorder and bander, the initials of the recorder and bander were placed here, and their full names at the bottom of the page (these were not entered into the database).
3) Code, this column tells if it was a: new banding (N); recapture (R), a bird previously banded; unbanded bird (U); destroyed band (D); lost band (L); or a changed band (C), a band that replaced an old or worn band make a note of the old band number was made.
4) Band number: the full right-aligned number of the first band on the first line. Thereafter, the final three digits of new bands only. On recapture pages, the full band number was to be entered each time.
5) Species: an abbreviation of the species name. The abbreviations were not entered into the data base, but were checked against the error-prone species code below.
6) Species code: the four letter code (the first two letters of a genus and the first two letters of the species names) of species name was used in this study because a Latin American version has not yet been prepared. For North America is in CWSS and USFWS (1991) is the four letter code for the common name.
7) Age: the following codes were used: A, adult plumage; J, juvenile plumage; M, molt; P, plumage in general; S, skull; T, tail length; W, wing length. For juvenile plumage, the extent of this plumage was recorded using the codes previously described.
8) Measurements: wing length (recorded to the nearest millimetre) and weight (recorded to the nearest tenth of a gram).
9) Sex: M for male, F for female, and U for unknown.
10) General information: date (month, day, and year, all in numbers); capture time (using the 24-hour clock, recorded to the nearest 10 minutes, e.g., 7:44 a.m. is 07:40, 5:48 p.m. was 17:55); and station/location (an abbreviation was recorded using the station number by each site and two numbers for the net location).

4.7 Vegetation

Vegetation was sampled at each census point according to protocols developed in ("Great Smokey Mountain") GRSM (Simons and Farnsworth, 1997). Whenever possible, vegetation was sampled on the first period of the census, recording several qualitative and quantitative variables. In general, the vegetation sampling consisted of two data sets: 1) a sample of trees, and 2) coverage estimates for canopy, subcanopy, tall shrub/sapling, low shrub/seedling, and herbaceous layers. The vegetation at each census point was sampled with the census point as the centre of a 10 m radius circular plot. For census points located on roads or trails, the vegetation was sampled 10 m off the road or trail to avoid sampling bias due to the break in vegetation. A coin was tossed to determine which side of the road or trail to sample. Data collection included a sample of trees counted with a wedge prism (Husch *et al.*, 1982). All trees detected within the limits of the wedge prism were identified and recorded with an associated dbh range estimate. Six dbh ranges were used: 0-10 cm, 11-25 cm, 26-50 cm, 51-75 cm, 76-100 cm, and >100 cm. The cover class and height range of five vegetation layers (tree canopy, subcanopy, tall shrub/sapling, low shrub/seedling, and herbaceous) were recorded at each point. The cover classes estimate the percentage of vegetation in the plot blocking sunlight to the layers below. Ten cover class categories, ranging from 1 (<0.1%) to 10 (>95%), were used. In addition to a cover class, a height range in m was recorded for each vegetation layer present. The composition of the canopy, subcanopy, and tall shrub/sapling layers was determined by identifying the dominant species in each layer. Each species was recorded with an estimate of its percent contribution to the layer. The herbaceous layer was characterised as deciduous, evergreen, fern, moss, or a combination of characteristics.

4.7.1. Data collection

All trees > 10 cm dbh occurring within the sampling plot boundaries were marked. Measurements included dbh (diameter at breast height, or 1.30 m), canopy (branching) and total height. On inclined trees, which occurred frequently, the dbh was measured along the trunk at 1.30m from the forest floor. When trees bifurcated below 1.30m, both stems were considered as single trees and measured separately. In the case of one stem being less than 31.4cm dbh, the stem was considered as single, but the value of the thinner was summed with it. In such a case it was also considered as an individual tree in the estimate of species density. The same procedure was adopted for height measurements.

The main difficulty in measuring tree heights was the dense and closed nature of the cloud forest canopy, with many overlapping crowns of different tree species with similar leaf size and shape, combined with the steep relief. For these reasons, the total and canopy (stem) heights were mostly estimated visually. The individual plants were identified by their local name, whenever the local guide knew it. Herbarium specimens were also collected for most plants (with duplicates). The botanical samples were heat-dried in the field and later deposited at the Botanical Herbarium of Instituto de Ecologia in Xalapa, Veracruz, and Instituto de Historia Natural, Tuxtla Gutierrez, Chiapas.

4.8 Data Analysis

The number of samples and timing of censuses were evenly distributed across the four habitat types in the study areas. The total number of point counts placed in different sites for Chiapas sites were 230 and 225 for Veracruz site. Overall 1 371 point count censuses were conducted from November 1996 to June 1997 and others from February to July 1999 in Chiapas, and another 670 in central Veracruz. Cloud forest was the habitat most extensively sampled due mainly because it is the most extensive ecosystem in the area.

4.8.1. Abundance, species richness and diversity

Point count data are commonly analysed in terms of relative abundance, species richness, and species diversity (Nur, *et al.*, 1995). Relative abundance was based on the number of detections per unit area. The number of individuals was determined at each point count station. Results from several point counts were averaged. If the point counts were censused more than one time, then the number of detections in all points were summed, or the average number per point count was calculated (Nur *et al.*, 1995). Abundance for bird species in this study was defined as the number of individuals found in all points for a particular habitat, divided by the number of samples.

Species richness was analysed as the total number of species detected. Totals were calculated for each point count station, or for each group of point count stations. Data from all point counts were used to calculate total species richness per habitat. In addition, species richness estimates were used to determine if sampling is sufficient to have collected all the species from a region.

Species diversity and sample size

Species richness was defined as the total number of bird species detected in each habitat. The expected species richness in each habitat (using the point counts and the mist net methods) was estimated by species accumulation curves and the use of a nonparametric estimator (Colwell and Coddington, 1994). Both analyses were used to assess completeness of the species inventory and to estimate the local richness of each habitat.

The analysis was developed by the software EstimateS version 5 (Colwell, 1997), which removes the effect of the sample order. The order in which samples are included affects the shape of the accumulation curves, thus this effect was removed by randomising 50 times in order to obtain the mean of the accumulation curves for each habitat (Colwell, 1997; Chazdon *et al.*, 1998). The ICE (Incidence based coverage estimator) was the non-parametric estimator of richness used and it is based on species found in 20 or fewer sampling units. This estimator included species not discovered in any sample. The degree of spatial aggregation (or effect of patchiness) was evaluated by comparison of the mean species accumulation curve with the Coleman curve, which is the curve expected if the individuals in all samples pooled had been randomly assigned to the quadrats (Colwell and Coddington, 1994; Colwell, 1997; Heyer *et al.*, 1999).

Two non-parametric estimators of richness (Chao and first-order Jackknife, Colwell and Coddington 1994) were used for analysis of the mist nets data. The "chao 1" method was proposed by Chao (1984) as a simple estimator based on the number of rare species in a given sample $S_1^* = S_{obs} + (a^2/2b)$ where, $S1^*$ = is the true number of species, S_{obs} = is the observed number of species in a sample, a = is the number of observed species that are represented by only one individual (singletons),and b = is the number of observed species represented by exactly two individuals (doubletons). Although simple, this estimator has been shown to work rather well if more than half the total fauna is observed (Colwell & Coddington, 1994).

Diversity indices often assume that the probability of two sampled individuals belonging to the same species is dependent only on the relative abundance of species within the community. To overcome this sampling methods need to provide for a random sample, although in practice it is difficult to ensure that the individuals detected are randomly sampled or even that the sampled sites themselves are randomly positioned (Magurran, 1996). Magurran suggested that Jack-knifing the estimate of a diversity index is one simple solution to this problem, since this technique had proved to be robust against any bias caused by clumping. The Jack-knifing method can be used to provide an estimation of minimum sample size. This method was used to estimate the minimum viable sample size, based on point counts pooled in random order and continuous recalculations of diversity on the basis of all the data in the pool. The point at which the curve flattens indicates the minimum viable sample size (Magurran, 1996).

The K dominance curve was used to compare biodiversity between habitats in the study areas, the abundance plot for K dominance is based on the species rank and is a graphical system used for comparing diversity. The abundance is plotted against log species rank and the output shows the plot and a table of the species in rank order for each sample (Clark, 1990). For the partial dominance curve the relative abundance of a given species is calculated only with respect to species of lower rank. While the shape of the k-dominance curve is dominated by the single most abundant species, the partial dominance curve allows the study of several of the more abundant species.

Species richness is only a component of diversity. Consequently, scientists have devised diversity indices that measure species richness, and at the same time take into account species abundance. The number of diversity indices is quite extensive and there is no consensus as to which index is preferable (Hayek and Buzas 1997; Magurran 1996). One of the most widely used diversity indexes is the Shannon's H' index, which is derived from information theory and reflects both species richness and evenness of distribution among species present (Nur *et al.*, 1995). It has been recognised by several ecologists that this index has several flaws (e.g. dependence on sample size); however, it may be more informative to use it as it is one of the most commonly used indices, thereby allowing direct comparison with another studies (Magurran, 1988). In addition, Hayek and Buzas (1997) suggested that using H' as a measure of diversity is not without problems, but the relative size of H' is an indication of the diversity in terms of the number of species and the spread of the individuals among those species. Estimation of diversity indices is closely related to sample size and effort. Thus to avoid any bias due to uneven sample size, diversity indices were calculated using the selected 32 samples from December 1999 and June 2000, using Shannon's H index:

$$H' = -\sum_{i=1}^{S} (p_i)(\ln p_i)$$

Where :

H' = Shannon Diversity

S = total number of species in the sample

p_i = proportion of all individual s in sample that belong to species i

$\ln p_i$ = natural log of p_i

The Shannon evenness measure (E), indicates a relative abundance of species in terms of evenness and is based on the Shannon diversity index, This measure is important to determine heterogeneity. Evenness is how equally abundant the species are and it was calculated using the following formula (Magurran, 1996):

$$E = H / \ln S$$

H = Shannon diversity index

S = Number of species

Similarity between habitats

Similarity within each habitat between bird species was evaluated using the Jaccard index. This index is designed to equal 1 in cases of complete similarity and θ if the samples are dissimilar and have no genera in common (Magurran, 1996). The index was calculated according to the formula:

$$J = \frac{j}{a + b - j}$$

where,

j = Number of genera found in both samples

a= Number of genera at ground level.

b= Number of genera in canopy and undercanopy.

The Sorensen similarity index was also used to assess similarity between habitats. This index is a binary coefficient and only takes into account presence and absence data (Magurran, 1988), it was calculated with the following formula: $S_s = 2a / 2a + b + c$ where,

S_s = Sorensen similarity coefficient

a = is the number of species in sample A and B

b = is the number of species in sample B but not in sample A

c = is the number of species in sample A but not in B

A cluster analysis employing the Bray-Curtis similarity index was used to compare wintering and breeding season between the habitats. Clusters were performed in BioDiversity Professional Beta 1 (MacAleece *et al.*, 1997) using single linkage cluster method. The total number of samples was used to cluster the four habitat types in the study areas.

Numerical classifications or cluster analyses are based directly on measurements of relative similarity of either the distribution of species or the composition of samples. They are considered to be more objective than traditional methods, as the use of standard procedures provides an objective measure of similarity (Greig-Smith, 1983). Numerical classification techniques operate either by grouping stands together on subjective assessment of similarities, or by dividing the whole set of stands into two or more groups on the basis of the presence of one or few dominant or indicator species. Ecological groups and characteristic species groups are primarily arbitrary groupings of species by similarity of distributional relationships. The resultant output is either a non-hierarchical or hierarchical arrangement of samples or species (Pielou, 1984).

Many classification procedures have no statistical element and can be regarded as a way to generate hypotheses. If the data contain a discontinuity they can serve as a basis for a 'natural' classification. Ordination enables visualisation of the continuity or discontinuity of the data, and also gives information on the number of clusters to be recognised. Among the advantages of numerical classification are its objectivity, the identification and use of natural discontinuities, and the adoption of optimisation procedures. Clustering can be done by calculating a matrix of indices of similarities between pairs of stands. The numerical procedure leads to an arrangement of the samples in a hierarchical pattern, which can be expressed as a dendrogram, reflecting both the successive steps and the presumptive relationships among the clusters distinguished. Rules can be established to define a point beyond which distal branches of the dendrogram will be regarded as members of the same class (Greig-Smith, 1983).

Indicator species analysis is a divisive polythetic method that uses reciprocal averaging ordination to reflect the most important vegetation gradient in the first axis (Hill *et al.*, 1975). The stands are divided into two groups at the centroid, the mean value of the stand scores. Species whose occurrences are most nearly confined to stands on one or the other side of the division are identified as 'differential species' or 'pseudo-species'. These species are used to refine the initial ordination of stand, dividing the stands into two groups. The method classifies objects judged to be similar according to distance or similarity measures. Data can be quantitative or presence/absence.

Group classifications

In order to compare and evaluate the effects of habitat mosaic on the bird community in each one of the different habitats, all the recorded bird species were classified into groups. These groups, based on many criteria, comprised the following: trophic guilds, trophic behaviour guilds, restriction to forest, use of forest interior, use of forest stratum, resident / migratory, range of distribution, endemicity, rarity and conservation status (see Appendix I). The nomenclature and taxonomic sequence of the recorded bird species followed the Association Ornithological Union (A.O.U., 1998).

a) Trophic guild: This group is based on the main food items consumed by each bird species and is divided into four categories: *primary consumer, omnivore, predator* and *scavenger* (Howell and Webb, 1995). Each one of these categories is classified according to the dietary specialisation using the point counts and mist net data set for this research (Table 4.1, Appendix I).

Table 4.1 Trophic guild categories and dietary specialisation (based on Howell and Webb 1995).

Primary consumer	Omnivore	Predator	Scavenger
Leaves, flowers, fruits and seeds	Leaves, fruits, seeds, invertebrates and vertebrates	Snails, insects, reptiles, mammals and birds	Carrion
Fruits and nectar	Nectar and insects	Insects and others invertebrates	
Fruits and seeds	Fruits and insects Seeds and insects	Invertebrates and fish	

b) Trophic behaviour guild: This group is divided in 33 categories (see list category in Appendix I), according to the main food habits, feeding behaviour and foraging substrate of the bird species. This classification was based on the research of Kattan *et al.*, (1994), Terborgh *et al.*, (1990) and Nocedal (1994) using the point counts and mist net data set of this study.

f) Resident and migratory status: This group classification was based on the bird status provided by Howell and Webb (1995). It was divided into the five following categories: *resident* (species that breed and stay all the round year in the area); *transient* (migratory species from the north that uses the area as a stopover during migration. From April to May and from August to October); *resident/winter visitor* (species with resident and migratory populations that utilised the area as a wintering refuge); *transient/winter visitor* (migratory species from the north, with populations that use the area as a stopover during migration and populations that use the area as a wintering ground from August to May); and *summer visitor* (species that use the area only during the reproduction season only, from about March to August).

g) Range of distribution: The altitudinal and geographic distribution range of all bird species was obtained from Howell and Webb (1995) and the checklist of North American birds (AOU, 1998). The edge of the distribution range of a bird species was defined as the edge area representing less than 20% of the distribution area of the species. This group was divided in two categories: *core* and *marginal* distribution. Core distribution was considered when bird species were well located within their geographic and/or altitudinal distribution range. In contrast, marginal distribution was considered when bird species were located at their edge of the geographic and/or altitudinal distribution range.

h) Endemicity: This group was based in the information provided by Howell and Webb (1995), and Escalante *et al*; 1998. Firstly, the recorded bird species were classified as *endemic* and *non-endemic*. The endemic were divided in three categories: endemic to Middle America (species whose distribution is restricted from the Tropic of Cancer, 23.5° latitude North, and to the south to northern Nicaragua, at about 13 ° latitude North); endemic to Mexico (species whose distribution is restricted to the limits of the Mexican territory); and restricted-range species (species which are considered to have a historical breeding range of less than 50,000 km^2, Stattersfield, 1998).

i) Rarity: This group is based on the rarity of the recorded bird species in both methods (point counts and mist net) in the study area. Rarity was classified in four categories:

Common (when one individual was detected in at least 20% of the point counts surveyed, representing daily visualisation of the species); *fairly common* (when one individual was recorded in 5 to < 20% of the point counts and mist net surveyed, representing observations of the species approximately once every other day), *rare* (when one individual was recorded in less than 1% of the point counts surveyed); and *uncommon* (when one individual was recorded in 1 to < 10% of the point counts surveyed and represented an observation of the species approximately once a week). In the case of migratory and transient birds, their rarity was estimated only for the months they occurred in the study area.

j) Conservation status: This classification was based in the categories used by the Mexican Secretary in charge of the administration of the natural resources (SEDESOL, 2001). The classification is mainly divided into species of *conservation concern* and *non threatened* species. However, the list is being currently reviewed and a new list of species of conservation concern will be produced shortly.

4.8.2. Statistical analysis

Analysis of variance (ANOVA) was used to compare variables between the different habitats. This analysis allows comparison between more than two means. When three or more samples are observed, it is not valid to conduct a series of t test analyses to find out if differences are significant (Fowler and Cohen, 1990; Zar, 1996). ANOVA overcomes these difficulties by allowing comparisons to be made between any number of samples. When it is used to compare only one set of means, it is termed one-way ANOVA. Departing from the null hypothesis that all means are equal, one-way ANOVA was conducted among habitats for total abundance of birds within each season.

One-way ANOVA was initially used to compare mean abundance between habitats per season, but this proved not to be applicable as none of the species showed a normal distribution, nor homogeneous variances, not even after logarithmic transformation (these are assumptions for one-way ANOVA). When data are not normal, nonparametric tests can be used. These methods do not require the estimation of the population variance and mean and do not make assumptions about the nature of the distribution of the sampled populations (Zar, 1996). The Kruskal-Wallis H test (Zar, 1996) was used when data were not normally distributed. For this test, as for many nonparametric procedures, the rank of the measures are used, rather than the actual values. Data may be ranked either from the lowest to the highest value or the opposite.

Regression analysis was used in order to analyse bird diversity against the size of the patch. This procedure performs regression with linear and polynomial (second or third order) terms, if requested, of a single predictor variable and plots a regression line through the data, on the actual or log10 scale. Polynomial regression is one method for modelling curvature in the relationship between a response variable (Y) and a predictor variable (X). by extending the simple linear regression model to include X**2 and X**3 as predictors. A linear regression was utilised to fit the model

$Y= \beta_0 + \beta_1 X + e$

Where Y is the response, X is the predictor, beta0 and beta1 are the regression coefficients, and e is an error term with a normal distribution with mean equal to 0 and standard deviation equal to sigma. Regression estimates beta0 by b0, beta1 by b1, and sigma by s. The fitted equation is

$Y = b_0 + b_1 X$

Y-hat is called the predicted or fitted value.

4.8.3. Community ecology

Community ecology, or synecology, concentrates on the study of several species at a time and their relations with environmental variables. These relations are usually very complex. From a methodological point of view, this complexity is reflected in the fact that many difficulties of empirical science are encountered at the same time. Wide variability in the variables studied, complex interaction between explanatory variables and response variables, and uncertainty on the causes of the observed variation are amongst the most common problems (Jongman *et al.*, 1995). The methods appropriate for the analysis of this kind of ecological data show the same tendency of increasing complexity. Experimental research is difficult to carry out, especially at the more complex levels of communities, ecosystems and landscapes. The analytical techniques complexity. Experimental research is difficult to carry out, especially at the more complex levels of communities, ecosystems and landscapes. The analytical techniques used are determined by the objectives of the project the results are influenced by what is sampled, and the way it is sampled (Jongman *et al.*, 1995).

Multivariate methods make such data easier to handle. These methods can be divided into three different categories: direct gradient analysis, or regression analysis; indirect gradient analysis, or ordination; and classification, or cluster analysis. Here ordination and cluster analysis classifications are described as these were used for data analysis. Data from all the points that were sampled for habitat description in June, along with the bird data for the same points in May, were used for these analyses.

Ordination

To explain the variation in the abundance of species of an ecological community, the first step was to summarise the species data by searching for the dominant patterns of variation in the composition of a particular community. Usually species abundance co-vary in a systematic way because the species are reacting to the same environmental variables. But if the environmental variables are unknown, it is possible to reconstruct such variables from the species data alone. This is termed ordination; in ordination, sites and species are arranged along axes that represent theoretical variables in such a way that these arrangements optimally summarise the species data (Jongman *et al.*, 1995). Ordinations are usually displayed as two dimensional diagrams where points represent sampled sites. Points are represented in such a way that the closer they are the more similar in species composition, and, on the other hand, points that are far apart correspond to sites with very dissimilar species composition.

Correspondence analysis is a widely used ordination method to describe such correlations. This analysis is based on direct gradient analysis and its extension, reciprocal averaging. A known gradient is taken from the sites, and is used to create a set of scores for the species. These scores are later used to obtain a new gradient where the species can be ordered; a new gradient for sites can be scored from this species gradient, and so on (Digby and Kempton, 1987). This data is usually displayed along a one-dimensional axis, but the correspondence analysis (CA) approach extends the reciprocal averaging procedure to a second and further axes. The theoretical variable constructed by CA is termed the first ordination axis; its values are the site scores on the first CA axis. Second and further axes also maximise the dispersion of the species scores but subject to the constraint of being uncorrelated with previous CA axes. This constraint provides that the new information is expressed in the later axes. To avoid confusion, normally only a few axes are plotted, in the hope that they will represent most of the variation in species data (Jongman *et al.,* 1995).

Ordination techniques such as indirect gradient analysis can explain the effects of environmental variables on species composition, even if the environmental variables cannot explain the main variation, they may still explain some of the remaining variation, which can be very important. If only four ordination axes are extracted (as usual), the relation of the environmental variables with the fifth axis may go unnoticed; this is very significant, considering that this relation can be very strong. To solve this problem canonical correspondence analysis (CCA) can be used (Jongman *et al.*, 1995). CCA detects the patterns of variation in the species data that can be "best" explained by a set of environmental variables. The resulting ordination diagram expresses both the pattern of variation in species composition and the main relations between the species and each of the environmental variables (Jongman *et al.*, 1995).

CCA maximises the dispersion of the species scores based on a selected linear combination of environmental variables. The first CCA axis is given by the selection of the best weights for the environmental variables. The second and further axes also select linear combinations of environmental variables that maximise the dispersion of species scores, but subject to the constraint of being uncorrelated with previous axes (Jongman *et al.*, 1995). Only the number of environmental variables considered limits the number of axes that can be extracted.

Detrended correspondence analysis (DCA) was carried out using log-transformed relative abundance of species at each site; this analysis produces a series of uncorrelated axes that maximise site dispersion along axes. Distances between each site are interpreted as habitat similarities in bird species composition. Canonical correspondence analysis (CCA) was also carried out using the following environmental variables per point: number of tree species, altitude (denoted as meters above sea level), canopy, wind speed, and temperature. CCA produces a species-environment correlation. This is the correlation between the site scores that are weighted averages of the species scores and the site scores that are linear. The programme CANOCO 4.01 was used to run both the DCA and CCA.

4.9 Additional environmental data

During the fieldwork period and in order to compare field procedures and methodological data, several visits were made to Mexican institutions and university departments. The visits included the "Centro de Investigaciones Biologicas" (CIB) from the University of Veracruz in Xalapa, Veracruz; the "Instituto para el Desarrollo Sustentable de Mesoamerica (IDESMAC), Departamento de Zoologia, Colegio de la Frontera Sur, in San Cristobal de las Casas Chiapas; and the "Instituto Nacional de Estadistica e Historia (INEGI) in Veracruz, Chiapas and Aguascalientes. These visits had the aim of collecting all information, mainly spatial data including topographical and geological maps (1:50 000 and 1:250 00), vegetation maps (1:250,000), and aerial photographs (1:22,000, from 1992), Additional data and information on El Triunfo Biosphere reserve and the Centre of Veracruz environment were also obtained from post-graduate theses, scientific papers, government reports and proceedings of congresses, workshops and seminars. This information was obtained in the Science Library of the Instituto de Ecologia in Xalapa, Veracruz and the National Science Library in the Universidad Autonoma de Mexico (UNAM).

CHAPTER 5

"El Triunfo": Forest patches and coffee plantations in Chiapas

5.1 Introduction

The areas of South Mexico and Central America are considered as the most important wintering areas for neotropical migratory birds. Unfortunately during the last 10-20 years human population growth in the area has resulted in a higher land demand, which results in higher rates of deforestation. Tropical deforestation is considered as one of the main factors contributing to observed population declines of both migrant and resident species. However, several recent studies have shown that migrant bird diversity and abundance is often very high in successional habitats and in areas that have suffered a moderate degree of disturbance (Greenberg *et al.*, 1997a; Calvo and Blake, 1998).

Many neotropical birds are adapted to habitat mosaics produced by natural disturbance regimes (Halffter,1991), among which the most important are large-magnitude and high intensity disturbances produced by the action of rivers on the upland forests. But more recently, attention has been drawn to the study of the effect of anthropogenic disturbance, especially on the composition and diversity and the ability of bird species to survive in fragmented and isolated habitats (Willis, 1979; Zimmerman and Bierregaard, 1986; Lovejoy and Bierregard, 1990). The study of anthropogenic disturbance that leads to agroecosystems has received relatively less attention, even though this is one of the most widespread kinds of disturbance in extensive regions of the tropics in Mexico and Central America.

As in many neotropical areas, where coffee agriculture has been the traditional land use, in the Sierra Madre of Chiapas the coffee plantation is one of the most important human activities. These kinds of plantations have proved to have different levels of impact when used in an unsustainable manner; which is today evident in many parts of the buffer zone of the "El Triunfo" biosphere reserve. In this area, the vegetation mosaic is occurring in a shorter cycle, as opposed to the traditional 20-30 year cycle, resulting in a landscape dominated by early successional habitats (5-10 years old). This research was carried out in La Chilana and Custepec. Those areas are located in the buffer zone and conservation areas numbers three and four, respectively of the "El Triunfo" biosphere reserve see figure 4.1. In general the avifuana of both regions (residents and migratory bird species) is unknown; a few studies have been carried out on the ecology of birds in "El Triunfo" but these were developed in the core zone of the reserve.

5.2 Structure of the argument

The present research is focused on the understory bird distributions throughout the habitat mosaic. This chapter aims to describe the composition and relative abundance of bird communities in four habitats: cloud forest (CF), natural shade coffee (NSC), inga shade coffee (Inga), and sun coffee (SC). Identification of all bird species detected, including their estimated population parameters and the expected bird species richness, provides an estimation of how these bird species are adapting in the study area. The chapter also characterises the bird community in terms of distribution of species by trophic guilds, dietary specializations, trophic-behavioural guilds, use of forest strata, level of restriction to cloud forest, distribution range, endemicity, resident/migratory status, level of rarity, and conservation status, see 4.8.1. Furthermore it calculates the species distributions of migratory and residents (adults and juveniles), providing evidence of their relationship with different habitats in the mosaic landscape.

Several studies have been carried out previously on the composition and structure of the bird community in habitat mosaics in different places of Mexico; however the understanding of these patterns and processes is still far from complete. To contribute to this knowledge, the following questions were developed to describe the composition and structure of the bird community occurring in the four habitats in three study areas on the South of Mexico (La Chilana and Custepec in the present Chapter, and Barranca Grande in Veracruz, Chapter 6):

1) what is the understory bird species composition in each of the surveyed habitats? Are there differences between these habitats in terms of species richness?

2) what is the bird composition in each habitat according to trophic behaviour, use of forest strata, conservation status and restriction or preference to one of the habitats?
3) what are the differences in species distributions between resident and migratory species among the habitats? Are there any habitat preferences for migratory bird species?
4) what are the effects of environmental variables, such as patch size, altitudinal range, temperature, wind speed and canopy complexity, on the species composition per habitat? And
5) which are the most important habitats in terms of bird conservation?.

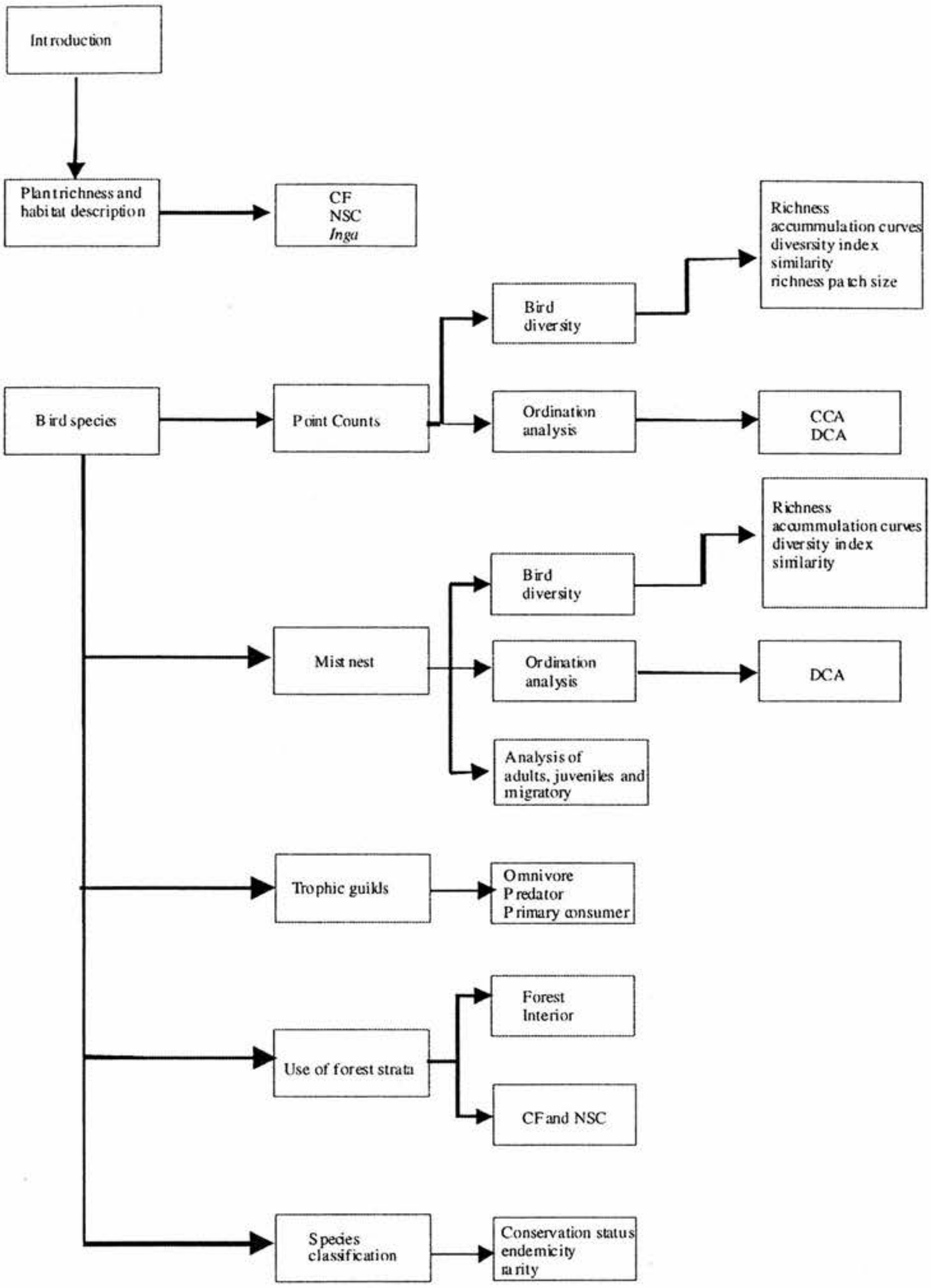


Figure 5.1 Schematic view of the structure of the analysis. The data were obtained from the forest structure characterisation, point counts and mist net methods (see chapter 4).

5.3 Plant richness and habitat description

In Custepec and La Chilana, the distributions of the habitats are well defined. The general characteristics of the vegetation at the study sites are given in Table 5.1.

A few tree species were dominant in the habitats such as cloud forest and natural shade forest. In both sites the highest richness for the tree and shrub layer was found in cloud forest, however the highest number of herb species was found in *Inga* for Custepec, and in the natural shade coffee for La Chilana. This observation can be explained because in these habitats the ecosystem structure is open with more sunlight. In both sites there was an absence of trees in sun coffee. The habitat ranked by number of plant species was also similar (CF, NSC, Inga and SC). The most common plant species found around the point counts are listed in Appendix II.

Table 5.1 Number of vegetation samples per habitat with the number of species at three defined layers.

Habitat	Number of samples	Number of plant species	Species in tree layer	Species in shrub layer	Species in ground layer
Custepec					
Cloud forest	30	167	65	90	51
Sun coffee	15	0	0	0	0
Natural shade coffee	20	121	54	42	38
Inga shade coffee	20	49	23	23	59
La Chilana					
Cloud forest	30	179	79	105	58
Sun coffee	15	0	0	0	0
Natural shade coffee	20	135	63	64	69
Inga shade coffee	20	64	34	43	45

5.3.1 Cloud forest

In Custepec a total of 106 patches were surveyed, ranging in size from 0.5 to 21 000 ha. Patches of CF were the large continuous areas and were surrounded by agricultural habitats (80% coffee and 10% maize). The remaining 10% comprised roads, rivers, etc. The patches in the area covered an altitudinal range between 1 450 to 2 100 m above sea level, and the region contained a very high percentage of steeply sloping ground. The forest is tall, dense and in many places dark at ground level. Canopy heights range between 30-40 metres.

In La Chilana, a total of 114 patches were surveyed, ranging in size from 0.1 to 51,000 ha. Patches of CF were also surrounded by agricultural habitats (70% coffee and 10% maize). The remaining 20% comprised roads, rivers, etc. The patches in the area covered an altitudinal range between 1 300 to 2 100 m above sea level, and the region contained a very high percentage of slopes between 60% to

90%. The bigger patches of forest are tall, dense and dark. Canopy height is between 25-40 meters. In both study sites shrub and small tree species are well represented by the Piperaceae, Rubiaceae, and Solanaceae families, further characterized by the abundance of arborescent ferns. These communities are dominated by the following species: *Ulmus mexicana, Phoebe chiapensis, Quercus salcofolia, Q. polymorpha, Clethra matuade, Carpinus caroliniana,* and *Magnolia schiedeana. Liquidambar macrophylla* was also important in Custepec.

Vegetation coverage ranges were categorised as follow: 5 - more than 75%, 4 - between 50% and 75%, 3 - from 25% to 49%, 2 - less than 25%, and 1 - dispersed. In both sites, the slopes protected from sunlight, lower vegetation layers, mainly bushes, showed a level of coverage 5. In exposed slopes, the herb layer showed coverages 4-5 and the tree layer was typically coverage 3-4. The number of strata in both sites was also similar. The tree stratum consistently showed two sub-layers, but sometimes three (mainly in CF). The bush stratum usually had one sub-layer, sometimes two. The herb stratum is usually composed of one clear layer. The tree stratum has generally 3-4 cover; but a few sites showed 3 to 5 cover (Table 5.2). At both sites, the most complex habitat structure was CF followed by NSC and then Inga.

Table 5.2 Number of layers and coverage categories per habitat at Custepec and La Chilana. Coverage categories: 5 - more than 75%, 4 - between 50% and 75%, 3 - 25% to 50%, 2 - less than 25%, and 1 - dispersed.

Habitat	Number of layers (coverage category)		
	Tree	Bush	Herb
Custepec			
Cloud forest	3-2 (4)	2 (4-5)	1(3-4)
Natural shade coffee	3(3)	1(2)	1(3)
Inga shade coffee	2-3(4)	1(2)	1(2)
La Chilana			
Cloud forest	3 (5)	2 (4)	1(3)
Natural shade coffee	3(3)	1(2)	1(3)
Inga shade coffee	2-3(3)	1(2)	1(3)

5.3.2. Natural shade coffee

Patches of natural shade coffee in this area are derived from cloud forest, accounting for the cloud forest species found in the upper tree layer. These habitats show a similar structure to that of the original forest, although coffee plantations have replaced the bush layer. In those plantations with a tree stratum comprised of only native species from the original forest, the number of trees per ha is around 190 and 205 for Custepec and La Chilana, respectively.

Different patterns of plantation management occur in the area, shade trees are used to build houses, for fuel, as a food source, for medicinal purposes and for decoration, so that each patch represents a different management history. The main difference in structure between natural shade coffee and cloud forest is the substitution of the herb and shrub layer by the coffee plants. Natural shade coffee showed 3 sub-layers in the tree stratum, only one sub-layer in the bush layer (coffee plants), and one in the herb layer. In Custepec, coverage was 2-3 for the tree stratum, 2 for the bush layer and 3 in herb layer, while in La Chilana coverage was 3 for the tree stratum, 1 for the bush layer and 1 in herb layer (Table 5.2).

5.3.3. Inga shade coffee

The stratum in this habitat is dominated by *Inga* species. The most abundant species are *Inga laurina*, *I. micheliana*, *I calderonii* and *I. sapinoides*. At each site there were other abundant species. In Custepec, the other abundant tree species were *Clethra obliquinervia*, *Phoebe chiapanensis*, *Belotia mexicana*, *Bursera simaruba*, *Trema micrantha* and *Heliocarpus apendiculatus.* In La Chilana the other abundant species (apart from the *Inga*) were *Clethra obliquinervia, Bursera simaruba, Trema micrantha, Phoebe chiapanensis*, *Belotia mexicana*, and *Heliocarpus apendiculatus.*

It was found that this plantation contained a number of trees, shrubs and palms for human use. Coverage was lowest in the bush layer composed of coffee plants. However tree coverage had the same amount as the cloud forest (4 in Custepec and 3 in La Chilana), the herb layer coverages were 2 and 1, respectively (Table 5.2).

5.4 Bird species (Point Counts)

5.4.1 Bird richness

A total of 287 and 224 bird species were registered in Custepec and La Chilana, respectively (Figure 5.2). The number of species recorded is the total of species identified using point counts and mist nets. In Custepec, 287 species were identified using point counts, 105 of which were also caught with mist nets. In La Chilana 80 species, from the total identified using point counts were also caught with mist nets.

species, from the total identified using point counts were also caught with mist nets. In Custepec, CF was the habitat with the highest richness (287 species), followed by NSC with 223, and Inga with 215 species. In La Chilana NSC was the habitat with the highest richness (223 species), followed by CF with a close richness of 214 species, and Inga with 148 species. In both areas SC had the lowest number of species, 31 and 28 species, respectively.

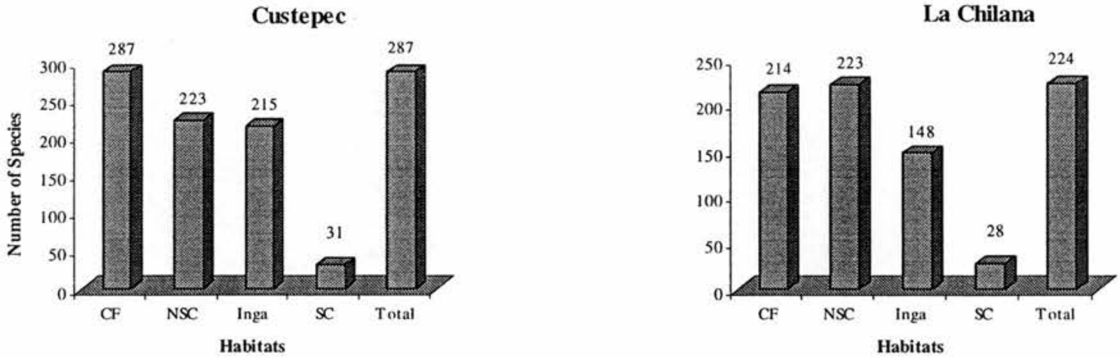


Figure 5.2 Number of species per habitat type, at Custepec and La Chilana, based on overall numbers. CF = cloud forest, NSC = natural shade coffee, Inga = Inga shade coffee and SC = sun coffee.

At the three study sites, nocturnal birds like owls and nighthawks, some parrots and soaring raptors that were flying overhead and passing through the point count were excluded from the analysis. However raptors below the tree canopy were included in the analysis of the total bird population. In all the sites the greater number of species recorded were residents. In Custepec 228 resident species were recorded in CF, 170 in NSC, and 162 in Inga. In La Chilana 167 resident species were recorded in CF, 170 in NSC and 95 in Inga. In both sites, the lowest numbers belong to SC with 19 and 17 (Table 5.3).

Table 5.3 Bird species richness and seasonality by habitat types at Custepec and La Chilana. Numbers in parentheses indicate percentages.

HABITAT	Resident and winter visitor	Resident	Summer visitor	Transient and winter visitor	Transient
Custepec					
Cloud forest	3(1)	228(82)	3(1)	45 (16)	8(3)
Natural shade coffee	2(1)	170(75)	2(1)	36(16)	13(8)
Inga shade coffee	2(1)	162(75)	2(1)	39(18)	10(5)
Sun coffee	0(0)	19(61)	0(0)	10(11)	2(10)
La Chilana					
Cloud forest	2(1)	167(82)	4(1)	49 (15)	6(3)
Natural shade coffee	1(1)	170(75)	2(1)	43(16)	10(8)
Inga shade coffee	2(1)	95(75)	2(1)	38(18)	8(5)
Sun coffee	0(0)	17(60)	0(0)	12(9)	1(10)

5.4.2. Species detected

In Custepec a total of 287 bird species, belonging to 30 bird families, were detected in the 4 different habitats (CF, NSC, Inga, and SC plantations). The families Emberizidae and Tyrannidae provided the greatest numbers of species for all the sites. In the case of La Chilana, a total 224 bird species, belonging to 28 families, were detected in the different habitats. In this area the families Parulidade and Tyrannidae accounted for greatest numbers of species in all the habitats (See Appendix III).

The species within the genera *Cypseloides* (in Custepec) and *Empidonax* (in Custepec and La Chilana) were not treated at species level in the point counts survey, because of the difficulty in identifying them by visual observations only. They were identified when mist-netted. It is possible that some birds remained undetected in the sampling effort. Estimation of relative abundance (see methods chapter) was calculated for all bird species detected in each habitat. The abundance for each area is presented in separate sections:

Custepec

The species with the highest relative abundances in CF were Plain Chachalaca, *(Ortalis vetula),* White-bellied Chachalaca, (*Ortalis leucogastra),* Blue-throated Motmot, *(Aspatha gularis),* Red-billed Pigeon, *(Columba flavirostris),* Blue-grey Gnatcatcher, *(Polioptila caerulea),* Blackburnian Warbler, *(Dendroica fusca),* Indigo Bunting, (*Passerina cyanea),* Acorn Woodpecker, *(Melanerpes formicivorus),* Inca Jay, *(Cyanocorax yncas),* Brown Jay, *(Cyanocorax morio)*, and Wilson's Warbler, *(Wilsonia pusilla).* These 11 species accounted for 65% of the total relative abundance of the bird community in the CF. Because these species also had high density estimates, their high relative abundance was not only the result of the species high levels of detectability, but the result of their higher true abundance, particularly in the case of Brown Jay and Wilson's Warbler.

For NSC the species with the highest relative abundance were Plain Chachalaca,, White-bellied Chachalaca, *(O. leucogastra),* Acorn Woodpecker. *(M. formicivorus),* Band-backed Wren, *(Campylorhynchus zonatus),* Spotted Nightingale-Thrush, *(Catharus dryas),* Golden-crowned Warbler, *(Basileuterus culicivorus),* Great Kiskadee, *(Pitangus sulphuratus),* Red-eyed Vireo, *(Vireo olivaceus),* Blue-grey Gnatcatcher, Orange-crowned Warbler, *(Vermivora celata),* Grey Catbird, *(Dumetella carolinensis),* and Wilson's Warble. These 13 species accounted for the 56% of the total relative abundance in NSC.

In the case of Inga, the species with the high relative abundance were Blue-diademed Motmot, *(Momotus momota)*, Blue-throated Motmot, Blue-grey Gnatcatcher, Slate-throated Redstart, *(Myioborus miniatus)*, Fan-tailed Warbler, *(Euthlypis lachrymosa)*, Great Kiskadee, *(Pitangus sulphuratus)*, Inca Jay, Brown Jay, Orange-crowned Warbler, Wilson's Warbler, and Boat-billed Flycatcher, *(Megarynchus pitangua).* These 11 species accounted for 70% of the relative abundance for Inga.

In SC four species accounted for most of the relative abundance of species recorded : Yellow-breasted Chat, *(Icteria virens),* Grey Catbird, Philadelphia Vireo, *(Vireo philadelphicus)* and Boat-billed Flycatcher (See Appendix IV).

La Chilana

In this area, the species with the highest relative abundances in CF were Plain Chachalaca, White-bellied Chachalaca, Band-tailed Pigeon, *(Columba fasciata),* White-winged Dove, *(Zenaida asiatica), Inca* Dove, *(Columbina inca),* White-faced Quail-Dove, *(Geotrygon albifacies),* Violaceous Trogon, *(Trogon violaceus),* Olivaceous Woodcreeper, (*Sittasomus griseicapillus),* Blue-headed Vireo, *(Vireo* *solitarius),* Blackburnian Warbler, *(Dendroica fusca),* Blackburnian Warbler, Painted Bunting, *(Passerina ciris),* Indigo Bunting, *(Passerina cyanea).* These 12 species accounted for 55% of the total relative abundance of the bird community in the CF. In particular, Blackburnian Warbler, and, White-winged Dove, were the species with the highest abundance in this habitat.

In NSC the species with the highest relative abundance were Plain Chachalaca, White-bellied Chachalaca, Inca Dove, Violet Sabrewing, *(Campylopterus hemileucurus),* Blue-tailed Hummingbird, *(Amazilia cyanura),* Blue-throated Motmot, Blue-diademed Motmot, Grey Cat Golden-winged Warbler, *(Vermivora chrysoptera),* Tennessee Warbler, *(Vermivora peregrina),* Slate-throated Redstart, and Indigo Bunting. These 12 species accounted for the 63% of the total relative abundance in NSC.

In the case of Inga the species with the high relative abundance were Blue-diademed Motmot, Plain Chachalaca,, Nashville Warbler, *(Vermivora ruficapilla) ,* Yellow Warbler, *(Dendroica petechia),* Wilson's Warbler, White-bellied Chachalaca, Social Flycatcher, *(Myiozetetes similis),* Orange-crowned Warbler, *(Vermivora celata),* Tropical Kingbird, *(Tyrannus melancholicus),* Inca Jay, *(Cyanocorax yncas),* Buff-bellied Hummingbird, *(Amazilia yucatanensis),* and Boat-billed Flycatcher, this 12 species shows the 69% of the relative abundance for Inga.

Finally, in SC the four species that accounted the most of the relative abundance were Great Kiskadee, Amethyst-throated Hummingbird, *(Lampornis amethystinus),* Groove-billed Ani, *(Crotophaga sulcirostris),* and Boat-billed Flycatcher (See Appendix IV), with 34% of the species total.

5.4.3. Species accumulation curves

To illustrate differences in diversity among habitat types graphically, the cumulative abundance was plotted against the species rank (Magurran, 1988). In this graph the lowest curve represents the most diverse community. In both sites sun coffee was clearly less diverse than the other three habitats. Cloud forest and natural shade coffee had very similar high diversity, with overlapping diversity curves. The Inga curve lay in-between sun coffee and natural shade coffee (Figure 5.3).

The species accumulation curves and the ICE (a non-parametric estimator of species richness) were used to assess completeness of the species inventory and to estimate the richness in the different habitats. The ICE (Incidence-based Coverage Estimator) estimated the total species richness from samples, including species not discovered in any sample.

The means of observed species accumulation (Sobs), the Incidence-based coverage (ICE), the Singletons (species with only one individual in the sample), the Doubletons (species with only two individuals in the sample) and the Coleman curve were plotted against the sample number (Figure 5.4). In Custepec and La Chilana, examination of species accumulation curves as a function of both sampled area and abundance of individuals, indicated that richness is lower in SC than in CF or NSC. The only difference between the sites was that in La Chilana the number of species in the cloud forest and the natural shade coffee was higher than in Custepec. The richness in Inga and sun coffee was similar between the sites.

An asymptote was nearly reached in all the habitats. According to this analysis all habitats were relatively overestimated. The richness estimated and the observed species curve coincided and were nearly flat by the end of the sample, and the singletons and doubletons curves were declining (Figure 5.4) suggesting that few species remain to be collected. It was estimated that fifty samples per habitat would provide enough data to ensure detection of at least 90% of the species. The degree of spatial aggregation (or effect of patchiness) was evaluated by comparison of the mean species accumulation curve with the Coleman curve (which is the curve expected if the individuals in all samples pooled had been randomly assigned to the quadrats). In all the sites, the species accumulation curve (Sobs) and the Coleman curve were nearly the same, indicating that species were not patchily distributed.

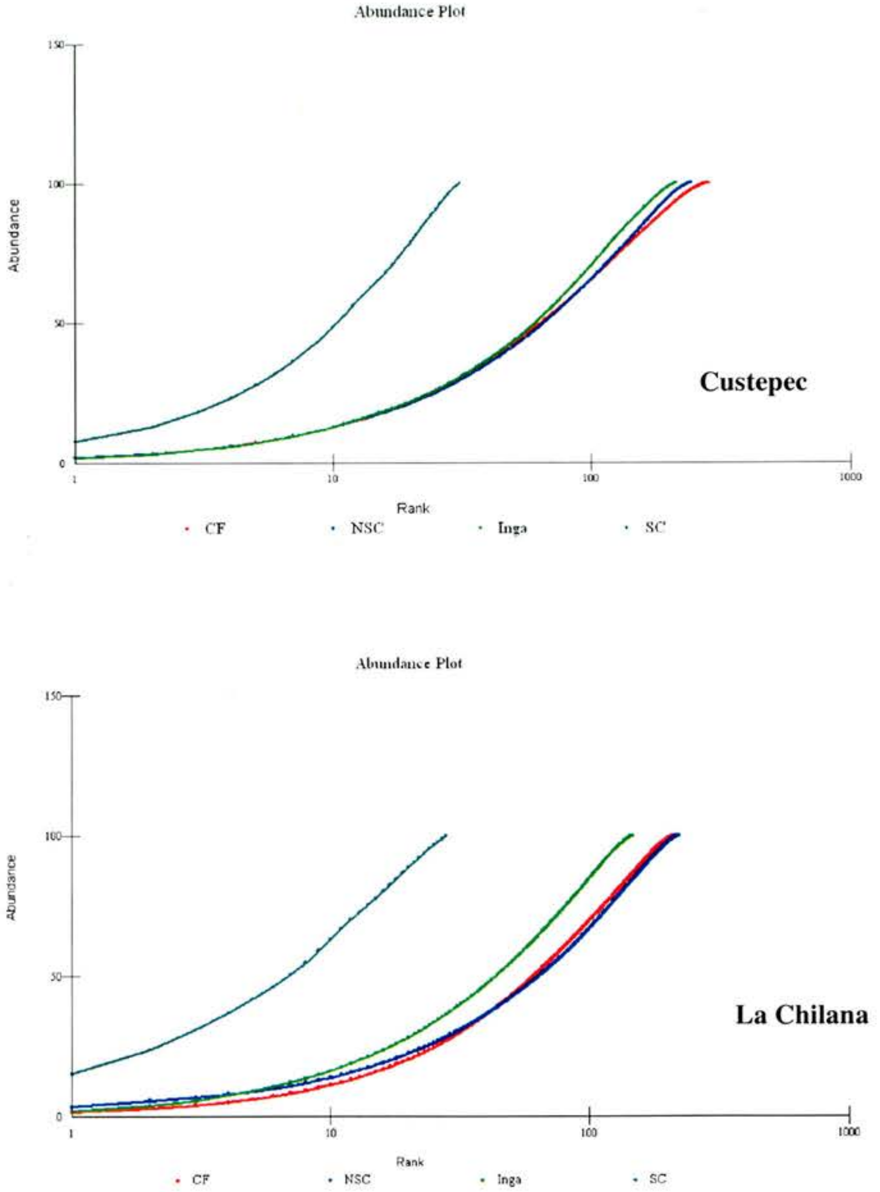
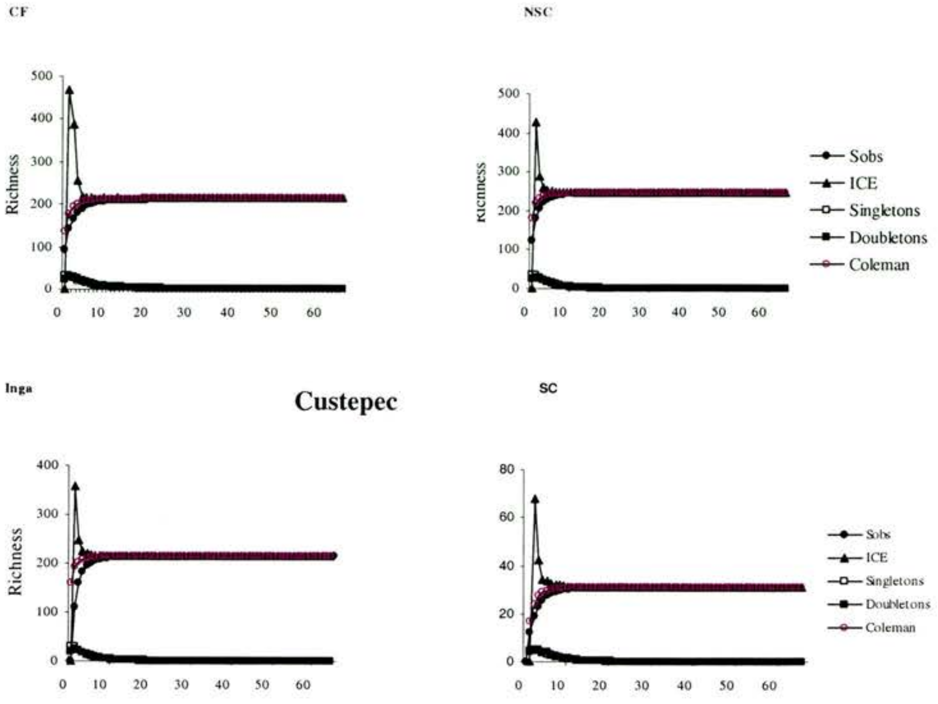
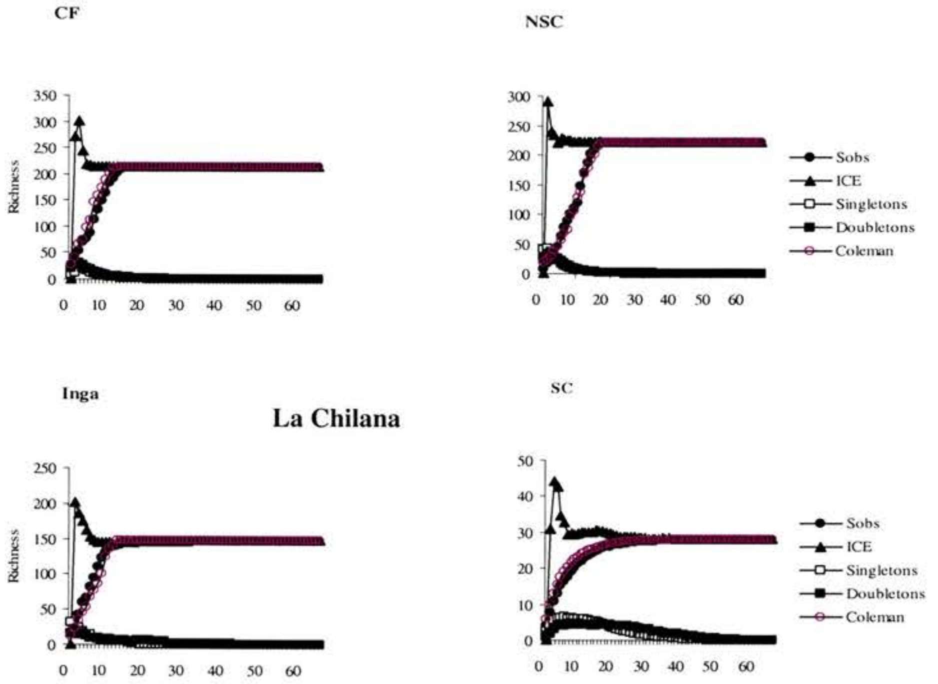


Figure 5.3 K-dominance plot for the four habitat types surveyed at Custepec and La Chilana, showing cumulative abundance against the species rank. CF = cloud forest, NSC = natural shade coffee. Inga = inga shade coffee, and SC = sun coffee.



Custepec



La Chilana

Figure 5.4 Species accumulation curves in the four habitats, in Custepec and La Chilana. Sobs is the mean number of species observed in 65 sampled points, singletons and doubletons (rare species) are number of species with only one or two individuals in the sample, ICE is the incidence-based richness estimator, and the Coleman curve.

5.4.4 Diversity index and similarity

In Custepec, the Shannon diversity index (H') confirmed that cloud forest followed by natural shade coffee and Inga were the most diverse sites. In La Chilana, the natural shade coffee and cloud forest had a similar index. In both sites the sun coffee was the least diverse habitat (Table 5.4). The increasing values for H' corresponded to the increase in the number of species at each site. Three of the habitats in Custepec (CF, NSC and Inga) showed the same evenness value. In contrast, in La Chilana, CF and NSC showed the highest value, which means that the species had a nearly equal abundance (Magurran, 1996; Table 5.4).

The Jaccard index was used as a measure of similarity between pairs of the four habitats (Table 5.4). The habitats with the highest similarities were CF and NSC for Custepec and La Chilana. In both sites SC showed the lowest value indicating a clear difference with the other habitats.

Table 5.4 Shannon index and Jaccard index between pairs of the 4 habitats (number of shared species given in parentheses). The first two columns corresponded to the Shannon diversity index (H') and the Shannon evenness (E).

Habitat	Shannon diversity index	Shannon evenness index	NSC	Inga	SC
Custepec					
CF	5.40	0.90	0.90(266)	0.50(146)	0.10(31)
NSC	5.30	0.90		0.60(143)	0.10(31)
Inga	5.20	0.90			0.20(31)
SC	3.40	0.80			
La Chilana					
CF	5.20	0.90	0.86(203)	0.60(138)	0.10(28)
NSC	5.20	0.90		0.60(136)	0.20(27)
Inga	4.80	0.80			0.10(28)
SC	3.10	0.70			

5.4.5 Bird species diversity in patches

Patches in all habitats were classified in three categories according to their size. Sites greater than 1000 hectares were defined as large. Patches between 100 to 1000 hectares were classified as a medium, while those that ranged between 0.1 to 100 hectares were defined as small. There were on average 219 and 210 bird species, for Custepec and La Chilana respectively, in large expanses of habitat. Species richness decreased markedly with area (Figure 5.5).

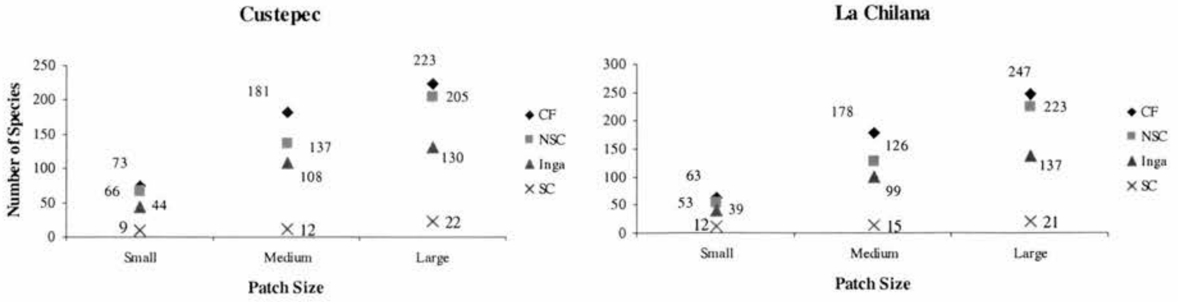


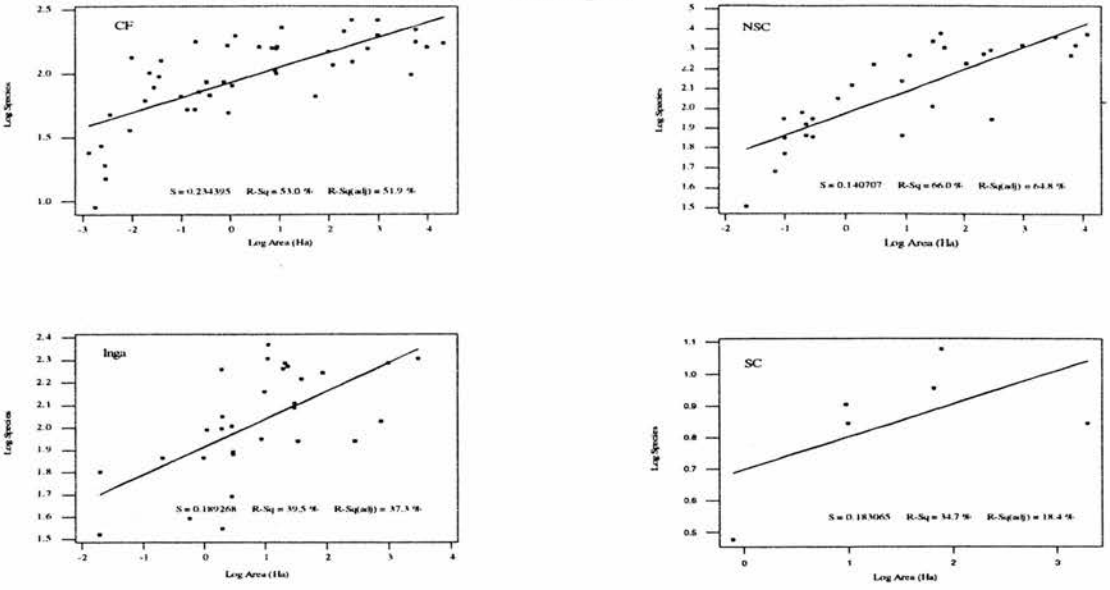
Figure 5.5 Number of bird species as a function of patch size in Custepec and La Chilana. Patch size categories are small (0.1-100 hectares), medium (100-1000 hectares), and large (greater than 1000 hectares). The numbers beside the symbols indicate the number of species.

Simple regression was used to analyse the relationship between the number of bird species and habitat size. For both sites, there was a significant positive regression between number of species and size of the patches ($P<0.001$; in Custepec, CF: $r^2 = 53.0$, df = 45; NSC: $r^2 = 66.0$, df = 28; and Inga: $r^2 = 39.5$, df = 28; and in La Chilana, CF: $r^2 = 61.9$, df 45; NSC: $r^2 = 66.6$, df = 33; and Inga: $r^2 = 48.8$, df = 29). In contrast SC did not showed a significant regression ($P > 0.05$; Custepec: $r^2 = 34.7$, df = 5 and La Chilana: $r^2 = 10.7$, df = 9; Figure 5.6). For bird assemblages in patches of both sites, one of the determinants for species richness was the size of the area.

5.4.6 Faunal similarity

Faunal similarity was examined using cluster analysis to classify samples and species (Figure 5.7). The data comprised 60 samples and 162 species for Custepec, and 65 samples with 224 species for La Chilana, excluding unique occurrences. According to the cluster diagram, in both sites, cloud forest and natural shade coffee were the most similar habitats, while Inga shade coffee was the nearest habitat outgroup. Sun coffee lay far apart, showing a similarity of less than 50% with the other three habitats.

Custepec



La Chilana

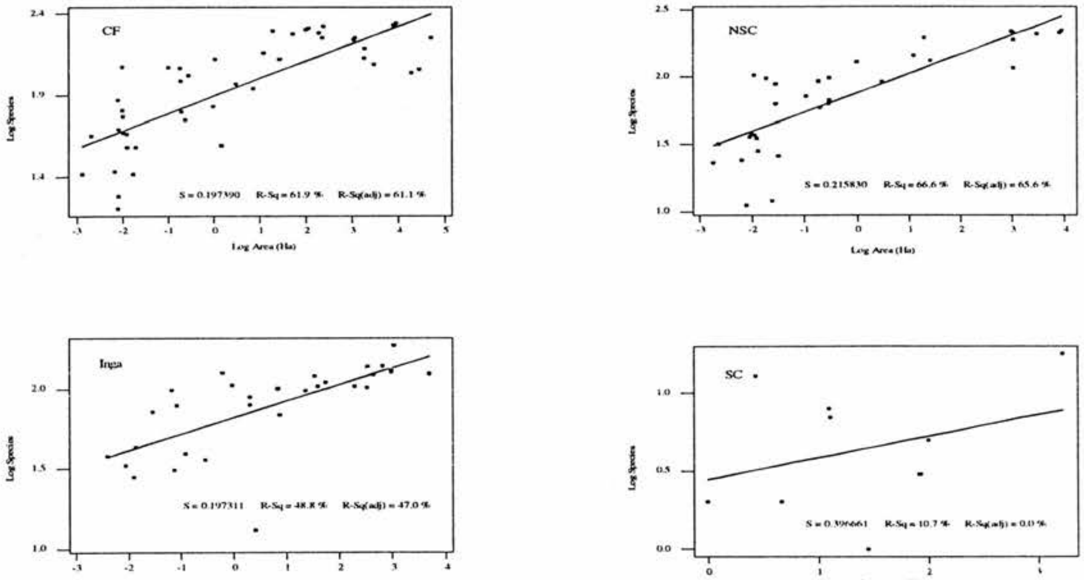


Figure 5.6 Relationship between bird species and patch size in Custepec and La Chilana. CF= Cloud forest, NSC= Natural shade coffee, Inga= Inga shade coffee and SC= Sun coffee.

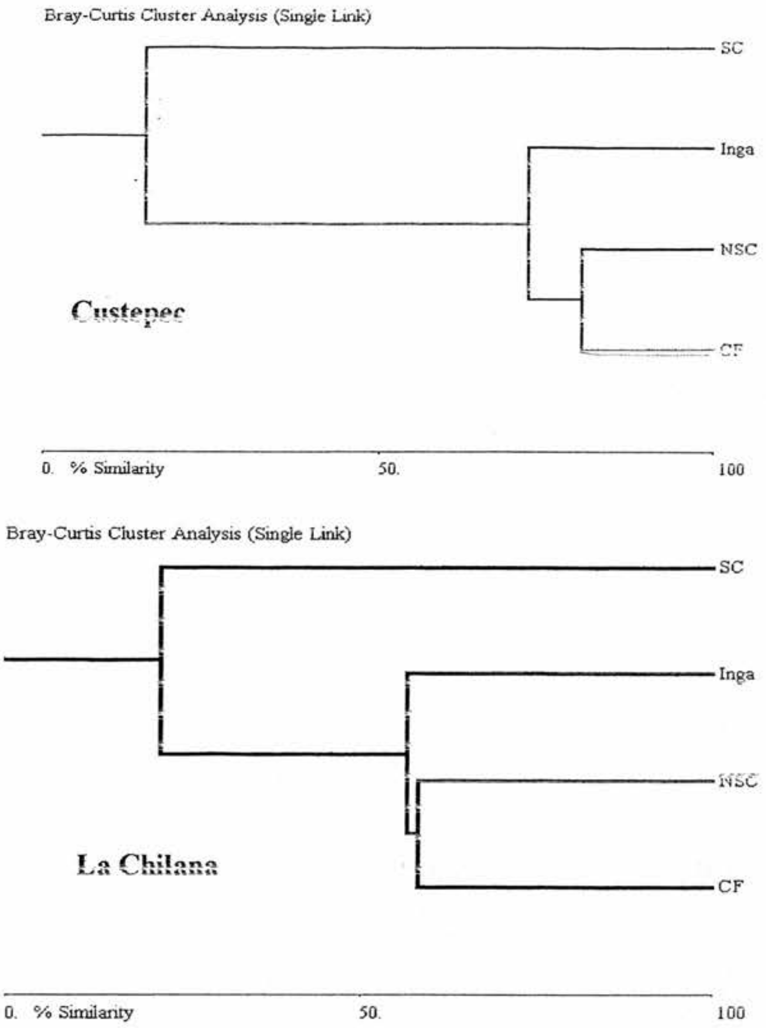


Figure 5.7 Cluster analysis based on the Bray-Curtis index to classify samples and species surveyed at Custepec and La Chilana. CF =Cloud forest, NSC = Natural shade coffee, Inga = Inga shade coffee, SC= Sun coffee.

5.4.7 Ordination Analysis

A Canonical Correspondence Analysis (CCA) was performed on bird diversity and environmental variables using all the bird species in the samples. The environmental variables included were canopy, altitude, wind speed and temperature together with the full data set of tree and bird species. The graph of CCA for Custepec and La Chilana shows very low eigenvalues. The values for Axis 1 were

0.4326 and 0.2355 respectively. Axis 2 gives 0.4736 for Custepec and 0.3245 for La Chilana. The first four axes explain less than 50 % of the variation (41.7 % for Custepec and 49.5 % for La Chilana) indicating that the environmental data collected does not explain all the variation seen in the species data (Figure 5.8).

The most important variables examined were canopy cover and altitude. The distribution of the sites is determined by the species that inhabit them and this distribution is related to environmental variables such as altitude and canopy. There was a strong relationship between bird species distribution and the mentioned variables. CF is present at a higher altitude, and contains a large number of tree species. This is related to the high number of exclusive species found in cloud forest. SC is found at lower altitude, and had the lowest number of tree species. Finally, NSC and Inga had similar distributions at medium altitudes, and had fewer species of tree species than CF. As a consequence these three habitats shared a great number of bird species. The result of the direct ordination is shown in a biplot of the sites and environmental variables (Figure 5.9) and in a biplot of species and environmental variables (Figure 5.8).

The environmental data are represented by arrows plotted in the direction of the maximum change whose length is proportional to the magnitude of that change. The arrows are almost the same length suggesting that the variables are equally important in the ordination and in influencing community variation. Species can be related to arrows by their relative position. Those found close to the tips of the lines are strongly correlated with the variable in question. The further down the line from tip the less affected are species found there (Kent and Coker 1992).

The ordination biplot of the first two axes of site and enviromental variables reveals varying degrees of correlation. Consideration of Figure 5.8 reveals bird and trees species associations with the environmental variables. Some of the species are clearly distinguished as found on only one of the field sites. The principal factor in grouping the above species appears be the habitat type. In addition to tree species that have an obvious link to field site, some grouping by environmental gradients is revealed. In the case of CF (at both sites) and NSC in La Chilana, canopy and altitude are influencing species sensitive to habitat. Temperature and wind speed are important in defining species grouped in NSC and Inga in the left side of the diagram.

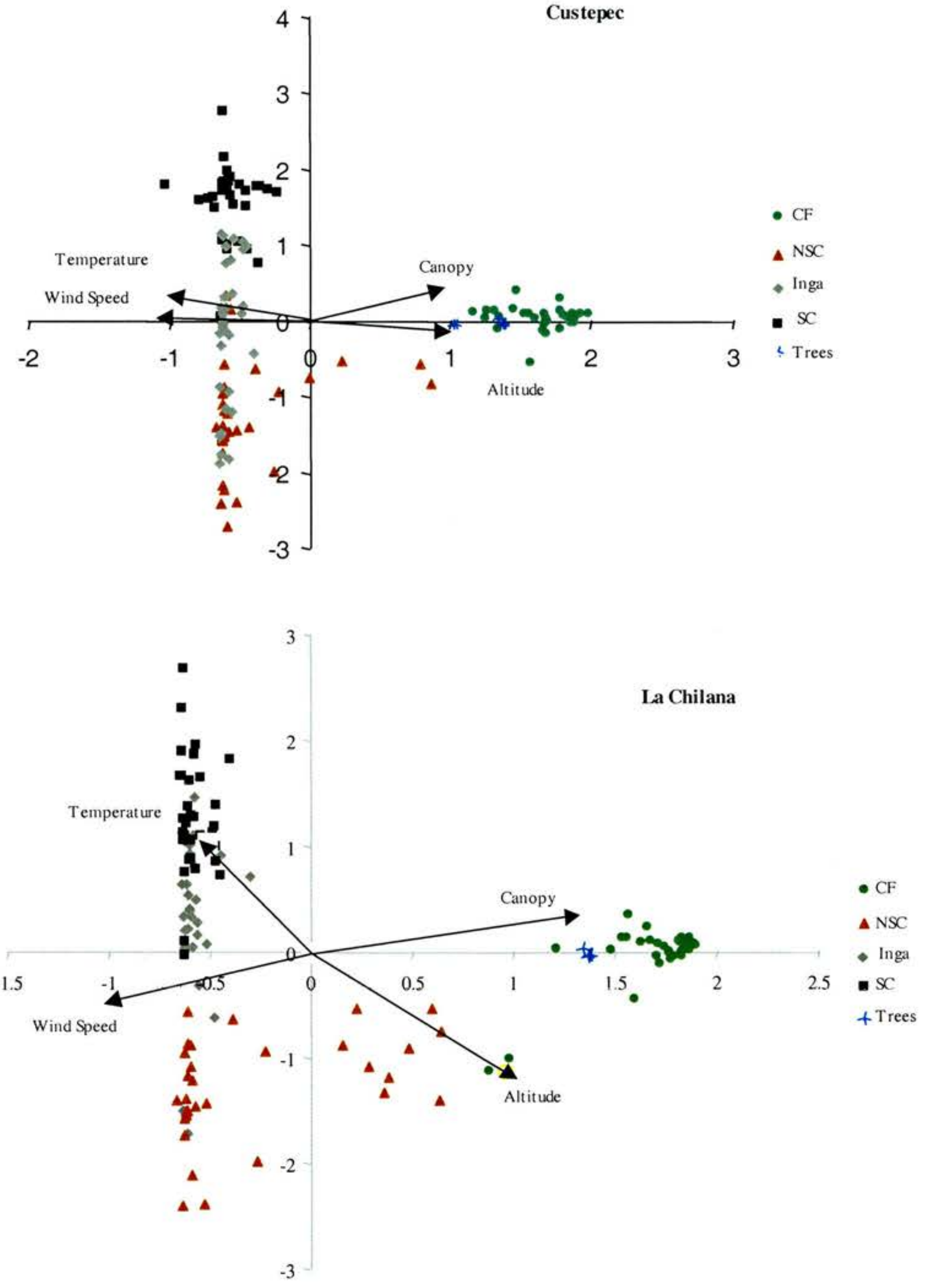


Figure 5.8 CCA ordination biplot of all the sites based on the bird and tree data set and environmental variables. Arrows represent the environmental data.

Figure 5.9 shows that the similar habitats tend to group together. In Custepec, CF is grouped separately from the rest of the habitats, NSC and Inga are together showing variation along axis 1. SC is also well separated from other habitats. NSC and Inga showed an similar distribution, but CF showed a wide variation on axis 2, whilst NSC formed a more discrete cluster with relatively low variation on both axes, NSC and Inga habitats are close together because they share a large number of species, whereas CF sites lie apart from the main cluster, possibly reflecting the higher bird diversity of CF with more rare species. In La Chilana, CF is grouped separately from the rest of the habitats; however NSC is the habitat with more similarity than Inga and SC. This last habitat is clustered and clearly apart from other habitats. NSC and Inga showed different distributions, but CF showed a wide variation on axis 2, whilst NSC formed a more discrete cluster with relatively low variation on both axes. NSC and CF habitats are found close together, they share a large number of species and begin apart from the main cluster may reflect the higher bird diversity, because they may be sites with more rare species.

Detrended Correspondence analysis (DCA) was also used to assess species-environment correlation more accurately. In the DCA analysis, the full data set of bird species was included. In Custepec CF had eigenvalues of 0.1863 and 0.1024, respectively, and in La Chilana the eigenvalues were 0.2851 and 0.1613, respectively. As in the CCA similar habitats tended to cluster together. Cloud forest was densely grouped, with only few points apart, and this shows the least variability. Meanwhile the NSC distribution was not much different than CF, and Inga. However some sites were found separately meaning that these have species in common with other sites. A different pattern, which is very spread out and showed high variability was found, for Inga shade coffee. SC was grouped distinctively apart (Appendix V). Figure 5.8 shows that in the CCA, SC and CF were clearly separated, while Inga and NSC were coinciding partially. The only difference in the figures between both sites is that in La Chilana some species from NSC were more closely related with the CF habitat.

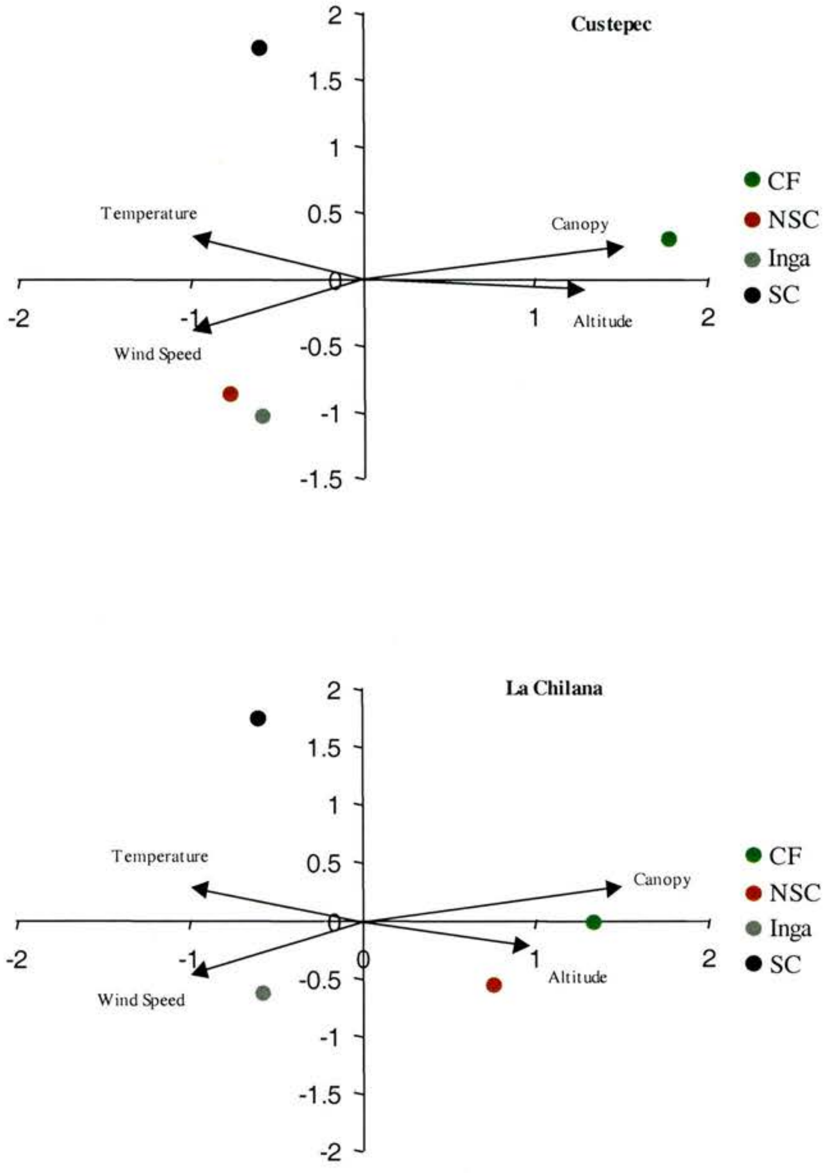


Figure 5.9 CCA ordination biplot of all the sites based on the full bird data set and the sites. This figure show that similar habitats are grouped. The length of the arrows indicate the determining influence of environmental variables; the canopy itself is likely to reflect altitude, temperatures and wind speed.

5.5 Mist Net Surveys

Sampling effort at Custepec and La Chilana was constant in the four habitats: 1000 net/hours were sampled per month with a total of 24,000 net/hours sampled (1 net/hour = 1 hour open 12 m net). This resulted in a total of 33,436 captures comprising 101 species for Custepec; and a total of 29,718 captures comprising 79 species for La Chilana (Table 5.5).

Table 5.5 Number of species, total of individuals captured, and mist-net sample effort per month in the four habitats in Custepec and La Chilana

Habitat	Net/ Hour/month	Species	No of individuals	Indvid. * 1 net/hour
		Custepec		
CF	1000	101	7990	0.33
NSC	1000	96	12155	0.50
Inga	1000	77	13088	0.54
SC	1000	21	203	0.008
Total	4000	101	33436	
		La Chilana		
CF	1000	79	9914	0.41
NSC	1000	69	11043	0.46
Inga	1000	66	8662	0.36
SC	1000	14	99	0.004
Total	4000	83	29178	

In Custepec, the greatest numbers of individuals were captured in the Inga habitat with 13, 088 captures (Table 5.5), consisting of 77 species. The four most commonly captured species in the Inga were Magnificent Hummingbird, *Eugenes fulgens* (338), Green-throated Mountain-gem, *Lampornis viridipallens* (245), Magnolia Warbler, *Dendroica magnolia* (228) and Yellow-throated Euphonia, *Euphonia hirundinacea* (225). NSC gave a total of 12 155 individuals captured comprising 96 species (Figure 5.10). The most frequent species caught were Magnolia Warbler, *Dendroica magnolia* (308), Royal Flycatcher, *Onychorhynchus coronatus* (259) and Red-legged Honeycreeper, *C. cyaneus* (201), with no species recorded in a single capture.

In La Chilana, the greatest numbers of individuals were captured in NSC (11,043) see Table 5.5 belonging to 69 different species. The five most commonly captured species in the NSC were Worm-eating Warbler, *Helmitheros vermivorus* (233), Common Yellowthroat, *Geothlypis trichas* (224), Spot-breasted Wren, *Thryothorus maculipectus* (220), Baltimore Oriole, *Icterus galbula* (218), and Magnolia Warbler, *Dendroica magnolia* (218). CF gave a total of 9,914 individuals with 79 species (Figure 5.10). The most frequent species caught were Common Bush-Tanager, *Chlorospingus ophthalmicus* (266), Magnolia Warbler, *D. magnolia* (238), Golden-browed Warbler, *Basileuterus belli (211)*, and White-breasted Wood-Wren, *Henicorhina leucosticta* (212) with no species recorded in a single capture.

In Custepec, CF had 7,990 individuals captured. Most species were captured in this habitat (101 species, Figure 5.10). The most common captures were Common Bush-Tanager, *C. ophthalmicus* (262), Common Yellowthroat, *G. trichas* (234), and Black-and-white Warbler, *Mniotilta varia* (227). SC was the habitat with the fewest captures, with only 184 individuals representing 21 species (Table 5.5 and Figure 5.10); White-bellied Emerald, *Amazilia candida* was the species most frequently captured.

In La Chilana, Inga had 6,290 individuals captured (Table 5.5). This was the habitat with most individuals captured. Magnolia Warbler, *D. magnolia* (242), Baltimore Oriole, *I. gularis* (221), and Violet Sabrewing, *C. hemileucurus* (194) were the most captured species in this habitat. The SC was the habitat with the fewest captures with only 99 individuals and 14 species (Table 5.5 and Figure 5.10). The Brown-crested Flycatcher, *Myiarchus tyrannulus* was the species most frequently captured.

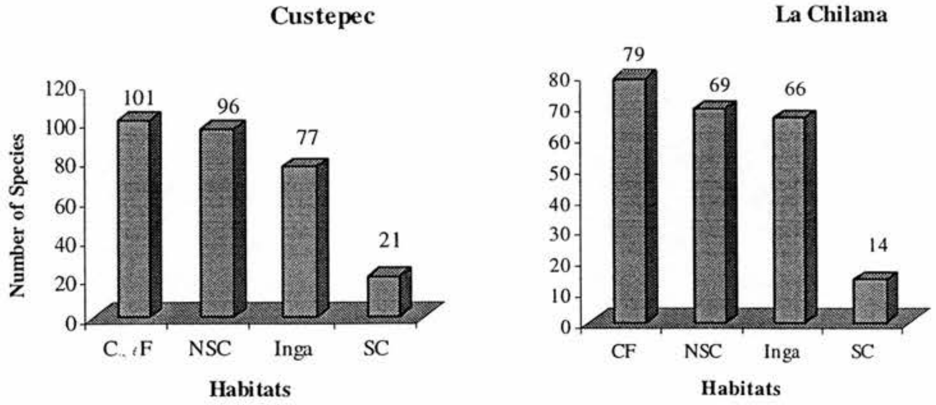


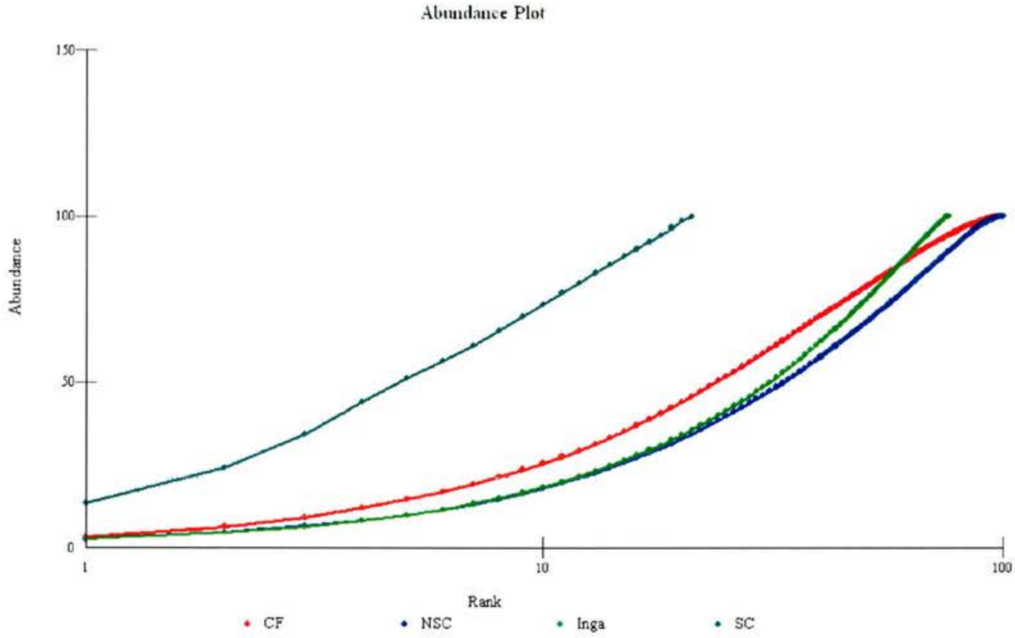
Figure 5.10 Total number of species captured in the four habitats at Custepec and La Chilana.

5.5.1. Species richness

To show differences in diversity among habitat types the percentage cumulative abundance was plotted against log species rank (Figure 5.11). This graphical system is used for comparing diversity (Magurran 1988).

In Custepec, CF had the higher abundance and diversity. NSC was more closely related to CF than *Inga*. However Inga showed the same abundance but less diversity than NSC. In La Chilana, NSC had the higher abundance and diversity (Figure 5.11). CF was more closely related with NSC than Inga. However this habitat presented almost the same abundance but less diversity than CF. At both sites, in the K-dominance plot for the bird count data, SC clearly was the habitat with lowest bird diversity.

Custepec



La Chilana

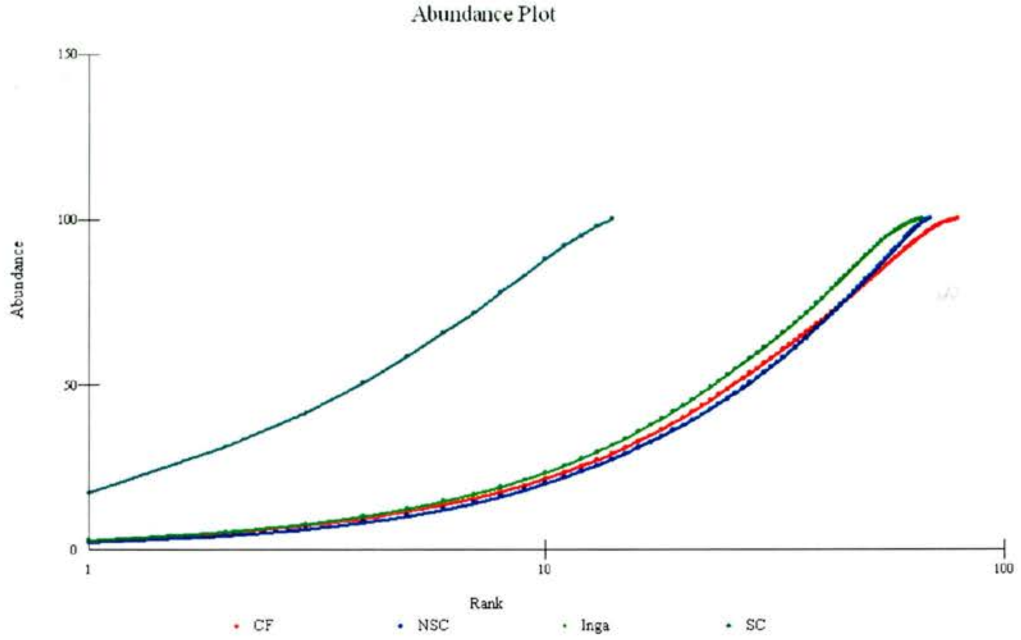


Figure 5.11 Comparison of diversity between the four habitats using k-dominance plot with data surveyed by mist nets at Custepec and La Chilana. CF =cloud forest, NSC= natural shade coffee, Inga= Inga shade coffee, SC= sun coffee.

5.5.2. Species accumulation curves

There are three general methods for estimating species richness: extrapolating species accumulation curves, fitting parametric models of relative abundance, and using non-parametric estimators. Species accumulation curves can be fitted to asymptotic equations, and the asymptote becomes the estimated species richness of the community. Some non-parametric methods show the greatest promise for richness estimation. These methods have been developed for the general problem of taking a sample of classifiable objects and estimating the true number of classes in the population see methods chapter.

In ecology, such methods have been most frequently applied to estimate population size from mark-recapture data. Estimating richness is essentially the same problem with the abundance of species in a sample, equivalent to the number of captures of an individual in a mark-recapture study. Data on bird captures suggest that in Custepec, between 1,600m and 2,500 m elevation, at least 101 bird species were present at the four habitats. In La Chilana, between 1,700m and 2,300m elevation, at least 83 bird species were present at the four habitats. The bird survey, however, was complete, as there is evidence of saturation in the capture data.

In order to obtain a better estimate of richness, a non-parametric estimator of richness was used (Chao's and first-order Jackknife. Colwell and Coddington 1994; see methods chapter 4). In all the habitats (at both sites) the accumulation curves showed that the observed species (Sobs), the Jacknife and Chaos curves were nearly the same, indicating that most of species were recorded. In Custepec it was estimated that 5 samples per habitat would provide enough data to cover the curves and at least around 75% of the species. While in La Chilana the estimation was that 4 samples per habitat, except for SC, would provide enough data to cover the curves and at least 80% of the species (Figures 5.12).

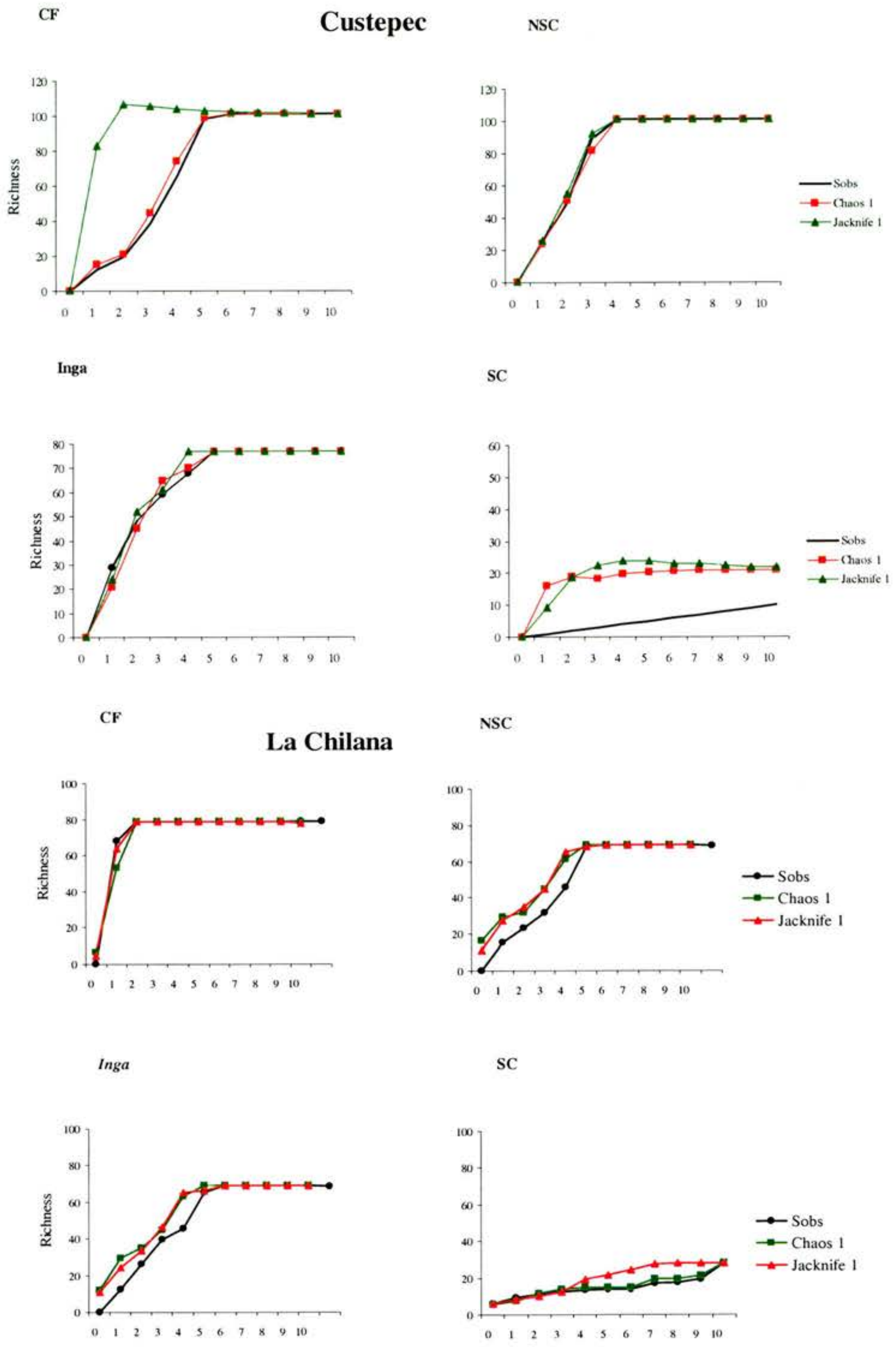


Figure 5.12 Species accumulation curves in the four habitats at Custepec and La Chilana. CF= Cloud forest, NSC= Natural shade coffee, Inga = Inga shade coffee. SC= Sun coffee. Sobs is the number of species observed (in black). A non parametric estimator Chaos 1 (in green) and Jacknife (in red) were used for extrapolate species.

5.5.3. Diversity Index and similarity

In Custepec, the Shannon diversity index (H') showed NSC to be the most diverse habitat, followed by CF and Inga, whereas SC was the least diverse. In La Chilana, CF was the most diverse habitat, followed by NSC and Inga, SC was the least diverse. The increasing values for the Shannon diversity index corresponded to the increase in number of species at each site.

The Evenness index (E) was used for analysing the similarity in species abundance within the habitats. Equitability is greatest when species are equally abundant. At both sites, the three most diverse habitats also showed the highest evenness values which means that in each habitat the species had a nearly equal abundance (Table 5.6), a value of 1 represents a situation in which all species are equally abundant (Magurran, 1996). According to the Sorensen index, at both sites, CF and NSC were the habitats with higher similarity in species composition. Inga also showed a high similarity index value in relation to CF.

Table 5.6 Shannon diversity index (H'), Shannon evenness (E) and Sorensen index between pairs of the 4 habitats (number of shared species given in parentheses).

Habitat	Shannon diversity index (H')	Shannon evenness Index (E)	NSC	Inga	SC
		Custepec			
CF	4.40	0.90	0.90(95)	0.80(75)	0.30(21)
NSC	4.50	0.90		0.80(65)	0.40(21)
Inga	4.30	0.80			0.40(21)
SC	2.80	0.60			
		La Chilana			
CF	4.30	0.90	0.80(62)	0.80(59)	0.30(14)
NSC	4.20	0.80		0.80(53)	0.30(14)
Inga	4.10	0.80			0.40(14)
SC	2.50	0.40			

5.5.4. Ordination analysis

Detrended correspondence analysis was performed on the data for bird species captured in the four habitats. The results for both sites (Custepec and La Chilana) were similar. In CF there was a small association between nets and species. The species had a spread distribution throughout the area, with some species found in the upper and bottom side of the graph (see Appendix VI) which can be related to the borders within patches. The NSC, in Custepec, showed that the bird species cluster together in the centre of diagram suggesting that the species were more related with four nets and showed similar species. In contrast, in La Chilana, the species showed a spread out distribution inside the area. In the Inga habitat, the nets were clustered in the centre and have association with bird species in the centre of the habitat. However in this habitat the bird species could be captured at any place throughout the area. SC showed a different pattern from the other habitats. The species were not related to the nets and were found through the area in any net. Bird species were likely to be found in all nets but in different proportions.

5.6 Analysis of adults, juveniles and migratory species

5.6.1. Analysis of adults and juveniles

Captures for adults and juveniles in both sites were very successful. With 33, 436 captures (24,623 adults and 8,813 juveniles) for Custepec and 29,178 captures (16,153 adults and 13,025 juveniles) for La Chilana, over 12 months of 12 m net deployment (an average of 2,066 and 2,621 birds per month for Custepec and La Chilana, respectively). This represents a significant capture rate for the tropics.

In Custepec, the most productive habitat for mist-netting of adults was NSC with 7,742 individuals caught. CF recorded 5,277 adult individuals and Inga 4,984 (Figure 5.13). The most abundant adult species caught across CF were *Chlorospingus ophthalmicus* (244), *Heliomaster longirostris* (179) , and *Hylocichla mustelina* (176). For NSC the most abundant species were *Onychorhynchus coronatus* (211), *Henicorhina leucosticta* (185), and *Hylocichla mustelina* (181). For Inga *Eugenes fulgens* (241) dominated the captures closely followed by *Chiroxiphia linearis* (173) and *Zenaida asiatica* (160). In SC *Geothlypis trichas* (10) was the species with most captures.

In La Chilana, the most productive habitat for mist-netting of adults was NSC with 7,719 individuals caught. CF recorded 6,804 adult individuals and Inga 3,875 (Figure 5.13). The most abundant adults species caught across NSC were *Euphonia affinis* (215), *Diglossa baritula* (210), and *Cyanerpes cyaneus* (201). For CF the most abundant species was *Chlorospingus ophthalmicus* with 251, *Basileuterus belli* with 201, and *Henicorhina leucosticta* with 199. For Inga, *Dendroica magnolia* (168) dominate the captures, closely followed by *Diglossa baritula* (157) and, *Hylocharis eliciae* (14). In SC *Myiarchus tyrannulus* (10) was the species with most captures.

Comparing numbers of species and individuals within each habitat type there were consistent differences among them. In order to avoid artifacts, a non-parametric test (Kruskall-Wallis) for species and individuals was made for the four habitats: CF, NSC, Inga and SC. The number of individuals and species were significantly different between the habitats (for Custepec: species, H = 34.43, DF = 3; individuals, H = 33.51, DF = 3, P<0.000. For La Chilana: species, H = 36.59, DF = 3; individuals, H = 34.26, DF = 3, P<0.000).

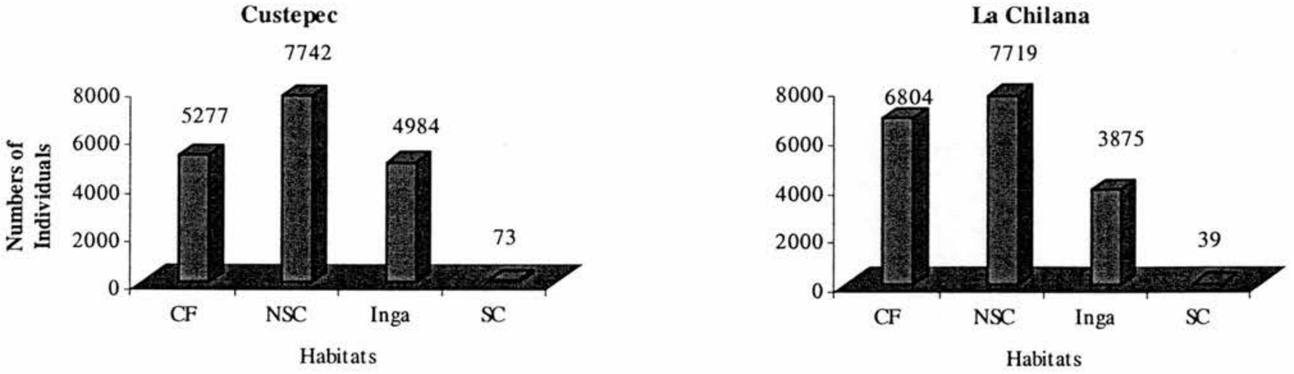


Figure 5.13 Numbers of adult individuals per habitat in Custepec and La Chilana.

In the case of the juvenile species, differences among the habitats were found when comparing species and individuals within each habitat type (Kruskal-Wallis, Custepec: species, H = 36.67, DF = 3; individuals: H= 36.61, DF = 3, P<0.000. La Chilana: species, H = 37,80, DF = 3; individuals: H= 35.04, DF = 3, P<0.000.), suggesting different levels of heterogeneity. In Custepec, Inga was the habitat with the greatest number of individuals (4,899, Figure 5.14) and the species with the greatest abundance were *Lampornis viridipallens* (159), followed by *Oncostoma cinereigulare* (144) and *Cyanerpes cyaneus* (140). The NSC gave the second greatest number of individuals. In this habitat the most frequent species were *Onychorhynchus coronatus* (48), *Thryothorus maculipectus* (39), and *Diglossa baritula* (38). In La Chilana, NSC was the habitat with the greater numbers of individuals (5 449, Figure 5.14). The most abundant species were *Habia fuscicauda* (154), followed by *Xiphorhynchus flavigaster* (150) and *Platyrinchus cancrominus* (with 146). CF showed the second greatest numbers of individuals with *Eugenes fulgens* (147), *Euphonia affinis* (134), and *Chlorospingus ophthalmicus* (124) as the most frequent species.

In Custepec, CF was one of the habitats with most adult species but it had a lower numbers of juvenile individuals (530) than Inga and NSC. *Euphonia hirundinacea* was the species with highest numbers (33), followed by *Euphonia affinis* (27), and *Habia fuscicauda* (24). The SC was the habitat with the lowest number of adults species (19). In contrast, in La Chilana NSC was the habitat with more adult and juveniles species (Figure 5.13 and 5.14).

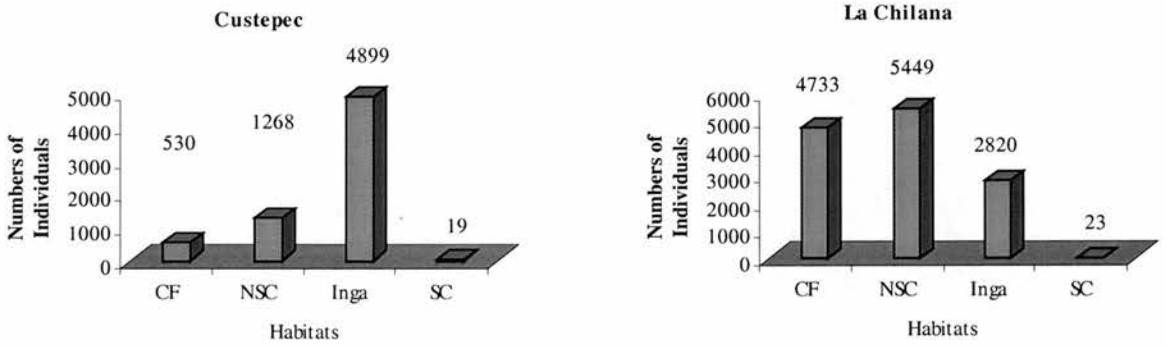
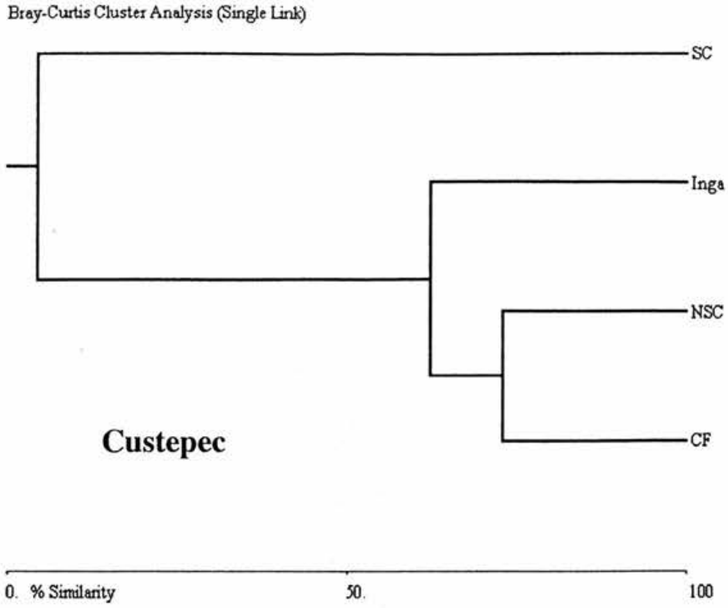


Figure 5.14 Numbers of juvenile individuals per habitat in Custepec and La Chilana

5.6.2. Similarity

Data for adults and juveniles were analysed by the Bray-Curtis similarity index in order to assess the similarity between habitats at Custepec and La Chilana. The data used for the classification of species captured comprised 10 samples and 80 species for Custepec and 61 for La Chilana. The results are presented in a dendrogram form (Figure 5.15).



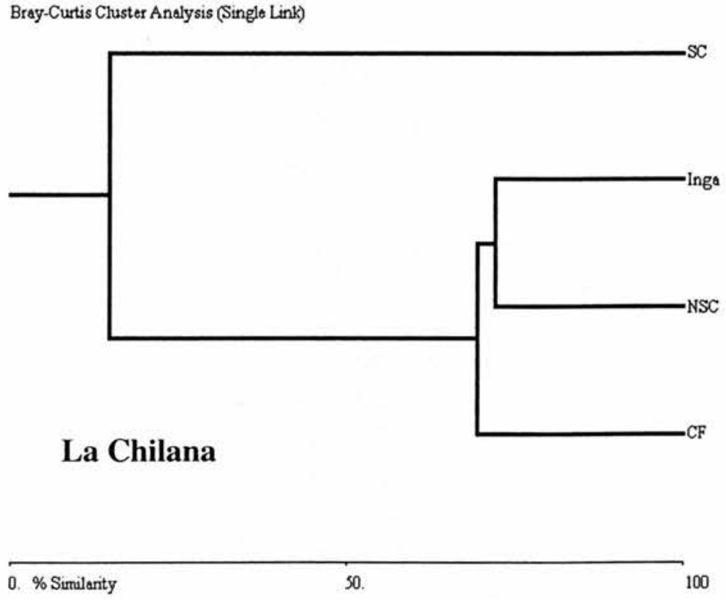


Figure 5.15 Cluster analysis based on the Bray-Curtis similarity index of habitats surveyed at Custepec and La Chilana. CF =cloud forest, NSC = natural shade coffee, Inga = Inga shade coffee, SC= sun coffee.

In Custepec, as was shown in the dendrogram for the point count section of this research, CF and NSC were the most similar habitats, while Inga is the nearest habitat outgroup and showed values higher than 50%. The SC sites lie very far apart, and showed much less than 50% similarity with the other habitats. The result of the Bray-Curtis data is shown in Table 5.7. In La Chilana the dendrogram is different from the whole dataset of nets, NSC and Inga are the most similar habitats, while CF is the nearest habitat outgroup and shows values highest than 50%. The SC sites lie very far apart, and presented a similarity much less than 50% with the other habitats (Table 5.7).

In both sites, juveniles show a clear similarity between the CF and NSC habitats. Both were keeping a higher number of juveniles than Inga. As before, the SC was the habitat with the least similarity with the others (Figure 5.16)

Table 5.7 Bray-Curtis index between pairs of the four habitats for juveniles and adults, in Custepec and La Chilana.

ADULTS	CF	NSC	*INGA*	SC	JUVENILES	CF	NSC	*INGA*	SC
Custepec									
CF	*	73.0164	54.5171	4.2277	CF	*	73.0164	62.3136	2.729
NSC	*	*	62.3762	2.9524	NSC	*	*	64.1364	1.8682
Inga	*	*	*	3.6863	Inga	*	*	*	2.8871
SC	*	*	*	*	SC	*	*	*	*
La Chilana									
CF	*	69.525	65.1852	14.3479	CF	*	72.8134	61.6476	12.5616
NSC	*	*	72.1437	11.2728	NSC	*	*	71.2105	9.4043
Inga	*	*	*	14.6405	Inga	*	*	*	10.7149
SC	*	*	*	*	SC	*	*	*	*

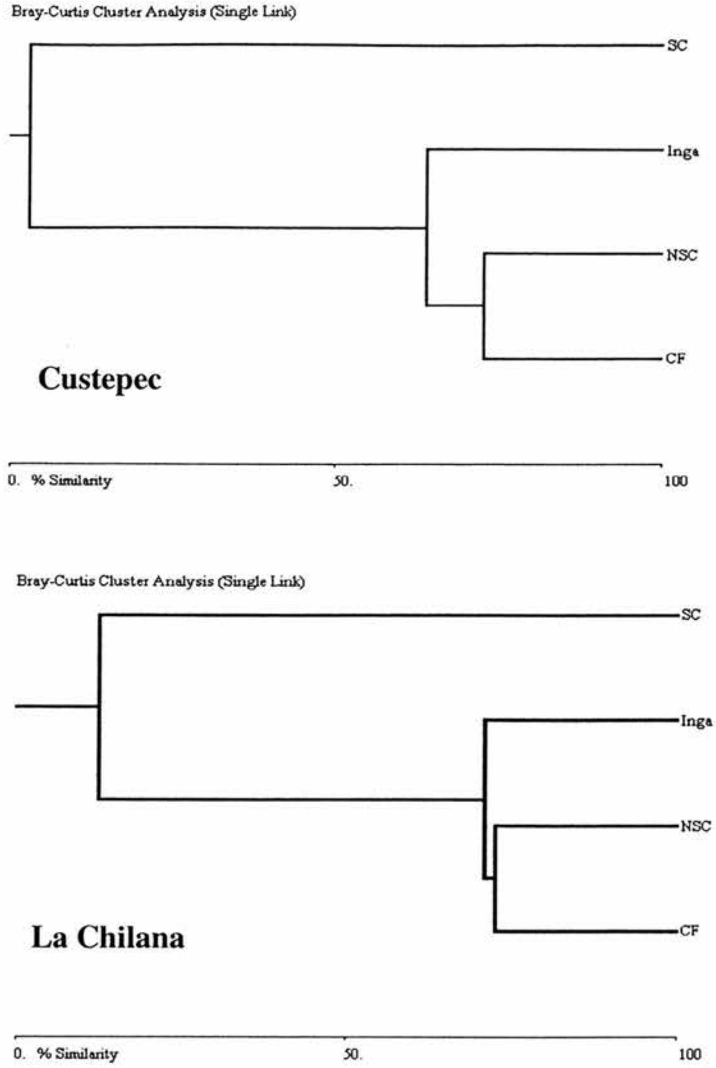


Figure 5.16 Cluster analysis based on the Bray-Curtis similarity index of juveniles in habitats surveyed at Custepec and La Chilana. CF =cloud forest, NSC = natural shade coffee, Inga = Inga shade coffee, SC= sun coffee.

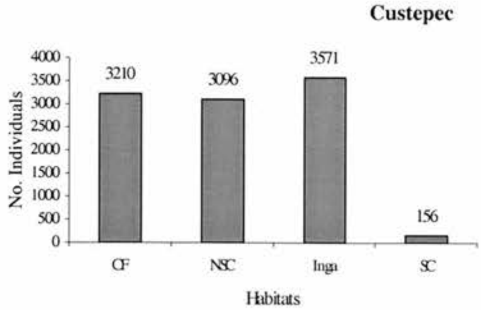
5.6.3. Analysis of migratory species

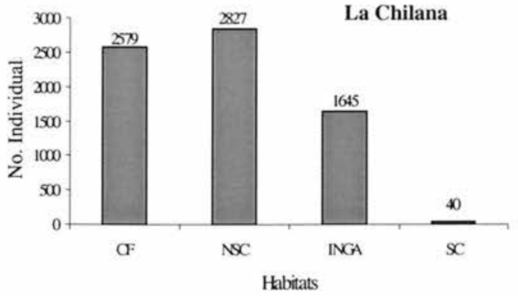
The data for migratory birds in the four habitats were taken in the period between November-February at the end of the season 1999-2000, and at the beginning of the next season during the period August–December 2000. The patterns are almost the same for the three main habitats. Comparison between the number of species and individuals within each habitat type, resulted in differences among the habitats in the two sites (Kruskal Wallis; Custepec: species, $H = 37.78$, $DF = 3$;

habitats in the two sites (Kruskal Wallis; Custepec: species, H = 37.78, DF = 3; individuals, H = 25.92, DF = 3. La Chilana: species, H = 36.59, DF = 3; individuals, H = 33.74, DF = 3, P < 0.000).

At Custepec, CF was the habitat with the largest numbers of species (33 spp), followed by NSC (25 spp), Inga (20 spp) and SC with the lowest number (12 spp). However Inga is the habitat with the highest numbers of individuals (3 571 individuals, Figure 5.17). The most abundant species in CF in terms of individuals, were *Geothlypis trichas, Mniotilta varia, Dendroica magnolia, Catharus dryas, Cyanerpes cyaneus, Contopus cinereus* and *Chlorospingus ophthalmicus.* In NSC *Catharus dryas*, *Vermivora celata, Catharus frantzii, Diglossa baritula,* and *Seiurus noveboracensis* were the species with most individuals. In Inga, *Dendroica magnolia, Oporornis formosus, Oporornis tolmiei,* and *Diglossa baritula* were the species with most numbers of individuals, and the most abundant species in SC were *Amazilia candida,* and *Vermivora celata.*

At La Chilana, CF was the habitat with the largest numbers of species (23 spp), followed by NSC (18 spp), Inga (14spp) and SC with the lowest number (8spp). In contrast NSC was the habitat with highest numbers of individuals (2,827, Figure 5.17). In CF the most abundant species in terms of individuals were *Dendroica magnolia, Catharus dryas, Vermivora celata, Oporornis formosus* and, *Empidonax oberholseri.* In NSC *Dendroica magnolia, Diglossa baritula, Geothlypis trichas,* and *Oporornis philadelphia* were the species with most individuals. For Inga, *Dendroica magnolia, Geothlypis trichas* and *Diglossa baritula* were the species with most individuals. In SC the most abundant species were *Oporornis formosus, Vermivora rufuicapilla,* and *Vermivora cellata.*





In Custepec migratory species showed a clear similarity between the Inga, NSC and CF habitats. In La Chilana, CF and NSC were more similar and with more species than Inga. In both sites SC was the habitat with no relationship with the others (Figure 5.18)

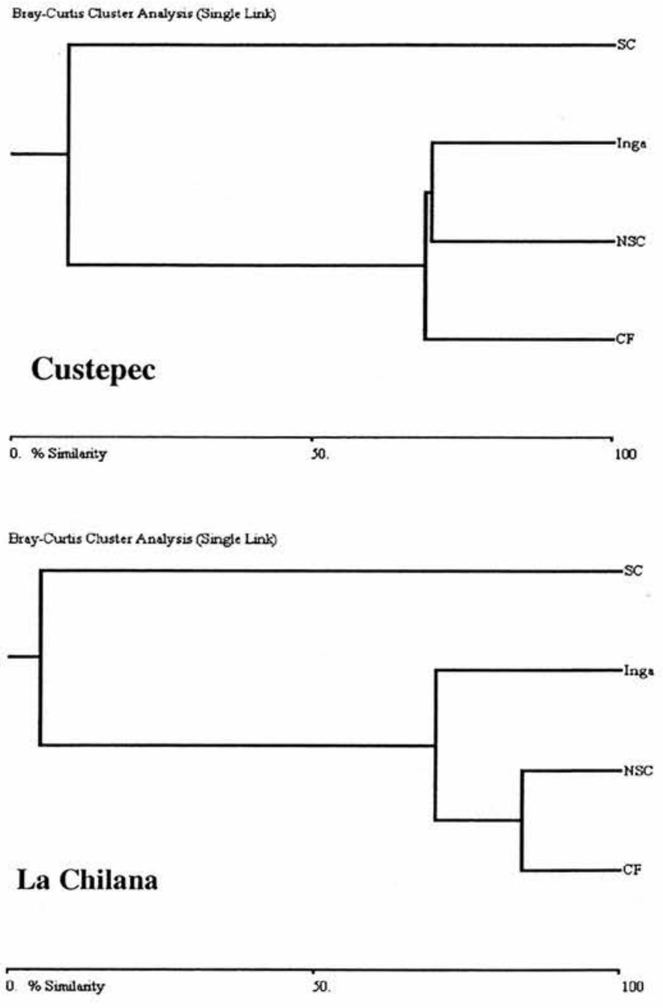


Figure 5.18 Cluster analysis based on the Bray-Curtis similarity index of migratory species in habitats surveyed at Custepec and La Chilana. CF =cloud forest, NSC = natural shade coffee, Inga = Inga shade coffee, SC= sun coffee.

5.7 Trophic guild

The full point count and mist net data sets were classified into trophic guilds according to dietary specialisation, based on the categories of Howell and Webb

(1994). For the full data set of species characteristics see Appendix VII). Twenty-nine categories were recorded in the four habitats. For the Custepec and La Chilana avifauna, three categories of trophic guild were recorded (Figure 5.19), omnivores were the largest category in term of number of species and in individuals. Predators had similar number but with fewer species and more individuals. Primary consumers had fewest species and individuals. For all categories the main bird food resources were insects, other invertebrates and fruits (Figure 5.20).

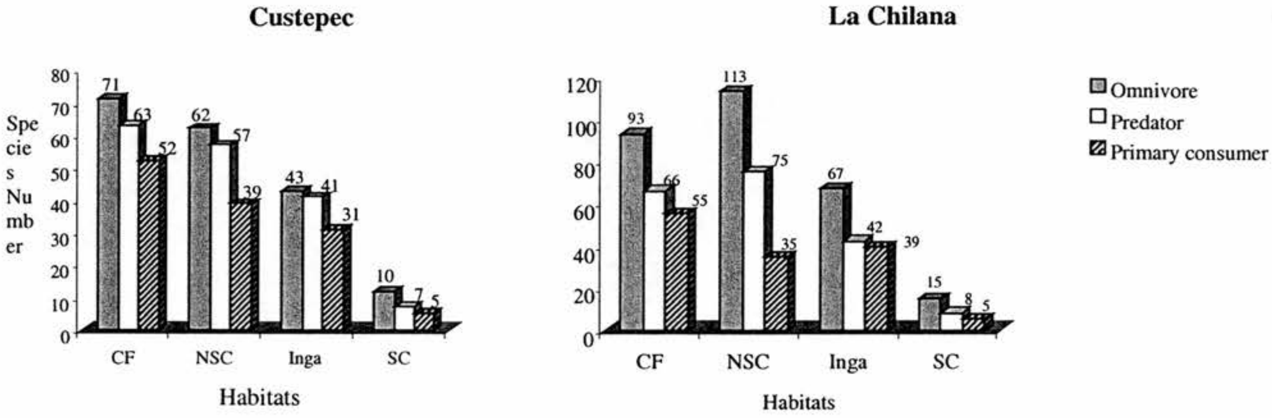
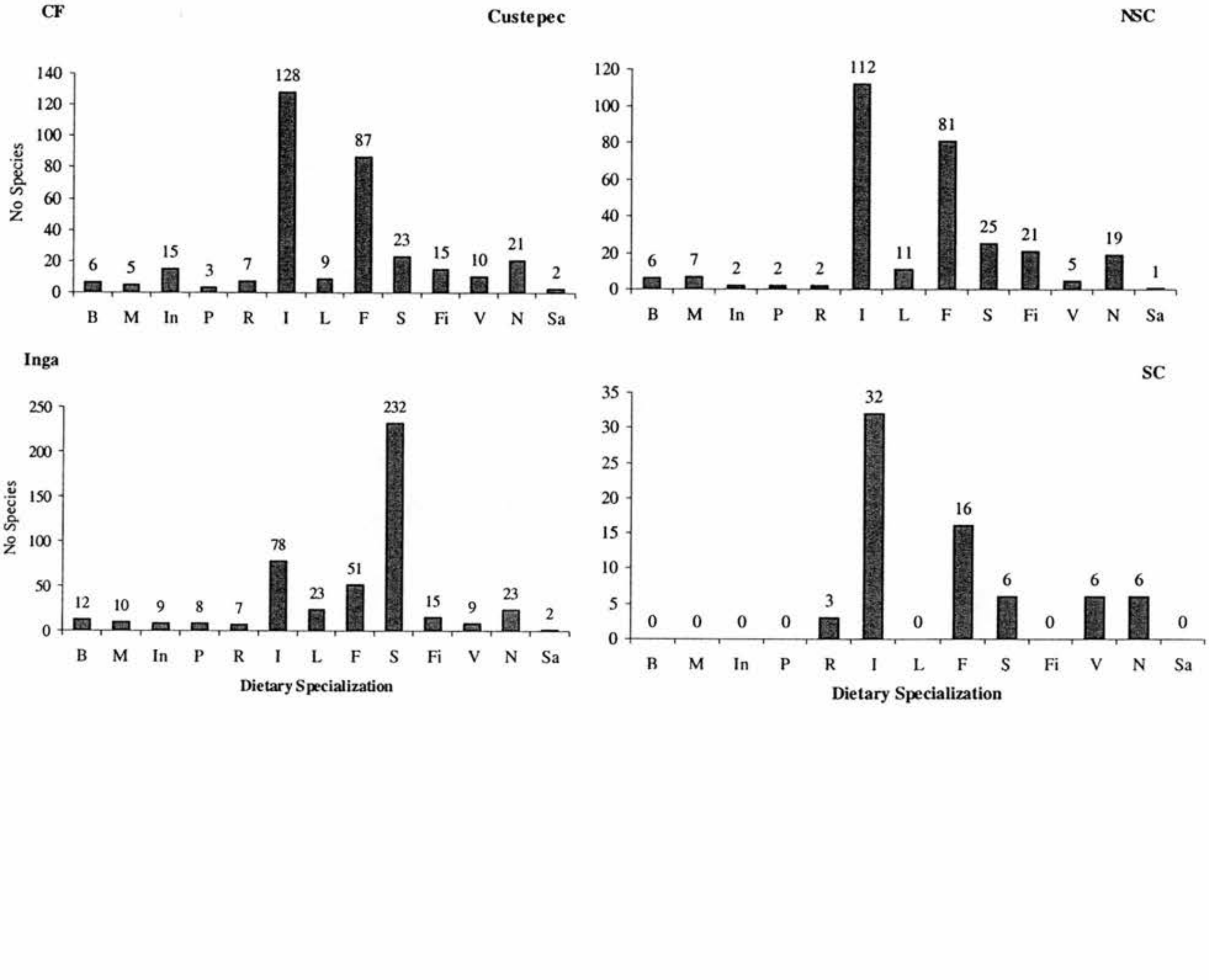


Figure 5.19 Distribution of bird species in categories of trophic guild for the four habitas at Custepec and La Chilana.

In Custepec, *Campylopterus hemileucurus*, *Abeillia abeillei*, *Aspatha gularis*, and *Pitangus sulfuratus* were the most abundant omnivores in CF and NSC. However in Inga, *Melanerpes aurifrons, Dumetella carolinensis* and *Aspatha gularis* had the highest numbers of individuals among omnivores. SC had fewer species, and the most abundant omnivores were *Amazilia yucatanensis, Cyanolyca pumilo* and *Megarynchus Pitangua.* In the case of the generalist primary consumers, the most important species were *Ortalis vetula, Ortalis leucogastra, Columba livia, Cyanerpes cyaneus*, *Columba flavirostris, Columbina inca*, *Aratinga nana*, and *Leptotila jamaicensis* in CMF and NSC. Inga again had fewer species; however it had a high number of individuals and the most frequent species were *Columba faciata, Ortalis vetula, Columba inca* and *Thraupis episcopus.*

In La Chilana, *Trogon violaceus*, *Amomotus momota, Abeillia abeillei*, *Megarynchus pintanga*, and *Pitangus sulfuratus* were the most abundant omnivores in CF and NSC . In Inga, *Melanerpes formicivorus, Vermivora chrysoptera* and *Dumetella carolinensis* had the highest numbers of individuals. SC had fewer omnivores, *Pitangus sulphuratus* and *Myiarchus tuberculifer* were the most abundant. In the case of the generalist primary consumers, the most important species in CF and NSC were *Ortalis vetula, Ortalis leucogastra, Pionus senilis, Geotrygon albifacies, Aulacorhynchus prasinus, Cyanerpes cyaneus, Columba flavirostris, Columbina inca*, and *Leptotila jamaicensis*. In Inga the number of species was fewer but showed a high number of individuals.



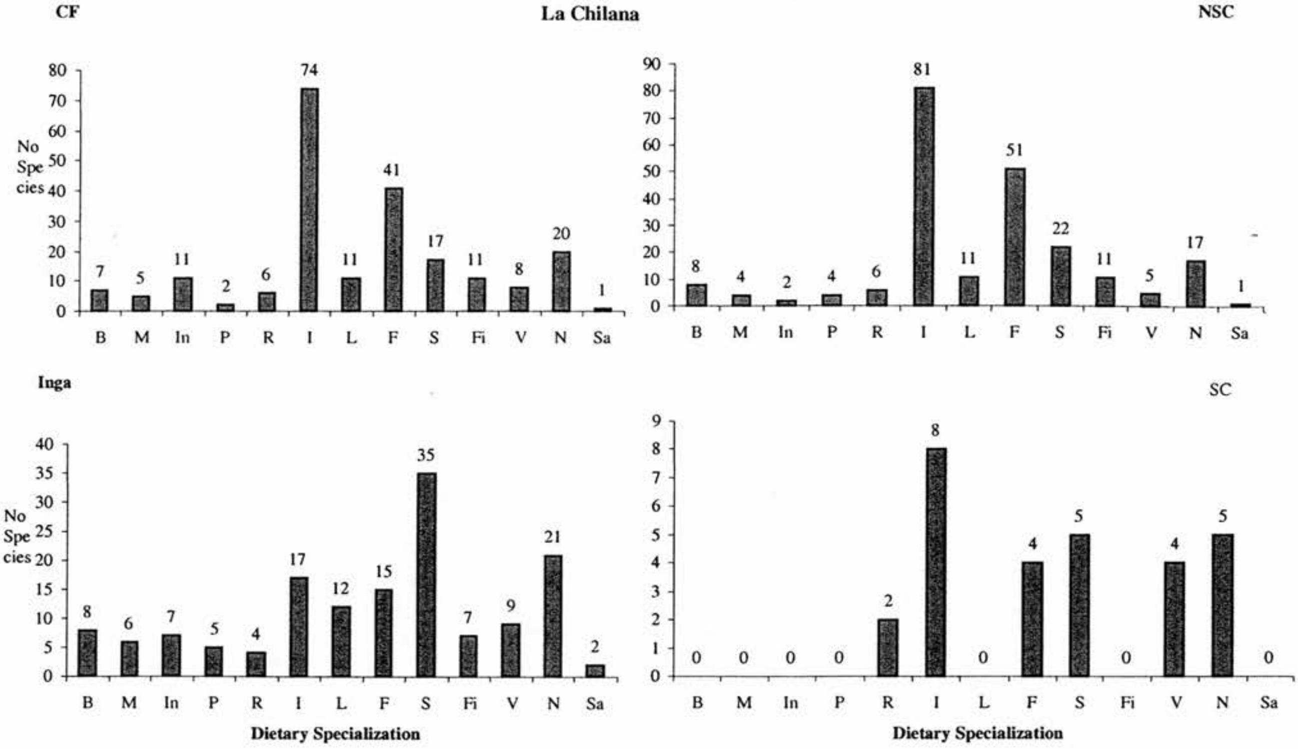
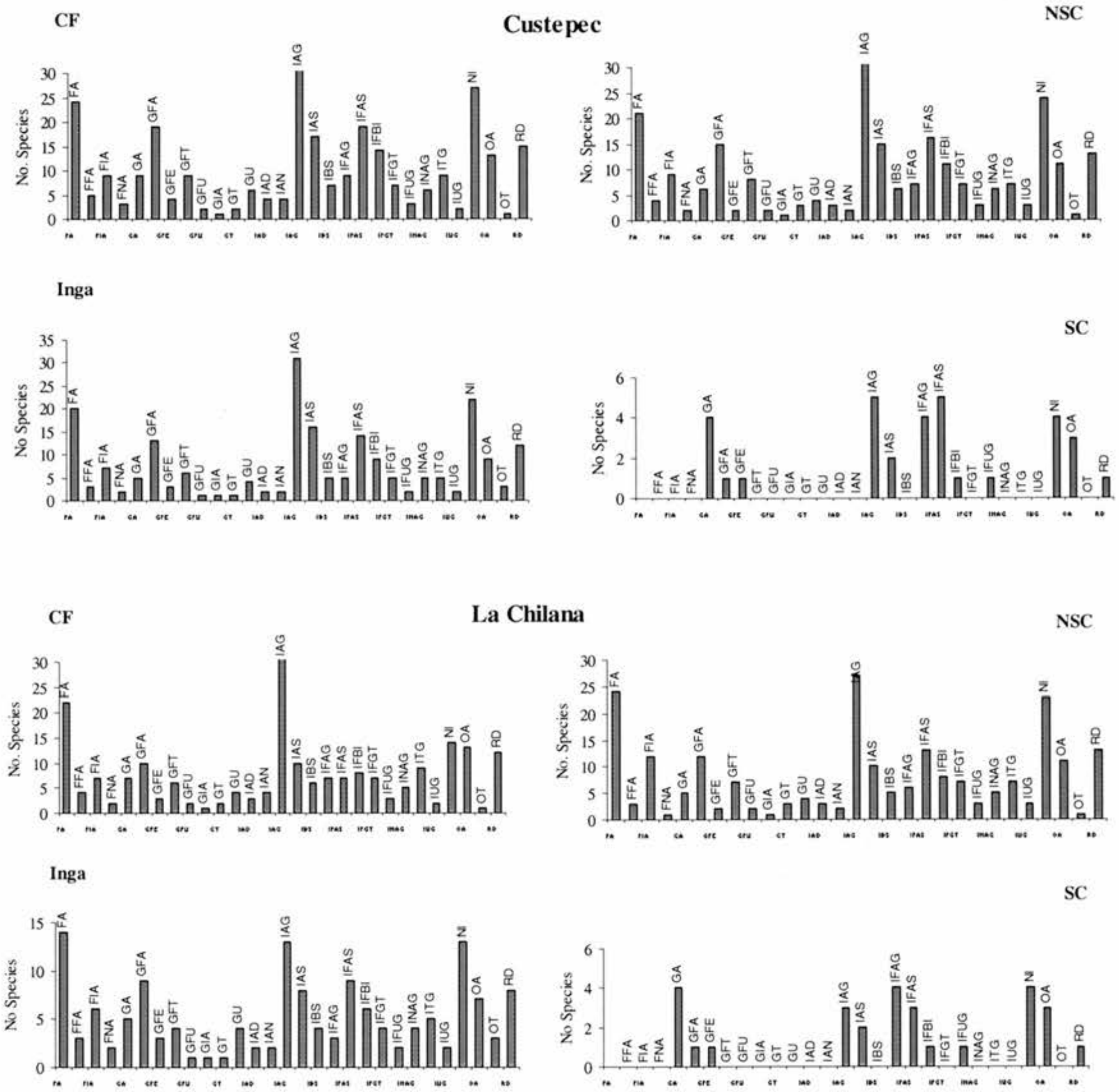


Figure 5.20 Bird dietary specialisation (see Appendix I for code) in the four habitat in Custepec and La Chilana. CF = Cloud forest, NSC = Natural shade coffee, Inga = Inga coffee plantation and SC= Sun coffee.

In both La Chilana and Custepec, there were small differences in the numbers of species in each trophic guild at the three main habitats (Figure 5.21) All trophic behaviour classes were present in CF, NSC and Inga but not in SC. Gleaning arboreal insectivores represented the guild behaviour with highest diversity (in Custepec: CF 37 spp, NSC, 34 spp, Inga 31 spp and SC just 5 spp; in La Chilana: CF 33 spp, NSC 27 spp, Inga 13 spp and SC just 3 spp). The species included in this category are chickadees, wrens, yellowthroats warble, and gnatcatchers. Nectarivore-insectivores had relatively the same amount of species in numbers than the last group including all the species of hummingbirds. The gleaning arboreal insectivore-frugivores were the third group in the four habitats including vireos, catbirds, bluebirds, shrike-vireos, and thrushes. The arboreal frugivores included orioles, chachalaca and guans. The arboreal insectivore-frugivores included flycatchers, becards, kingbirds, motmots, attilas, and kiskadees, and the aerial onmivores included cuckoo, jays and toucanets. The arboreal granivore-frugivores included chachalaca and guans. The arboreal insectivore-frugivores included flycatchers, becards, kingbirds, motmots, attilas, and kiskadees, and the aerial onmivores included cuckoo, jays and toucanets. The arboreal granivore-frugivores included pigeons, parakeets, parrots, and grosbeaks. Finally, the most important terrestrial granivore-frugivores included quail-doves, quails and doves.



Custepec

CF

NSC

Inga

SC

La Chilana

CF

NSC

Inga

SC

Figure 5.21 Distribution of bird species in categories of trophic-behavioural guilds in Custepec and La Chilana. See the key for the trophic-behavioural guilds in Appendix I.

5.8 Use of forest strata

in each stratum. Except for the midstory stratum, which was preferred by most species, all other strata were preferred by a similar numbers of bird species.

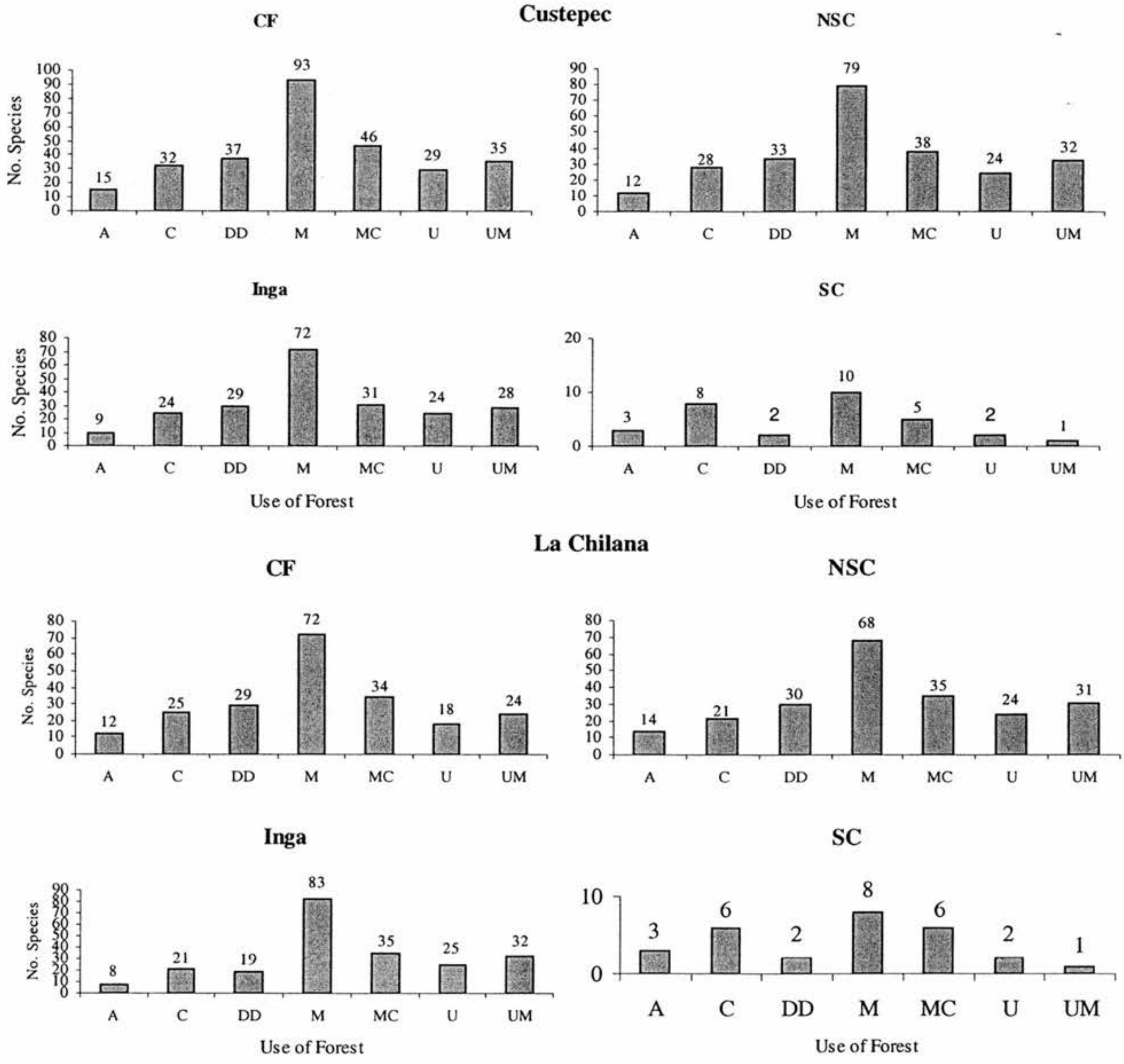


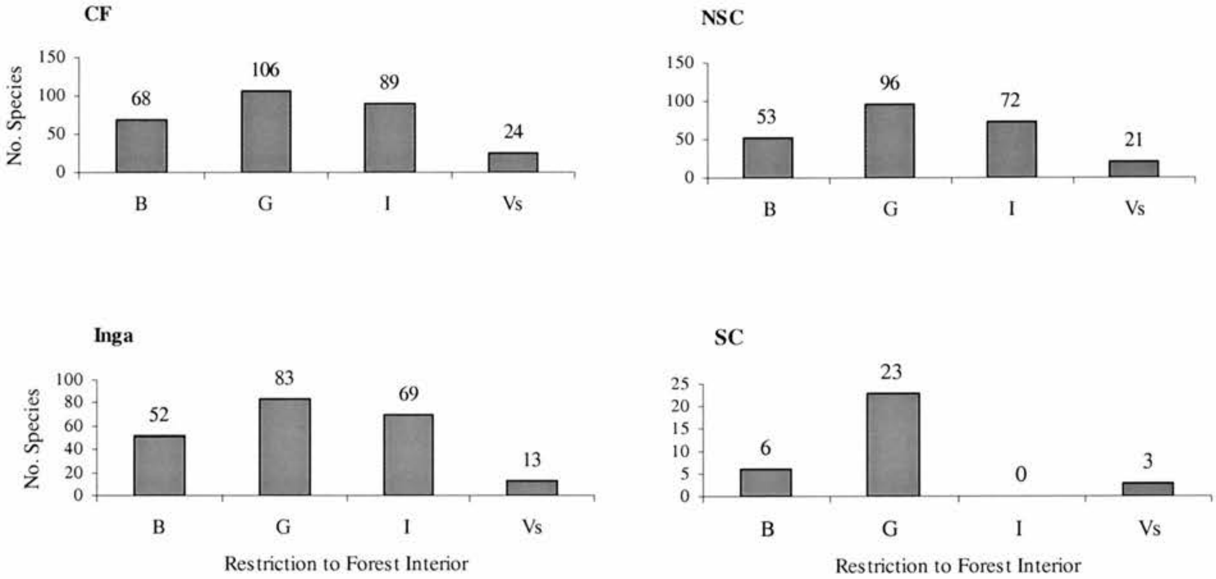
Figure 5.22 Distribution of bird species in the forest strata in the four habitats at Custepec and La Chilana. A= all strata, C= canopy, DD= data deficient, M= midstory, M-C= midstory and canopy, NA= not applicable, U= understory, U-M= understory and midstory.

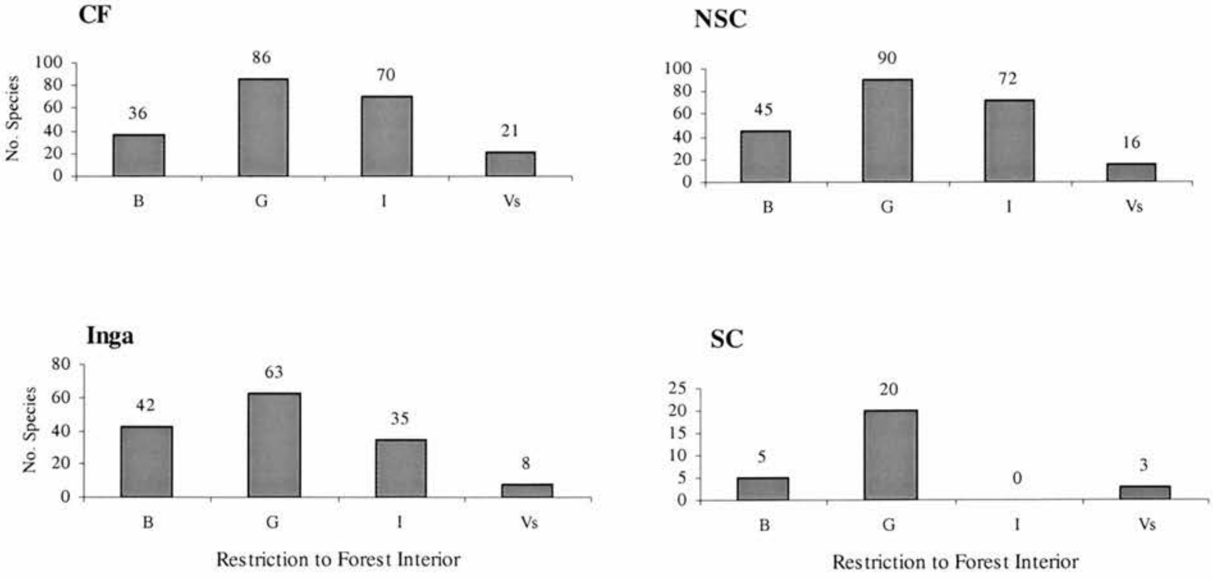
At Custepec, only *Wilsonia pusilla, Icteria virens, Carpodacus mexicanus*, and *Dendroica fusca* showed no preferences. In the three main habitats (CF, NSC and Inga), canopy and midstory-canopy categories maintained similar numbers of species. The most abundant species observed in the midstory included *Dendroica fusca, Chlorospingus ophthalmicus*, *Wilsonia pusilla*, *Dendroica coronata*, and *Mitrephanes phaeocercus, Mniotilta varia.* For midstory-canopy the most abundant species were *Piaya cayana, Ortalis vetula*, *Ortalis leucogastra*, *Melanerpes formicivorus, Automolus rubiginosus,* and *Megarynchus pitangua.*

At La Chilana, *Wilsonia pusilla, Icteria virens, Carpodacus mexicanus, Dendroica virens, Megarynchus pitangus and Dendroica fusca* were the only species with no preferences. The stratum with largest numbers of species and individuals was the midstory. Canopy and midstory-canopy categories showed similar numbers of species in the three main habitats (CF, NSC and Inga). The most abundant species observed in the midstory were D*endroica virens, Chlorospingus ophthalmicus, Wilsonia pusilla*, and *Mniotilta varia.* For midstory-canopy the most abundant species were *Piaya cayana, Ortalis vetula*, *Ortalis leucogastra*, *Melanerpes formicivorus, Automolus rubiginosus,* and *Megarynchus pitangua.*

5.8.1. Restriction to forest interior

At Custepec, in the CF habitat, 89 bird species were classified as restricted to the forest interior, 106 species were classified as forest generalists, and 68 species were classified as restricted to the forest border. The remaining 24 bird species were detected only in forest patches smaller than 50 ha (Figure 5.23). These 24 species might not be truly forest bird species, but they can be species that mainly use the vegetation matrix surrounding the forest patches, composed of vegetation types such as secondary growth and crops (mainly maize). For the NSC a total of 96 species were classified as a forest generalist, 72 as forest interior, 53 as habitat border sites and 21 in the vegetation surrounds. Inga was similar to NSC with 83 forest generalist species; 69 forest interior, 52 border site and 13 species in surrounding vegetation. For the SC, 32 species were recorded and were classified as 23 forest generalists, 6 border, and 3 in vegetation surrounds. In Custepec and also in La Chilana, the forest generalist species were the most common species and had the highest relative abundance. Among forest generalist species in the main habitats, the most important were *Columba livia*, *Ortalis vetula*, *Trogon mexicanus*, *Chlorospingus ophthalmicus*, species; 69 forest interior, 52 border site and 13 species in surrounding vegetation. For the SC, 32 species were recorded and were classified as 23 forest generalists, 6 border, and 3 in vegetation surrounds. In Custepec and also in La Chilana, the forest generalist species were the most common species and had the highest relative abundance. Among forest generalist species in the main habitats, the most important were *Columba livia*, *Ortalis vetula*, *Trogon mexicanus*, *Chlorospingus ophthalmicus*, *Aratinga nana*, and *Trogon collaris*. Among the species at the edge, the most important were *Melanerpes aurifrons*, *Turdus assimilis*, *Turdus grayi* and *Thryothorus maculipectus*.





At La Chilana, in the CF habitat, 70 bird species were classified as restricted to the forest interior, 86 as forest generalist and 36 species as restricted to the forest border (Figure 5.23). Some bird species (21) were detected only in forest patches smaller than 100 ha. These species might be species that use the vegetation matrix surrounding the forest patches (mainly secondary growth and crops). For NSC a total of 72 species were classified as a forest interior, 90 as a forest generalist, 45 as a habitat border sites and 16 in the vegetation surrounded. Inga was similar to CF with 63 forest generalist species; 35 forest interior, 42 border site and 8 in the surrounding vegetation. For SC, 20 species recorded were classified as forest generalists, 5 as borders and 3 in vegetation surrounded. Among the main habitats the most important forest generalist species were: *Ortalis vetula*, *Trogon violaceus*, *Chlorospingus ophthalmicus*, *Pionus senilis*, and *Trogon collaris*. Among the border species the most important were *Melanerpes formicivorous*, *Turdus assimilis*, *Turdus grayi* and *Thryothorus maculipectus*.

5.8.2. Restriction to cloud forest and natural shade coffee

From the 20 to 26 species considered to be restricted to or preferentially using the cloud forest in Mexico (Howell and Webb 1995, Escalante *et al.* 1998), 23 and 24 species were detected in Custepec and La Chilana, respectively. They included, for both sites: *Penelopina nigra, Penelope purpurascens, Crax rubra, Pharomachrus mocinno, Dendrortyx barbatus, Geotrygon albifacies, Automolus rubiginosus, Sclerurus mexicanus, Xiphorhynchus erythropygius, Xiphorhynchus erythropygius, Vireo leucophrys, Mimus gilvus, Henicorhina leucophrys, Myadestes unicolor, Catharus mexicanus, Turdus infuscatus, Turdus plebejus* , *Turdus rufitorques, Basileuterus belli, Basileuterus delattrii, Chlorospingus ophthalmicus*, and *Atlapetes albinucha*. *Cyanolyca pumilo* was recorded only in Custepec and the species *Oreophasis derbianus* and *Xiphorhynchus flavigaster* were recorded only in La Chilana. In terms of species richness and relative abundance, the bird species restricted to the cloud forest represented from 14% to 49% of the bird community in Custepec, and from 17% to 52% in La Chilana.

5.9 Distribution range

Based on the geographical and altitudinal location of the study area (within the reported distribution range of the bird species recorded), Custepec represented the southern distribution limit for 24 species. La Chilana showed the same patterns as Custepec and represented the distribution limit for 24 species. Such species, recorded in both sites, were *Dendrortyx barbatus*, *Geotrygon albifacies*, *Lampornis clemenciae*, *Tyrannus melancholicus, Tityra semifasciata, Trogon mexicanus, Trogon collaris*, *Aulacorhynchus prasinus*, *Buteogallus anthracinus, Automolus rubiginosus*, *Sclerurus mexicanus*, *Xiphorhynchus erythropygius*, *Vireolanius melitophrys, Aphelocoma unicolor, Campylorhynchus gularis*, *Thryothorus maculipectus*, *Myadestes unicolor*, *Catharus frantzii*, *Chlorospingus ophthalmicus*, *Habia fuscicauda*, and *Atlapetes albinucha. Xiphocolaptes promeropirhynchus*, *Cyanolyca cucullata* and *Poecite sclateri* were recorded only in Custepec, while *Xiphorhynchus flavigaster* and *Campylorhynchus chiapensis* were only recorded in La Chilana. Additionally, four species recorded in Custepec (*Xenotriccus callizonis, Dendroica tigrina, Dendroica nigrescens,*and *Dendroica graciae)* were outside their reported distribution range; thus, it was assumed that they were also at the limits of their distribution range.

5.10 Conservation status, endemicity and rarity

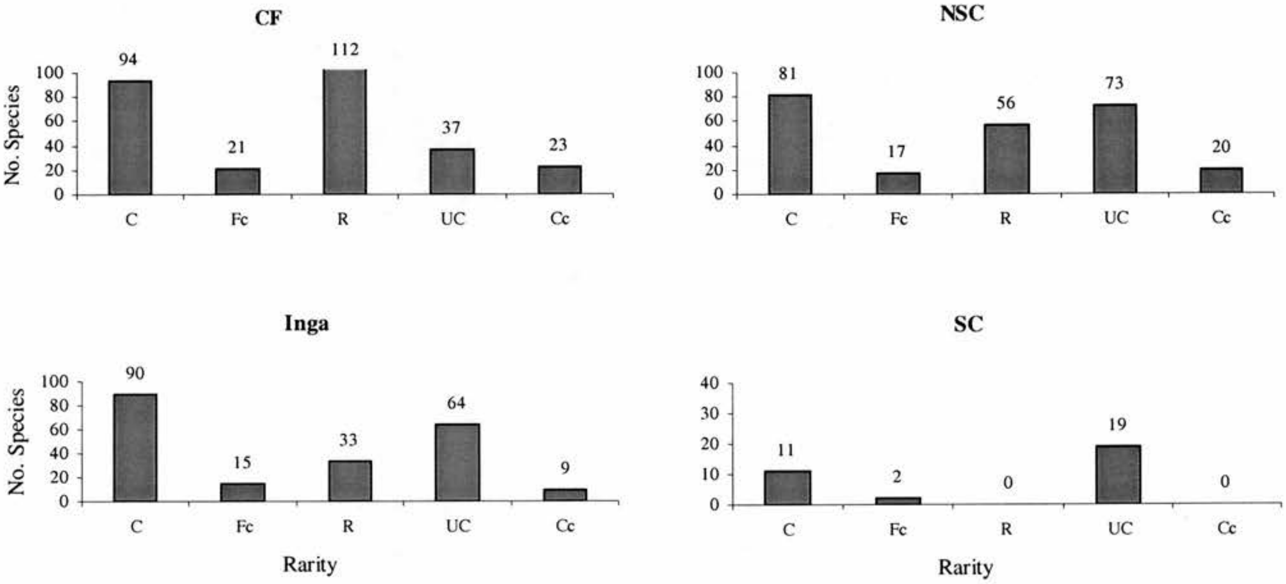
The Custepec bird community holds 34 species (17%) with some level of endemicity. These included 23 bird species endemic to Middle America (Howell and Webb, 1995), 7 species endemic to Mexico (Howell and Webb, 1995), and 4 restricted-range species (Stattersfield *et al.*, 1998). In La Chilana the bird community holds 34 species (21%) with some level of endemicity. These included 24 bird species endemic to Middle America, 7 species endemic to Mexico and 3 restricted-range species (see Table 5.8 for Middle America and Mexican endemic species). The restricted-range species were *Dendrortyx barbatus*, *Crax rubra, Penelope nigra,* and *Pharomachrus mocinno* which accounted for 11% and 18% of the individuals detected of the bird community in Custepec and La Chilana, respectively.

In terms of number of bird species (Figure 5.24), most of the species recorded were classified as rare or uncommon (23% in Custepec and 25% in La Chilana), since they were detected in less than 10% to 15% by the two methods. The remaining bird species were classified either as common, or fairly common. At both sites, the most important common species in terms of number of individuals were *Glaucidium minutissimum, Sclerurus mexicanus*, *Dives dives*, and *Ergaticus versicolor. Caprimulgus ridgwayi* was also common in Custepec.

Table 5.8 Endemic species recorded in Custepec and La Chilana

Middle America	Mexico
Dendrortyx barbatus, Dactylortyx thoracicus, Penelopina nigra , Crax rubra , Campephilus guatemalensis, Trogon mexicanus ,Geotrygon albifacies, Amazilia cyanocephala, Pharomachrus mocinno, AratInga holochlora, Glaucidium minutissimum, Lampornis amethystinus, Trogon collaris, Vireolanius melitophrys, Vireolanius pulchellus, Cyanolyca nana, Geothlypis poliocephala, Aphelocoma unicolor, Myadestes unicolor, Turdus infuscatus, Basileuterus belli, Thraupis abbas, and *Atlapetes albinucha*	*Dendrortyx barbatus, AratInga holochlora, Atthis heloisa, Campylorhynchus chiapensis, Melanotis caerulescens, Atlapetes albinucha*, and *Trogon mexicanus*

The Custepec and La Chilana community included 19 and 20 respectively, bird species considered of conservation concern in Mexico by the Secretary in charge of the administration of natural resources (SEDESOL 1994). Such species were *Buteogallus anthracinus*, *Buteogallus urubitinga*, *Spizaetus ornatus*, *Dendrortyx barbatus*, *Micrastur ruficollis, Penelopina nigra, Crax rubra*, *Dactylortyx thoracicus*, *AratInga holochlora*, *Pionus senilis*, *Amazilia cyanocephala, Pharomachrus mocinno*, *Glaucidium minutissimum, Campephilus guatemalensis, Xiphorhynchus flavigaster, Xiphorhynchus erythropygius, Onychorhynchus coronatus, Dendroica magnolia* and *Dendroica petechia. Oreophasis derbianus* was also included in La Chilana,.


CF
No. Species
100
80
60
40
20
0
94
21
112
37
23
C
Fc
R
UC
Cc
NSC
100
80
60
40
20
0
81
17
56
73
20
C
Fc
R
UC
Cc
Inga
No. Species
100
80
60
40
20
0
90
15
33
64
9
C
Fc
R
UC
Cc
Rarity
SC
40
30
20
10
0
11
2
0
19
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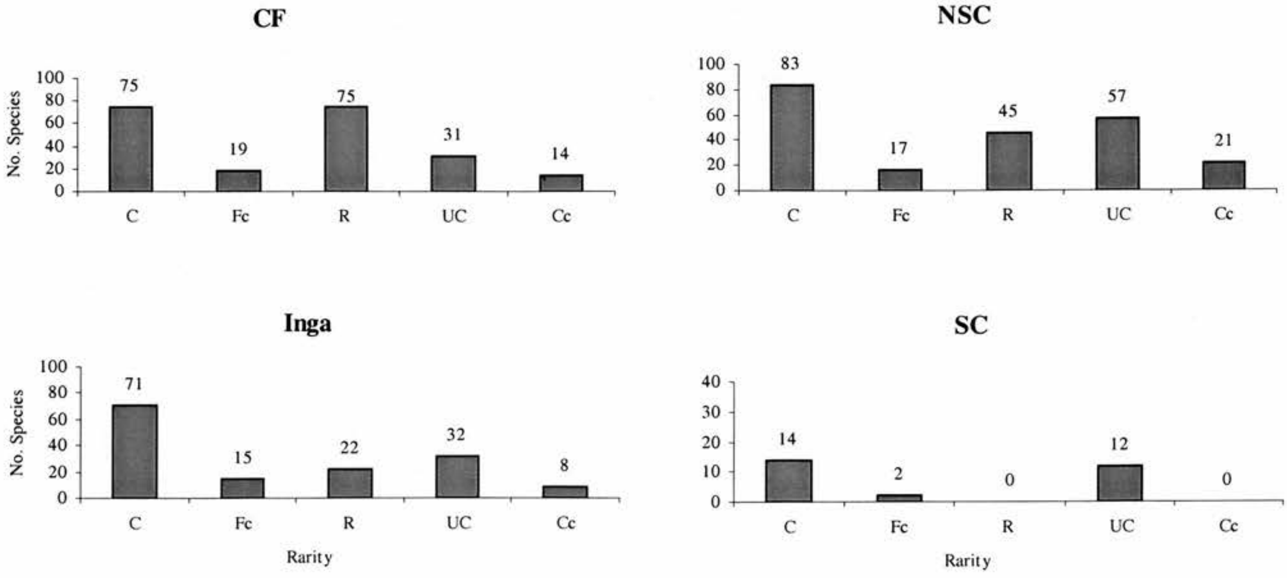
CF
No. Species
100
80
60
40
20
0
75
19
75
31
14
C
Fc
R
UC
Cc
NSC
100
80
60
40
20
0
83
17
45
57
21
C
Fc
R
UC
Cc
Inga
No. Species
100
80
60
40
20
0
71
15
22
32
8
C
Fc
R
UC
Cc
Rarity
SC
40
30
20
10
0
14
2
0
12
0
C
Fc
R
UC
Cc
Rarity

5.11 Interpretation and preliminary discussion

This chapter has examined the bird communities in four habitats in two different coffee fincas in "El Triunfo" Biosphere reserve in Chiapas, Mexico and its response to habitat mosaics over a gradient of human impact. It investigated the results of land use change on bird species diversity, abundance and composition. The results of the survey of understory bird species in 4 different habitats (cloud forest, natural shade coffee, Inga and sun coffee), shows that CF was the habitat with the highest richness in the tree strata, followed by NSC, which is an habitat derived from CF and for that reason shares many species in the upper tree layer. The difference with Inga is that the bush layer of the NSC is composed of coffee plants but still conserves the tree cover (mainly Inga species). The three main habitats have more complex vegetation structure than the SC where all the trees have been removed. Some of the advantages of this structure (for birds) are: More shade, provide more sites for refuge and nest, and higher foraging plataform.

The use of two independent methods (point counts and mist nets) accounted for the high number of species registered in both sites. The most diverse habitats were CF and NSC; they were also similar in terms of species composition. SC was the less diverse habitat with few species accounting for 80% of the total abundance.

In the most conserved habitats (CF, NSC) the species richness was related to the patch area. An increase in the area increases the number of the number of species. By contrast, in the most disturbed habitat (SC) there was a slight relationship between patch size and diversity.

At both sites, the capture of adults was higher than that for juveniles (mainly CF and NSC). In Custepec the juveniles did not use the same habitat as the adults and this result suggests that species of juveniles moves to this habitat because adults are occupying the natural forest habitats. In contrast, in la Chilana the capture of both groups was higher in NSC habitats. CF registered the highest diversity in migratory species but Inga had the highest density.

Insects, fruit and other invertebrates were the main food resources and omnivores were the most common group in all the habitats. In a gradient of habitat perturbation, the most conserved habitats (CF and NSC) showed the highest number of species restricted to forest interior, while in the less conserved habitats (Inga, SC) the most common species classified are forest generalists. Most of the species considered as restricted to the Mexican Cloud Forest were detected in both studies areas, representing almost 50% of the recorded species.

There are several compelling reasons to protect the richest habitats: These include the presence of rare species, the frequency of species with some level of endemicity and other species of conservation concern. It is important to take into consideration the fact that some shade coffee plantations (mixed in a matrix with forest patches) have been used by birds as a corridor between large forested areas.

These ideas are tested for the site study in Barranca Grande in Veracruz State, in the following chapter, where the levels of disturbance for the natural forest are considerably greater.

CHAPTER 6

Barranca-Grande: Forest patches and coffee plantations in Veracruz

6.1 Introduction

As indicated earlier, of the ecosystems in Mexico, cloud forest has one of the richest avifaunas (Escalona *et al.*, 1995). It also contains one of the highest proportions of habitat-restricted bird species, and holds some of the largest numbers of endemic species (Escalante *et al.*, 1998). It also been noted that the role of agricultural land in the tropics is very important because of its potential value as conserving biological diversity following the transformation of natural vegetation (Pimentel *et al.*, 1992; Greenberg *et al.*, 1997a). A few studies have supported the importance of agroecosystems such as shade coffee plantations as a refuge for understory birds (Aguilar-Ortiz, 1982; Robbins *et al.*,1992; Wunderle and Waide, 1993; Vannini, 1994; Wunderle and Latta 1996; Greenberg *et al.*, 1997; Wunderle and latta, 2000). Consequently it is important to compare areas with relatively high levels of conservation (as in Chiapas, chapter 5) with regions of similar cloud forest which endure high levels of disturbance and land use change.

In general, for the central region of Veracruz the incidence of tropical birds (residents and migratory) is well known, however the nature of the avifauna in different types of coffee plantations is poorly-known. Despite several studies that have been carried out on the avifauna of tropical forests in Mexico, the conservation of tropical birds requires a still deeper knowledge of species ecology, for example their ability to survive in disturbed habitats.

6.2 Structure of the argument

This chapter aims to describe the composition and relative abundance of bird communities in four habitats (CF, NSC, Inga and NS) in Central Veracruz, Mexico. The research recorded all bird species detected in the study area, including their estimated population parameters and with calculations the expected bird species richness in each of the habitats surveyed. The research also characterised the bird community, in terms of distribution of species by trophic guilds, dietary specialisation, trophic-behavioural guilds, use of forest strata, level of restriction to forest interior, level of restriction to cloud forest, distribution range, endemicity, resident/migratory status, level of rarity, and conservation status. Distributions of species in adults, juveniles, migratory and residents, and the relationship between them in a mosaic habitat landscape, were also taken into consideration. For the purpose and comparison the structure of the argument and analysis follows the outline for Chiapas (See Figure 5.1)

6.3 Plant richness and habitat description

The general characteristics of the vegetation at the study site (Table 6.1), showed similar numbers in tree species between CF and NSC. In natural ecosystems, the highest richness for the three strata was natural shade coffee, while Inga shade coffee contained the lowest numbers in all the strata. The Inga habitat supported only sixteen tree species, a very low number compared with the other habitats. However it had almost the same number of herb species as CF, mainly because of its open structure with more sunlight. For the total number of plant species, habitats ranked as follows: cloud forest (CF), natural shade coffee, Inga shade coffee (Inga) and sun coffee (Table 6.1).

Table 6.1 Number of vegetation samples per habitat with the number of species at three defined layers.

Habitat	Number of samples	Number of plant species	Species in tree layer	Species in shrub layer	Species in ground layer
Cloud forest	30	137	45	78	51
Sun coffee	15	3	28	26	34
Natural shade coffee	20	93	46	37	32
Inga shade coffee	20	49	16	19	52
Total	85	282	135	160	179

6.3.1. Cloud forest

A total of 19 patches were sampled, ranging in size from 0.09 to 750 ha. Patches were surrounded by non-forest habitats (70% cultivation and 10% pasture). The remaining 20% contained a mix of roads, rivers, small buildings, etc. The patches in the area covered an altitudinal range between 1,450 and 2,100 m above sea level, with a very high percentage of slopes between 30% to 90%.

The patches of cloud forest in Veracruz were similar to the patches in Chiapas (tall,dense and in some places dark). Canopy height was between 20-30 m. Shrubs and small trees were also represented by the same families (Piperaceae, Rubiceae and

Solanaceae) with abundance of arborescent ferns. Some of the dominant species in Chiapas (such as *Quercus polymorphe*, *Carpinus caroliniana*, *Liquidambar macrophylla*, *Ulmus mexicana* and *Magnolia schiedeana*) were also dominant in these patches. *Quercus sartoli* was another dominant species in these patches.

Slope orientation and the amount of direct sunlight determined the percentage of vegetation coverage. The categorization of these coverages was explained in chapter 5. On slopes protected from sunlight the lower vegetation (mainly bushes) layers fall into category 5. In contrast, on exposed slopes the tree layer showed 3-4 and the herb layer 4-5 coverage. In these patches the tree stratum showed 1 or 2 sub-layers and the herb stratum showed only one. The tree stratum generally has 4 of coverage category but some few sites have coverage 3 and 5 (Table 6.2).

Based on the number of layers per strata, the habitat complex vegetation structure was CF followed by NSC and Inga. The same gradient of vegetation structure was found in Chiapas. However, in Veracruz the vegetation cover in the herb layer is reduced or absent for long periods due to the use of herbicides.

Table 6.2 Number of layers and coverage categories per habitat at Barranca Grande. Coverage categories: 5 more than 75%, 4 between 50% and 75%, 3 25% to 49%, 2 less than 25%, and 1 dispersed.

Habitat	Number of layers (coverage category)		
Habitat	Tree	Bush	Herb
Cloud forest	3-2 (4)	2 (4-5)	1(3-4)
Natural shade coffee	3(2-3)	1(2)	1(3)
Inga shade coffee	2-3(4)	1(2)	1(2)

6.3.2. Natural shade coffee

In this area, as in Chiapas, patches of NSC are derived from CF. For that reason CF species are found in the upper tree canopy. The habitat structure is similar to the original forest, the main difference is the substitution of herb and shrub layer by coffee plants.

Each patch shows a different management history, so that plantations can be found with a tree layer comprising only native species from the original forest, as well as an assemblage of fruit trees (for human food) that have replaced the original species. The number of tree individuals per ha is around 150.

This habitat showed 2-3 sub-layers in the tree stratum, only one sub-layer in the bush stratum (coffee plants), and one for the herb stratum. Coverage was 2-3 for the tree stratum, 2 for the bush and 3 in herb stratum (Table 6.2). In this habitat (and sometimes also in Inga shade coffee), the pruning of shade trees may affect the seasonal distribution of foliage and reduce the coverage in the tree stratum.

6.3.3. Inga shade coffee

Inga species are dominant in the tree layers. The most abundant species are *Inga laurina* and *Inga micheliana*, with *Inga sapinoides* in lower numbers. Other tree species in order of abundance are *Belotia mexicana*, *Trema micrantha* and *Heliocarpus apendiculatus.* This plantation had an intense production of several trees, shrub and palms for human use, with more tropical fruit trees than in Chiapas. The main fruit trees in the patches are orange (*Citrus sinensis)*, avocado (*Persea americana*), small avocado (*Persea schiedeana*), banana (*Musa* sp), guava (*Psidium guajava*), guanabana (*Annona muricata***)**, apple (*Malus domestica*), mango (*Magnifera indica*) and two species of *Chamaedora* palms. Coverages were the lowest in the bush layer, (composed of coffee plants) and in the herb layer (2). However tree coverage had the same amount than CF (4).

6.4 Bird species (Point Counts)

6.4.1 Bird richness

For the habitats sampled with the same number of point counts, the highest number of species was recorded in the CF patches, followed by the NSC, Inga and sun coffee (Figure 6.1). The number of species detected is the total of species identified using the two techniques mentioned earlier. A total of 162 species were identified using point counts

Bird abundance, using point counts, showed a total of 162 species recorded in four habitats sampled (Figure 6.1) CF was the habitat with the greatest richness with 162 species, while the SC had the lowest with 25. CF had 143 species, while Inga had 111. The results in the patches showed that resident species were the category with most species recorded: 103 species were found in CF, 88 in NSC and 77 in Inga. SC had the lowest number of species (15 spp, Table 6.3)

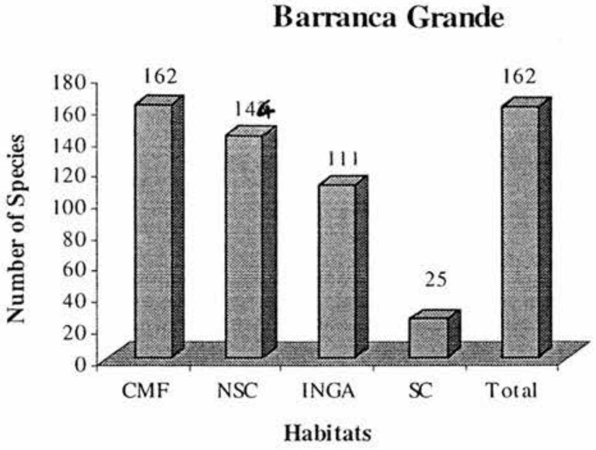

Figure 6.1 Number of species per habitat type at Barranca Grande based on the overall numbers of recorded species. CF= cloud forest, NSC = natural shade coffee, Inga = Inga shade coffee and SC = sun Coffee.

Table 6.3 Bird richness and seasonality by habitat types at Barranca Grande. Numbers in parenthesis indicate percents.

HABITAT	Resident and winter visitor	Resident	Summer visitor	Transient and winter visitor	Transient
Cloud forest	2(1.25)	103(63.20)	2(1.25)	40 (25.45)	15(8.65)
Natural shade coffee	2(1.40)	88(61.05)	2(1.40)	38(26.35)	14(9.80)
Inga shade coffee	2(1.80)	77(69.37)	2(1.80)	18(16.21)	12(10.82)
Sun coffee	0(0)	15(60)	0(0)	8(32)	2(8)

6.4.2. Species detected

A total of 28 bird families and 162 bird species were detected in the 4 different habitats (CF, NSC, Inga and SC). Parulidae and Tyrannidae were the families with the greatest numbers of species in all the habitats (Appendix VIII). As in the Chiapas survey, species from the genera *Cypseloides* and *Empidonax* were treated as a genus for the point count method and as a species in the mist-net method.

In this area the sampling effort was of 1, 440 survey point, however (as in Chiapas), nocturnal or migratory species may be underrepresented because censuses were only diurnal and from October to May.

The species with the highest relative abundances in CF were *Ortalis vetula, Leptoptila verreauxi, Geotrygon montana, Columba flavirostris, Columbina inca, Melanerpes formicivurus, Momotus momota, Cyanocorax morio*, *Wilsonia pusilla*, and *Vireo olivaceus*. These 10 species accounted for 72% of the total relative abundance of the bird community in the habitat. The high relative abundance of these species was the result of the high levels of detectability and their high density, particularly in the case of *Cyanocorax morio* and *Wilsonia pusilla*.

The species with the highest relative abundances for NSC were *Pitangus sulfuratus, Vireo olivaceus, Camplorhynchus zonatus, Polioptila caerulea, Vermivora celata, Archilochus colubris, Piculus rubiginosus, Myadestes obscurus, Dumetella carolinensis,* and *Wilsonia pusilla.* These 10 species accounted for 62% of the total relative abundance. In the case of Inga the species with high relative abundance were *Pitangus sulphuratus, Cyanocorax yncas, Cyanocorax morio, Saltator atriceps, Quiscalux mexicanus, Vermivora celata, Wilsonia pusilla,* and *Megarynchus pitangus.* These 8 species represented 73% of the relative abundance. In SC, three species accounted for most of the relative abundance with 83% of the species total (*Quiscalus mexicanus, Megarynchus pitangus,* and *Cyanocorax morio;* Appendix IX).

6.4.3. Species accumulation curves

The cumulative abundance was plotted against the species rank to show differences in diversity among habitat types (Figure 6.2, Magurran, 1988). The lowest curves are the most diverse communities, which are represented by CF and NSC with overlaped curves followed by Inga. SC is the least diverse of all the habitats (Figure 6.2).

The means of the observed species accumulation (Sobs) and the incidence-based coverage estimator of species richness (ICE) were used to evaluate completeness of the species data set recorded and to estimate the richness at the different habitats. As in Chiapas the species accumulation curves, as a function of both sampled area and abundance of individuals, indicated that richness is lower in SC than CF or NSC. An asymptote was reached in all habitats. As is shown by the graphs (Figure 6.3) the curves for estimated richness and for observed species overlapped and were nearly flat at the end. The declining doubleton and singleton curves suggest that few species remained to be recorded. In all the habitats, the accumulation curves show that the Sobs (observed species) and the Coleman curves were nearly the same, which means that the species were not patchily distributed. It seems that for such high diversity communities, a large amount of sampling effort is needed because rare and accidental species continue to increase with sampling effort. However, it is necessary to determine when to stop sampling due to time and money restrictions. In this case, it was estimated that forty samples per habitat would provide enough data to cover at least around 95% of the species.

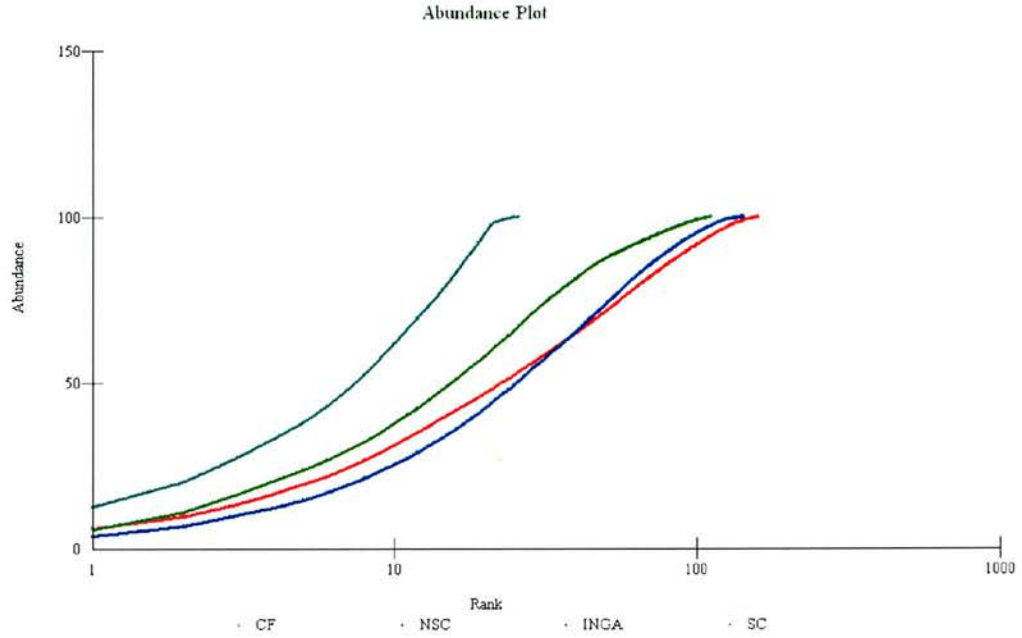

Figure 6.2 k-dominance plot for the four habitat types surveyed at Barranca Grande, showing accumulative abundance against the species rank. CF = cloud forest, NSC= natural shade coffee, Inga= Inga shade coffee, SC= sun coffee.

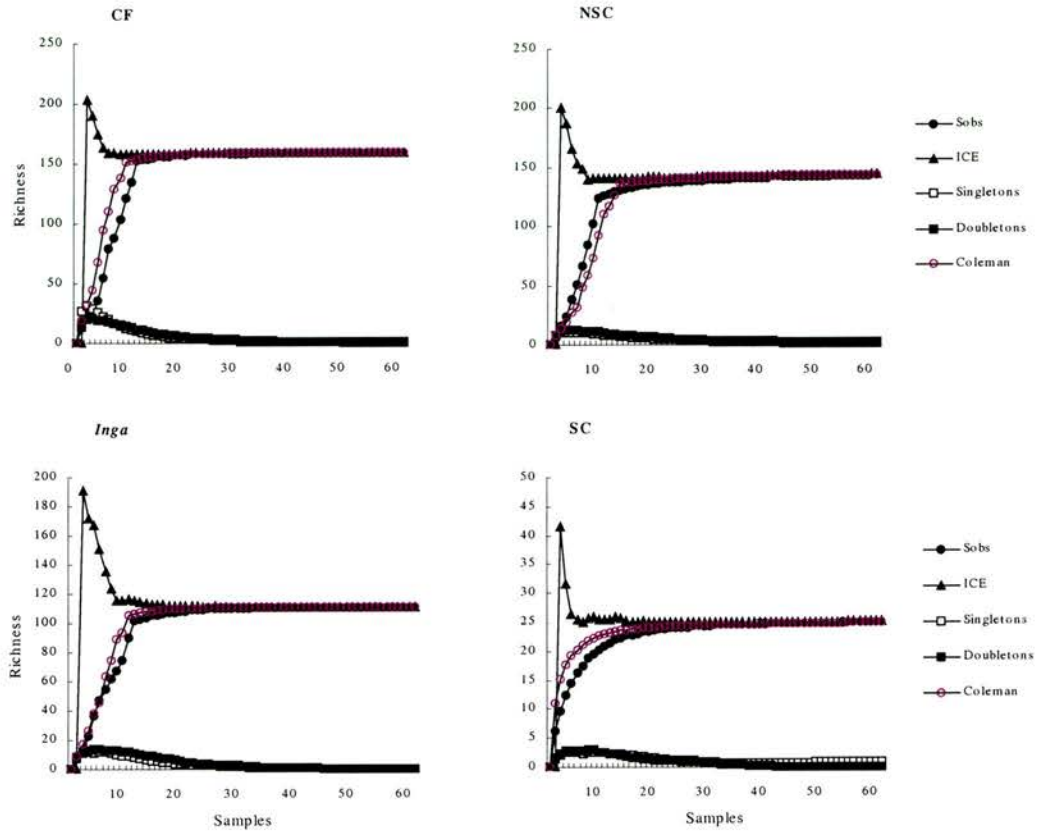

Figure 6.3 Species accumulation curves in the four habitats in Barranca Grande. Sobs is the number of species observed in the 60 sampled points, singletons and doubletons (rare species) are numbers of species with only one or two individuals in the sample, ICE is the incidence-based richness estimator, and the Coleman curve.

6.4.4. Diversity index and similarity

According to the Shannon diversity index, CF followed by NSC and Inga were the most diverse sites, whereas SC was the least diverse. These three sites also showed the highest evenness values, which means that at each site the species had an nearly equal abundance (Table 6.4). A value of 1 represents a situation in which all species are equally abundant (Magurran, 1996). According to the Jaccard index the habitats with the highest similarities were CF and NSC.

Table 6.4 Shannon index and Jaccard index between pairs of habitats (number of shared species given in parentheses). The first two columns corresponded to the Shannon diversity index (H') and the Shannon evenness (E).

Habitat	Shannon diversity index	Shannon evenness index	NSC	Inga	SC
CF	4.50	0.90	0.80(143)	0.70(11)	0.20(25)
NSC	4.50	0.86		0.60(95)	0.20(25)
Inga	4.10	0.65			0.20(25)
SC	3.00	0.49			

6.4.5 Bird species diversity in patches

Patch area was classified according to their size. The same categories used in Chiapas were used in these habitats: Large (more than 1000 Ha), medium (from 100 to 1000 ha) and small (from 0.1 to 100ha).

In Veracruz the species richness also decreased with area (Figure 6.4). A fitted line plot simple regression was used to analyse the relationship between bird species and habitat size. For the CF and Inga habitats there was a significant positive regression between the number of species and the size of the patches (CF, r^2 =16.8, df = 28 and Inga, r^2 = 22.3, df = 17 P<0.001). In contrast SC (r^2 = 0.3, df = 8 and NSC r^2 = 0.1, df = 22); did not show a significant regression (P > 0.05, Figure 6.5).

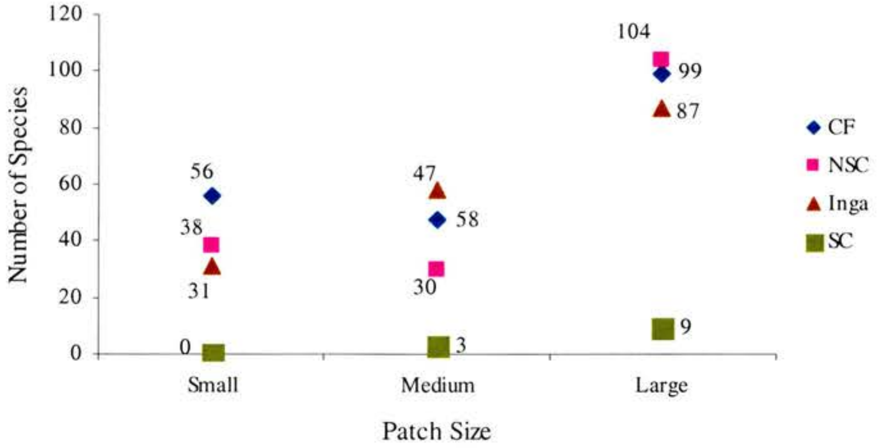

Figure 6.4 Number of bird species as a function of patches size in Barranca Grande. Patches size categories are small (0.1-100 Ha), medium (100-1000 ha), and large (greater than 1000 ha).

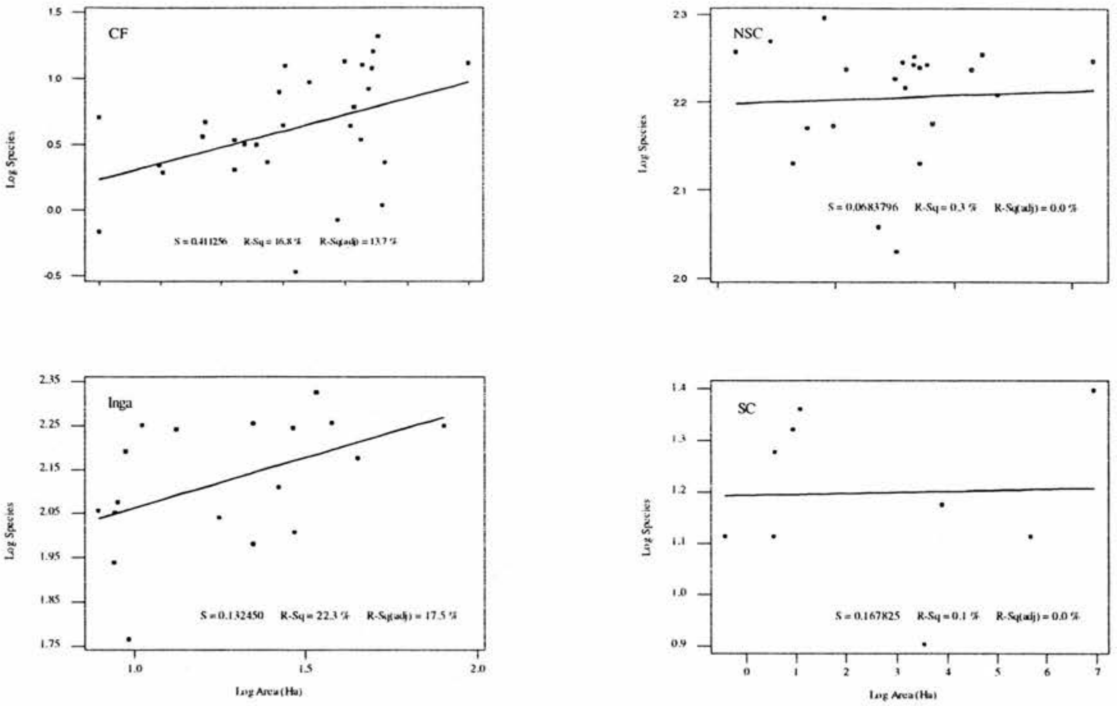

Figure 6.5 Relationship between bird species and patch size in Barranca Grande. CF = Cloud Forest, NSC= Natural Shade Coffee, Inga = Inga Shade Coffee and SC= Sun Coffee.

6.4.6 Faunal similarity

A Cluster analysis was used to classify samples and species. This method is one of the most widely used in ecology (Van Tongeren 1995). The data used for the classification of birds species consisted of 60 samples and 162 species, which excludes unique occurrences. As in Chiapas, CF and NSC are the most similar habitats, while Inga shade coffee is the nearest habitat outgroup. Sun Coffee is apart, showing less than 50% of similarity with the other three habitats (Figure 6.6).

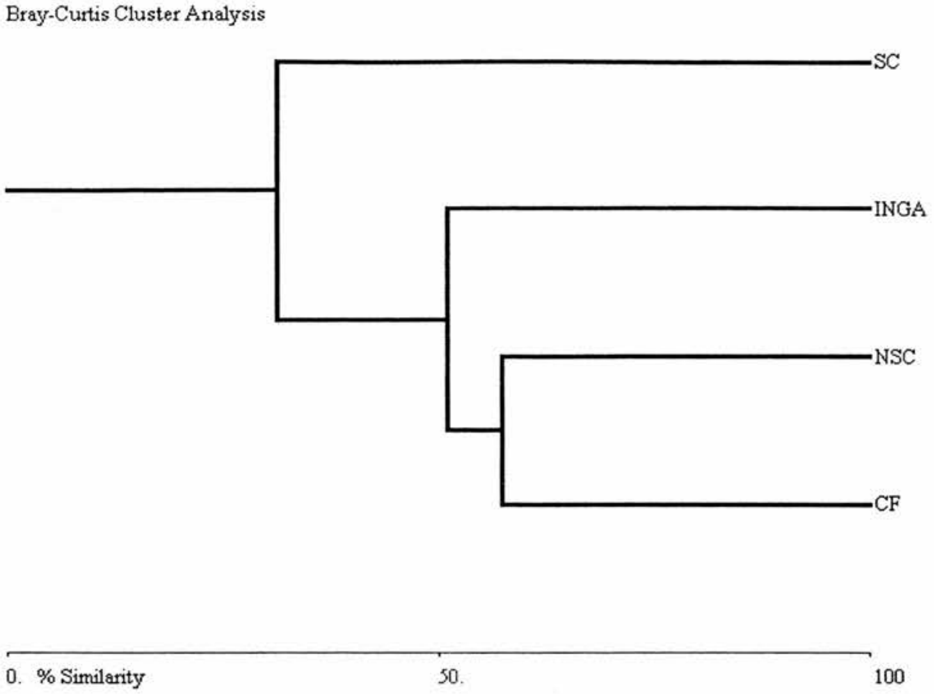

Figure 6.6 Cluster analysis based on Bray- Curtis index to classify samples and species surveyed at Barranca Grande. CF =Cloud Forest, NSC = Natural Shade Coffee, Inga= Inga Shade Coffee and SC= Sun Coffee.

6.4.7 Ordination Analysis

All the bird species were included in the canonical correspondence analysis (CCA), together with the following environmental variables: canopy, altitude, wind speed and temperature. The full data set of trees were also included. The analysis showed very low eigenvalues, 0.3016 for Axis1 and 0.19775 for Axis2. The first four axes explain the 39.43% of the variation, indicating that all the variation observed in the species data is not totally explained by the environmental (Figure 6.7). However the most important variables were canopy cover and altitude, which influence the species of CF and some of NSC that were grouped together and separated from the species of Inga and SC. The species of the latter habitats are clearly separated from the remaining habitats. Cloud forest and sun coffee are found at the higher and lower altitude, respectively. This is related to the large (in CF) and small number (in SC) of tree species present and to the number of bird species only found in these habitats.

Cloud forest is present at higher altitudes and contains a large number of tree species. This is related to the high number of exclusive species found in cloud forest. By contrast SC is found at lower altitude and had the lowest number of tree species; again only the species found in SC are related to this pattern. Finally, NSC and Inga were found at medium altitudes, they had fewer tree species than CF and shared a great number of species. In figure 6.7 the length of the arrows represents the importance of the environmental variables, tree species are shown by triangles.

The result of direct ordination is shown in a biplot of species and environmental variables (Figure 6.7) and in a biplot of the sites and environmental variables (Figure 6.8). The arrows represent the environmental data, which are plotted in the direction of the maximum change. The length of the arrows is proportional to the magnitude of that change. The position of the arrows almost shows the same length, which means that the variables are more closely correlated in the ordination. They are therefore more important in influencing community variation. The first two axes, of site and environmental variables, reveal varying degrees of correlation. Examination of Figure 6.7 reveals bird and tree species associations with the environmental variables. Some of the species are clearly distinguished as only found at one of the field sites. The principal factor in grouping the above species appears to be type of habitat use. In addition to tree species that have obvious links to field site, some grouping by environmental gradients is illustrated. Canopy and altitude are the main factors influencing species. Temperature and wind speed are important in defining species grouped in NSC and Inga.

Figure 6.8 shows that the habitats tend to group with similar species. CF is grouped separately from the rest of the habitats, but is however more close to NSC. Inga is situated between NSC and SC and showed variation along X axis 1. SC is clustered distinctly apart from the other habitats. CF and NSC show an overlapped distribution, however CF shows a wide variation on axis 2. CF and NSC habitats are sharing a large number of species. Inga shares most birds species with NSC. The location of CF apart from the main cluster may reflect its higher bird diversity, because it is one of the sites with more rare species.

In the DCA analysis,. Barranca Grande CF had eigenvalues of 0.1433 and 0.1003, respectively. As in the CCA analysis and DCA for the sites in Chiapas, similar habitats tended to cluster together. The least variability was shown by CF. The NSC distribution was similar to that of CF and Inga. However Inga had a higher variability with a more spread-out pattern and SC was distinct from the other habitats (Appendix

X). Figure 6.8 shows that in the CCA, SC and CF were clearly separated, while Inga and NSC were near located.

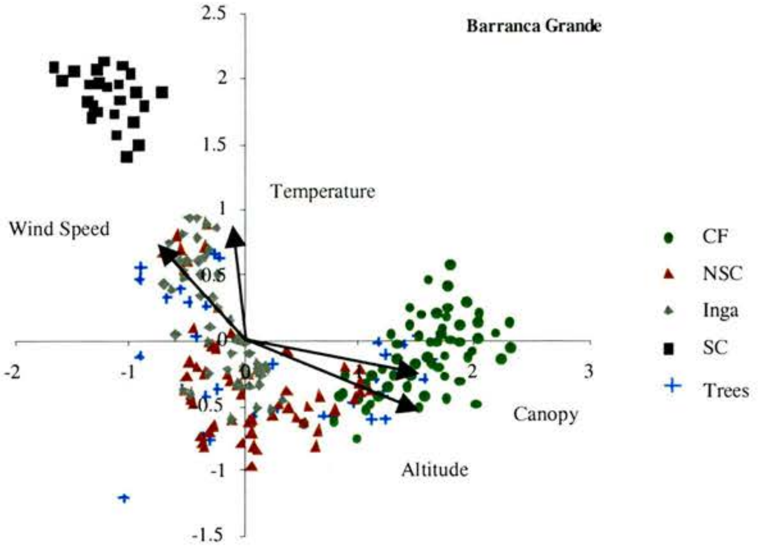

Figure 6.7 Canonical correspondence analysis of all the habitats based on the full bird, tree data set and environmental variables. Arrows represent the environmental data. The environmental variables are equally strong but their overall statistical influence is low.

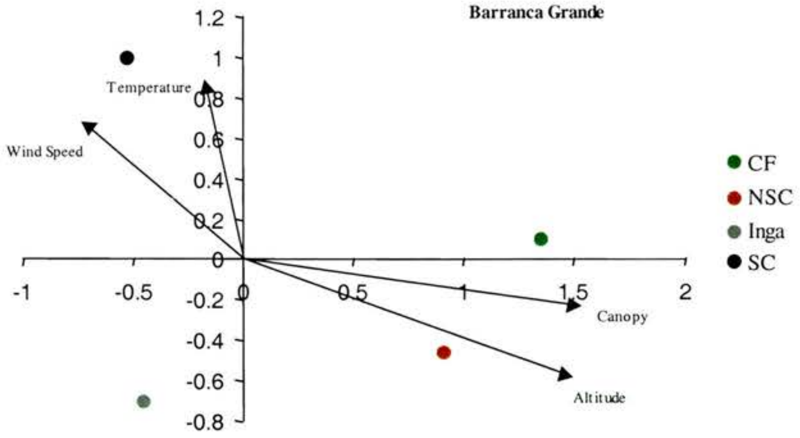

Figure 6.8 Canonical correspondence analysis based on the full bird data set and the habitats. This figure shows that similar habitats are grouped: where the green circle is CF; brown circle is NSC, grey circle is Inga and the dark circle is SC. Temperature relative to altitude is a significant determinant.

6.5 Mist Net Surveys

Sampling effort was constant for in the four habitats: 1000 net/hours were sampled per month in a period of 8 months (Table 6.5) for a total of 8,000 net/hours (1 hour = 1hour open 12m net). This resulted in a total of 13,598 captures comprising 83 species (Table 6.5).

The greatest numbers of individuals were captured in CF. A total of 5,339 captures, comprising 83 different species (Table 6.5 and Figure 6.9). The three most commonly captured species in CF were: *Wilsonia pussila* (223), *Amazilia yucatanensis* (187) and *Geotrygon montana* (163). NSC presented a total of 4,718 individuals captured, comprising of 59 species (Table 6.5 and Figure 6.9). The most frequent species caught in this habitat were *Empidonax minimus* (226), *W. pusilla* (193) and *Dendroica magnolia* (186). No species was represented by only a single capture.

Table 6.5. Number of species, total of individuals captured (recaptures excluded) and mist-net sample effort per month in the four habitats.

Habitats	Net/ Hour/month	Species	No of individuals	Indvid. * 1 net/hour
CF	1000	83	5339	0.667
NSC	1000	59	4718	0.589
INGA	1000	47	3440	0.43
SC	1000	22	101	0.012
TOTAL	4000	83	13598	

Inga had similar numbers of captured individuals than NSC with 3,440 from 47 species, (Table 6.5 and Figure 6.9). *Dumetella carolinensis* (210), *Vermivora cellata* (201) and *Amazilia yucatanensis* (184) were the most captured species. SC was the habitat with the fewest captures, only 101 of 22 species (Table 6.5 and Figure 6.9). *Amazilia yucatanensis* was the species most frequently captured.

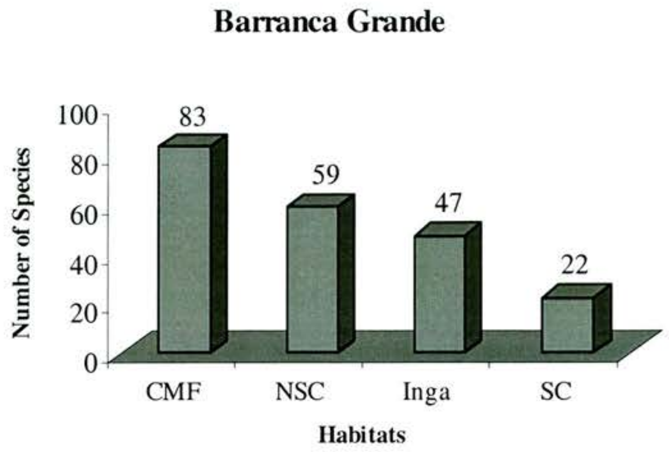

Figure 6.9 Total number of species captured in four habitats in Barranca Grande.

6.5.1. Species richness

The percentage of accumulative abundance was plotted against log species rank to show differences in diversity among habitat types. The lower line represents CF, which had the higher abundance and diversity (Figure 6.10). NSC was more closely related to the CF than Inga, however the Inga habitat showed almost the same abundance but less bird diversity. SC was the habitat with least bird diversity.

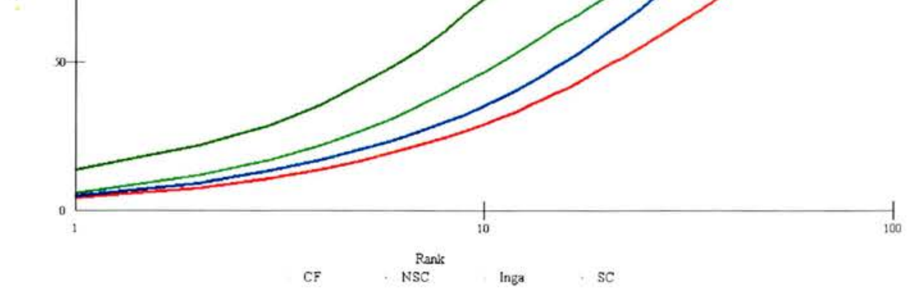

Figure 6.10 Diversity comparison between the four habitats using k-dominance plot with data recorded by mist nets at Barranca Grande. CF =cloud forest, NSC= natural shade coffee, *Inga*= *Inga* shade coffee, SC= sun coffee.

6.5.2. Species accumulation curves

Species accumulation curves were used to estimate the species richness of mist net captures. The species accumulation curves equations contain an asymptote and the asymptote becomes the estimated species richness of the community. Some non-parametric methods of accumulation curves were used to estimate the richness in each habitat (See methods and Chapter 5).

Data from captured birds suggest that at least 83 bird species were present at the four habitats (elevation from 1500m to 2000m).

Two non-parametric estimator (chaos and first-order Jacknife, See Methods, chapter 4) were used to obtain a richness estimation per habitat. In the four habitats the pattern was similar. The curve for observed species (Sobs) finished nearly equal than the Jacknife and Chaos curves, indicating that most species were recorded. It was estimated that 8 samples per habitat would provide enough data to record at least around 80% of the species (Figures 6.11).

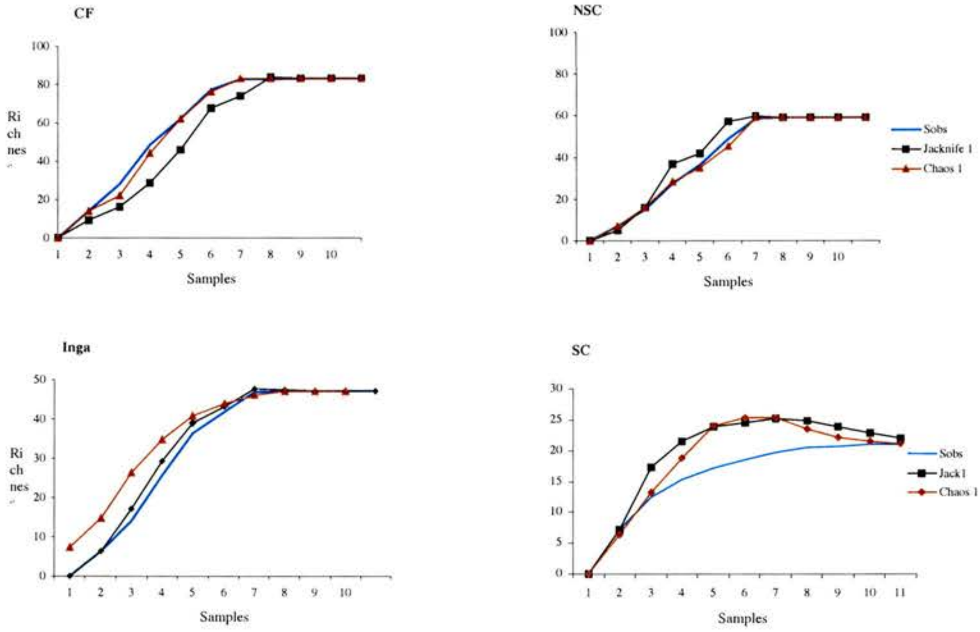

Figure 6.11 Species accumulation curves in the four habitats in Barranca Grande. CF= Cloud forest, NSC= Natural shade coffee, Inga= Inga shade coffee and SC= Sun coffee. Sobs is the number of species observed in the 10 sampled points, a non

6.5.3 Diversity index and similarity

The Shannon diversity index, showed that CF was the most diverse habitat, followed by NSC and Inga, whereas SC was the least diverse. Similarity in species abundance was evaluated by the evenness index (E). CF, NSC and Inga showed the highest evenness values, where the species had equal abundance (Table 6.6), According to the Sorensen index the highest similarity in species composition was showed by CF and NSC. The value showed by Inga (in relation with CF and NSC) was also high suggesting a certain similarity in species composition.

Table 6.6 Shannon diversity index (H'), Shannon evenness (E) and Sorensen index between pairs of the 4 habitats (number of shared species given in parentheses).

Habitat	Shannon diversity index (H')	Shannon evenness Index (E)	NSC	Inga	SC
CF	6.03	0.93	0.83(59)	0.72(47)	0.41(22)
NSC	5.58	0.76		0.75(40)	0.54(22)
Inga	5.16	0.71			0.63(22)
SC	4.18	0.55			

6.5.4. Ordination analysis

Detrended correspondence analysis was performed on bird species captured in the four habitats. CF showed low eigenvalues of 0.3016 and 0.1975. CF showed a close relation between nets and species, axes had the same length and had low variability. The species had the same distribution throughout the area, having just a few outliers, which are related to species close to the borders (Appendix XI).

6.6 Analysis of adults, juveniles and migratory species

6.6.1. Analysis of adults and juveniles

As in Chiapas, (in Veracruz) captures for adults and juveniles were successful with 5,366 captures, 3 690 adults and 1,676 juveniles (just resident birds were used for the analysis), over 8 months of 12 m net deployment (an average of 866 birds per month), a significant capture rate for the tropics. The habitat with most adult captures was CF (1,906 individuals). NSC recorded 1,004 adult individuals and Inga 754 (Figure 6.12). The most abundant adult species caught across CF were *Amazilia* *yucatanensis* (155), *Geotrygon montana* (145), and *Leptotila verreaux* (139). For NSC the most abundant species were *Campylopterus hemileucurus* (106), *Turdus grayi* (67) and *Basileuterus culicivorus* (56). For Inga *Amazilia yucatanensis* (107) dominated the captures, closely followed by *Pitangus sulphuratus* (95) and *Myiarchus tuberculifer* (86). In SC *Amazilia tzacatl* (5) was the species with most captures. There were differences between the number of species and individuals among the four habitats (CF, NSC and Inga. Kruskall Wallis; species: H = 36.42 DF = 3; individuals: 35.53 DF = 3, P<0.000).

For juveniles, there were also differences between habitats (Kruskal Wallis; species: H = 29.21, DF = 3; individuals: H= 31.65, DF 3, P<0.000). Inga was the habitat with the greater number of individuals (851, Figure 6.13). The species were *Myiarchus tuberculifer* (81), followed by *Amazilia yucatanensis* (77) and *Crotophaga sulcirostris* (72). CF presented the second greatest numbers of individual (623), and the most frequent species were *Basileuterus culicivorus* (60), *Xiphorhynchus flavigaster maculipectus* (45), and *Empidonax albigularis* (36). NSC showed lower numbers of individuals (168) than Inga and CF. *Geotrygon montana* was the species with highest numbers (49), followed by *Sayornis saya* (36) and *Cyanerpes cyaneus* (23). SC was the habitat with lowest numbers of species (34).

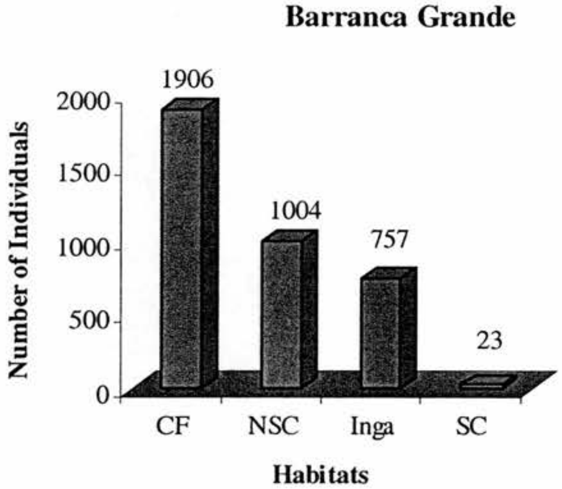

Figure 6.12 Numbers of adult individuals per habitat in Barranca Grande.

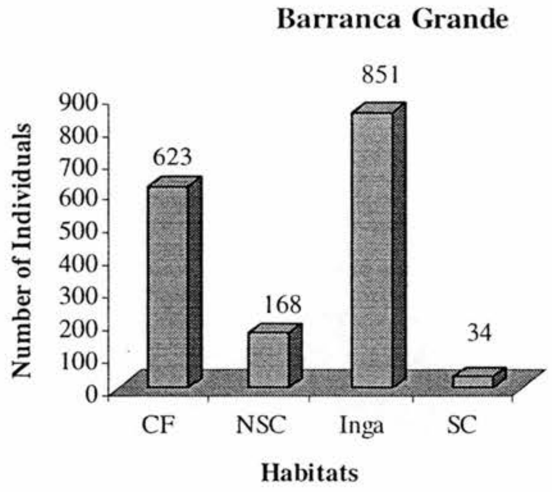

Figure 6.13 Numbers of juveniles individuals per habitat in Barranca Grande.

6.6.2. Similarity

A Bray-Curtis similarity for adults and juveniles was carried out using group-averages. The data used for the classification of species captured consisted of 10 samples and 83 species. The results are presented in a dendrogram (Figure 6.14).

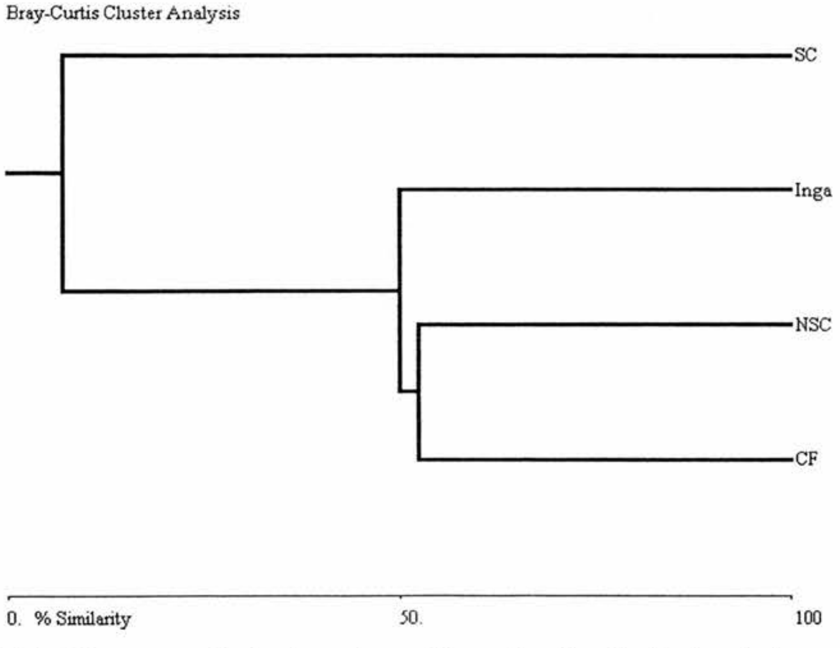

Figure 6.14 Cluster analysis based on Bray-Curtis similarity index of habitats surveyed at Barranca Grande. CF =cloud forest, NSC = natural shade coffee, Inga = Inga shade coffee and SC= sun coffee.

CF and NSC showed similar patterns for adults to that of the Chiapas sites, which represent similar habitats, while Inga is the nearest habitat outgroup with values higher than 50%. Sun Coffee was apart, and presented less similarity than (50%) with the other three habitats

The dendrogram for juveniles shows similarity between NSC and Inga habitats. Both habitats have a closer relationship to CF than SC. As in a cluster analysis for all the birds detected in point counts and mist nets, SC is the area with least relationship to the other habitats (Figure 6.15).

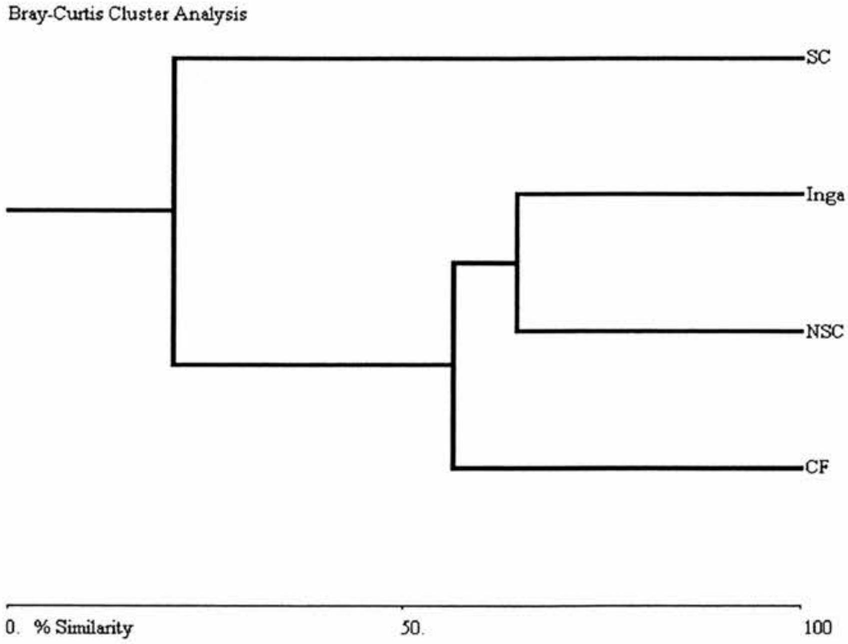

Fig 6.15 Cluster analysis based on Bray-Curtis analysis for juveniles in habitats surveyed at Barranca Grande. CF =cloud forest, NSC = natural shade coffee, Inga = Inga shade coffee and SC= sun coffee.

6.6.3. Analysis of migratory species

Migratory birds in the four habitats were surveyed in the period between November-April at the end of the season 2000-2001. The patterns were similar for CF, NSC and Inga. The contrasting number of species and individuals within each habitat type (Kruskal Wallis; species: H = 35.68, DF = 3; Individuals: H = 33.11, DF = 3, P<0.000) suggests different levels of heterogeneity. CF was the habitat with the greatest numbers of species (40) followed by NSC (32), while Inga (25) and SC had the lowest number of species (12). The most abundant species in CF in terms of individuals, were *Wilsonia pusilla, Mniotilta varia, Dumetella carolinensis, Empidonax minimus, Dendroica magnolia, Contopus cinereus* and, *Icteria virens.*

The habitat with the highest numbers of individuals was NSC (3,105 individuals, Figure 6.16). In this habitat *Empidonax minimus, Vermivora celata, Vermivora chrysoptera, Dendroica magnolia,* and *Mniotilta varia* were the most abundant species. In Inga, *Dendroica magnolia, Piranga rubra, Vermivora celata,* and *Dumetella carolinensis* were the species with most numbers of individuals. In SC the most abundant species were *Tyrannus vociferans, Vermivora celata* and *Contopus virens.*

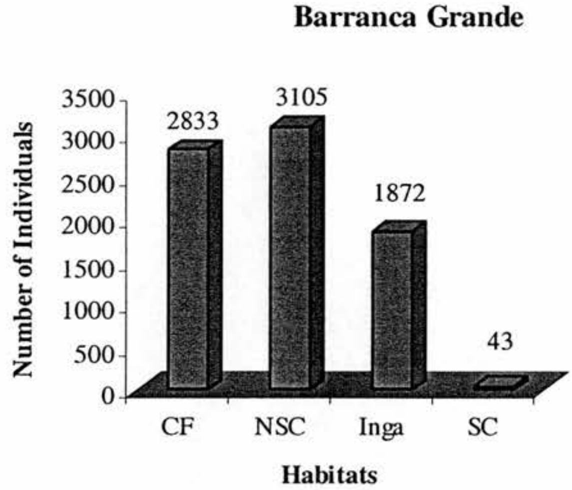

Figure 6.16 Total of individuals, for adults, juveniles and migratory species, per habitat in Barranca Grande.

In Barranca Grande migratory species showed similar patterns between Inga and NSC habitats. CF was closer to the latter habitats suggesting preference of the migratory species for places with trees (Figure 6.17).

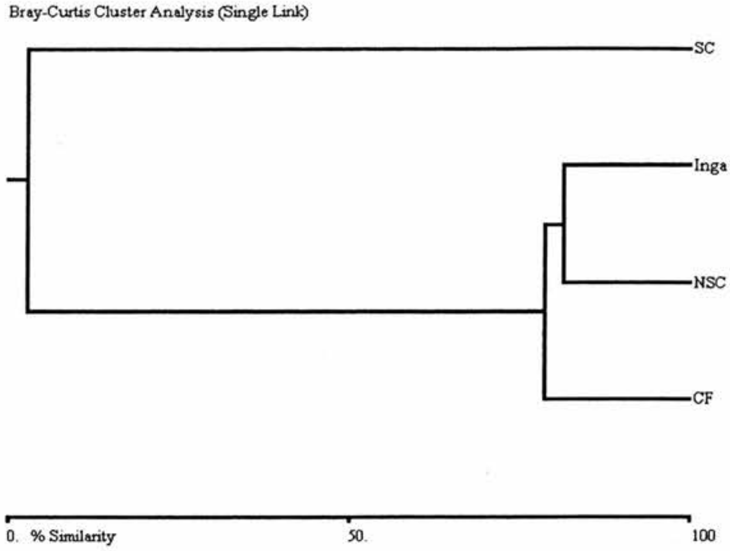

Figure 6.17 Cluster analysis based on the Bray-Curtis similarity index for migratory species in surveyed habitats at Barranca Grande. CF =cloud forest, NSC = natural shade coffee, Inga = Inga shade coffee and SC = sun coffee.

6.7 Trophic guild

The birds recorded by both methods: point counts and mists nets were classified in trophic guilds of dietary specialisation (for the full data set of species characteristics see Appendix XII). Omnivores were the largest category in terms of number of species but not in number of individuals. Predators had equal numbers to the previous category but with fewer species and more individuals. The primary consumer level gave fewer numbers of species and individuals (Figure 6.18). as in Chiapas the main bird food resources were insects, fruits and other invertebrates (Figure 6.19). *Melanerpes formicivorus*, *Chlorospingus ophthalmicus*, *Turdus assimilis*, and *Pitangus sulfuratus* were the most abundant omnivores in CF and NSC. In Inga *Myadestes obscurus, Dumetella carolinensis* and *Piranga rubra* had the highest numbers of individuals.

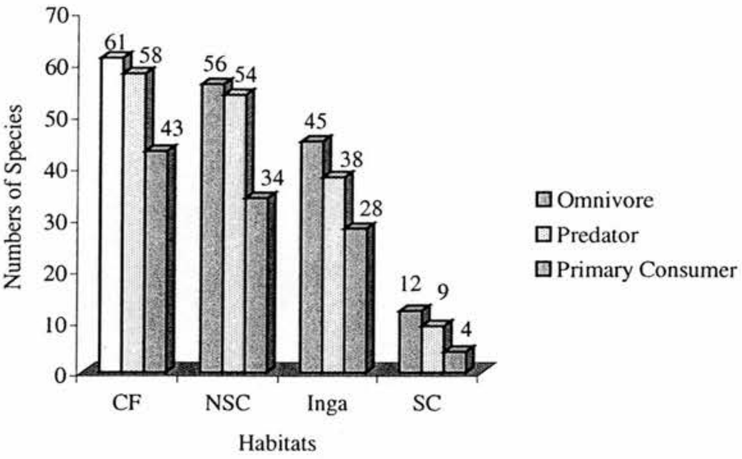

Figure 6.18 Distribution of bird species in categories of trophic guild for the four habitats at Barranca Grande.

SC had the smallest number of species, here *Pitangus sulphuratus* and *Megarynchus pitangus* were the most abundant omnivores. The most important species of generalist primary consumer were *Cyanerpes cyaneus*, *Dives dives*, *Columba fasciata*, *Leptoptila verreauxi*, *Geotrygon albifacies*, *Ortalis vetula* and *Leptotila jamaicensis*, recorded in CF and NSC.

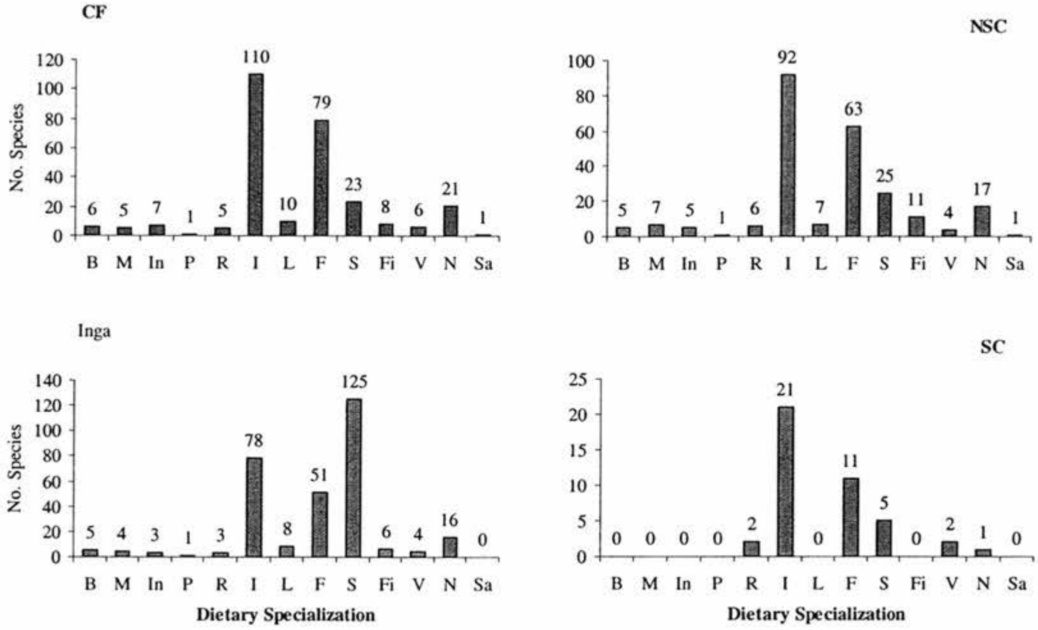

Figure 6.19 Bird dietary specialisation in the four habitats in Barranca Grande. CF = cloud forest, NSC = natural shade coffee, Inga = Inga coffee plantation and SC = sun coffee. See keys in Appendix I

All the trophic behaviour categories were registered in CF, Inga and NSC with a similar number of species. The gleaning arboreal insectivores guild was the category with greatest numbers of species 25 CF, 26 in NSC, 18 in Inga and 5 in SC species were recorded (Figure 6.20). The nectarivore-insectivore category had a similar number of species include all the species of hummingbirds. As in Chiapas the gleaning arboreal insectivore-frugivores were the third group recorded in the four habitats .

6.8 Use of forest strata

The use of forest strata showed similar patterns for the four habitats. As in Chiapas most of the bird species used all forest strata, but some species had a preference for one or two. Only *Dumetella carolinensis, Wilsonia pussilla, Icteria Virens* and *Carpodacus mexicanus* showed no preferences. The strata with the largest numbers of species and individuals was the midstory-canopy which presented similar numbers of species in all the habitats. The strata with least individuals was the understory, however in Inga the understory-midstory had only 9 species (Figure 6.21).

The most abundant species observed in the midstory, were *Wilsonia pussilla, Dendroica magnolia, Mniotilta varia, Dumetella carolinensis, Dendroica chrysoparia*, and *Regulus calendula*. In the canopy, the most important species in terms of number of individuals included *Melanerpes formicivorus*, *Cyanerpes cyaneus*, *Columba fasciata, Dendroica coronata,* and *Ortalis vetula*.

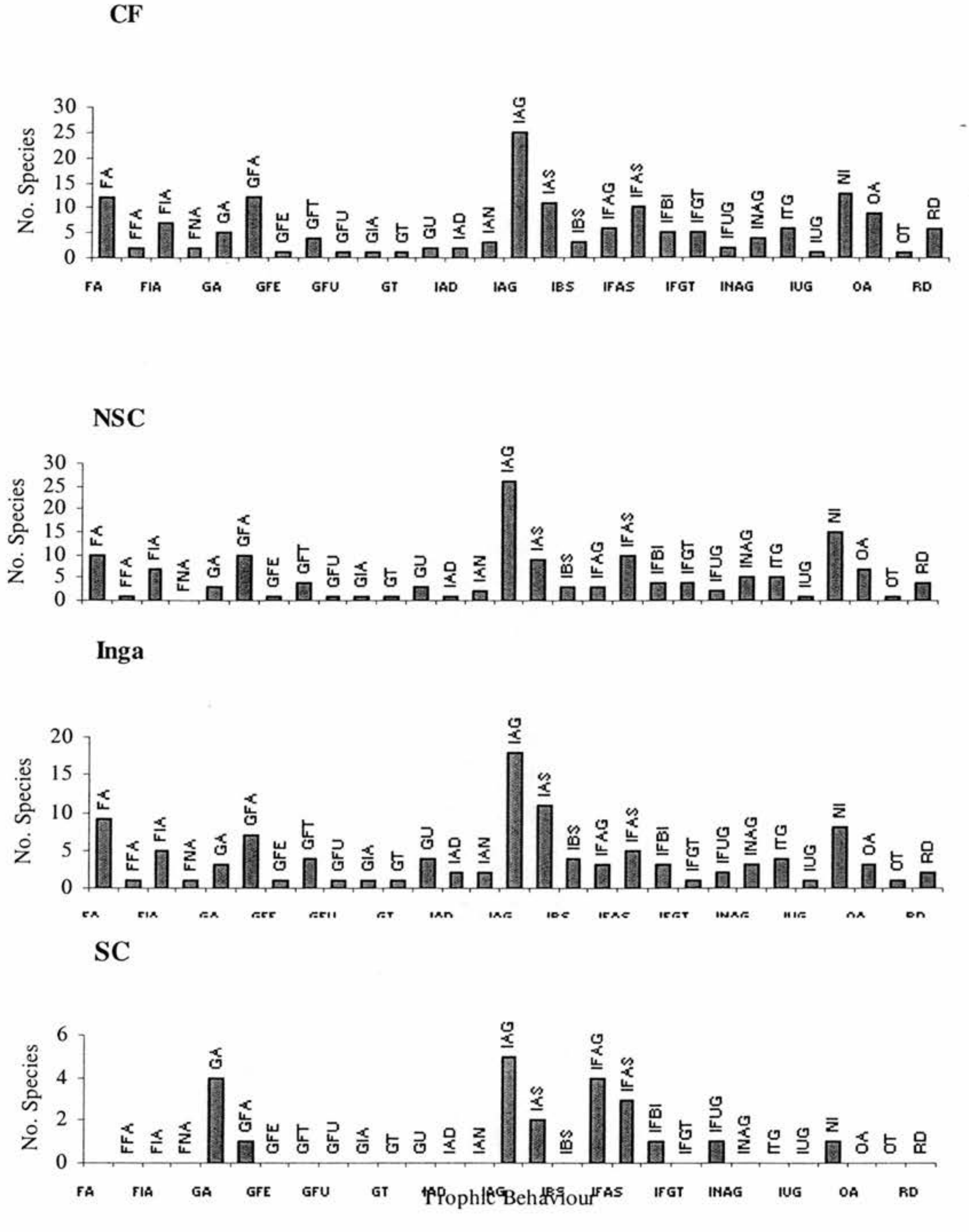

Figure 6.20 Distribution of bird species in categories of trophic-behaviour guilds. See keys to trophic-behaviour guilds in Appendix I.

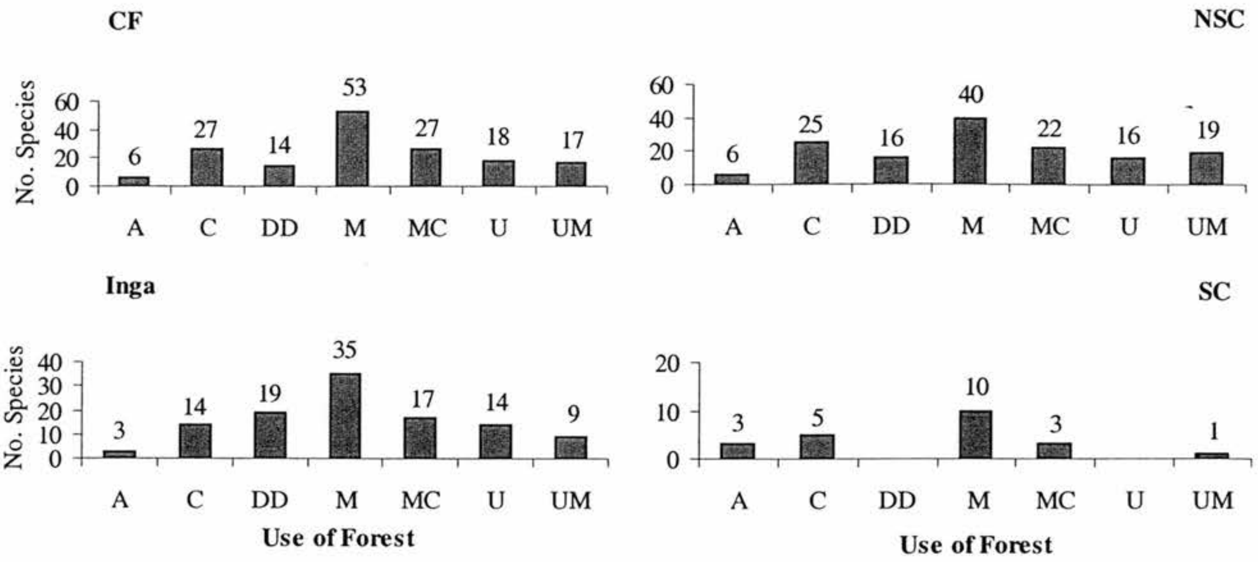

Figure 6.21 Distribution of bird species by number of individuals in the forest strata of Barranca Grande. CF= cloud forest, NSC= natural shade coffee, Inga= inga shade coffee and SC= sun coffee. A= all strata, C= canopy, DD= data deficient, M= midstory, M-C= midstory and canopy, NA= not applicable, U= understory, U-M= understory and midstory.

6.8.1. Restriction to forest interiors and natural shade coffee

In the CF, 69 forest birds were classified as a forest generalists, 44 as a restricted to the forest interior and 24 as border and transitional boundary species. In NSC a total of 55 species were classified as a forest generalists, 38 as a forest interior, 20 as a border and 15 in the vegetation surrounds (Figure 6.22). Inga was similar to NSC, with 32 forest interior species; 50 forest generalists, 24 border and 11 in the vegetation surrounding. SC had a total of 24 species which were classified as 13 forest generalists, 4 borders, 2 forest interior and 5 in surrounding vegetation. For the three main habitats (CF, NSC and Inga) the most common forest generalist species were *Catharus mexicanus, Columbina passerina, Momotus momota*, and *Melanrpes formicivorus*. Among forest interior species the most important were *Contopus virens, Thryotorus maculipectus, Wilsonia canadiensis,* and *Picoides scalaris*. *Turdus assimils* and *Amazila yucatanensis* were important border species.

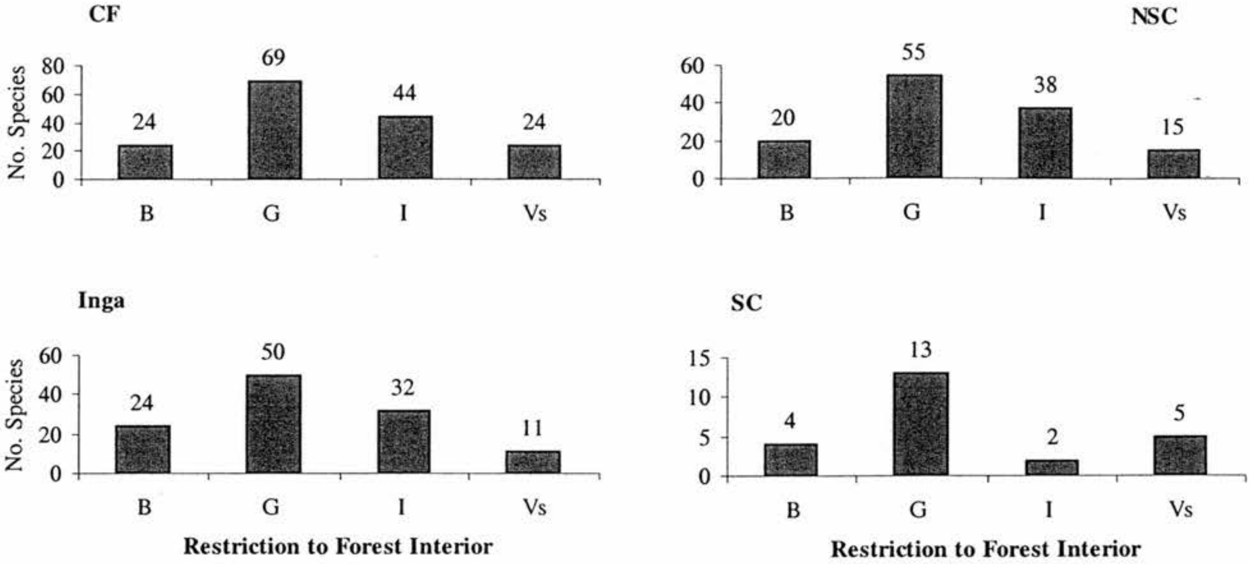

Figure 6.22 Distribution of the bird species according to their level of dependence on forest in the four habitats of Barranca Grande. B = border, G = forest generalist, I = forest interior and Vs = surrounding vegetation.

6.9 Distribution range

The four habitats of the study area represented the distribution limit for 11 species. Such species were *Aulacorhynchus prasinus, Geotrygon albifacies, Lampornis clemenciae, Xiphorhynchus erythropygius, Campylorhynchus gularis, Thryothorus maculipectus, Chlorospingus ophthalmicus, Habia fuscicauda, Atlapetes albinucha*, and *Atlapetes brunneinuchus* and *Attila spadiceus*.

6.10 Conservation status, endemicity and rarity

There were 12 species with some level of endemicity. 8 are endemic to middle America (*Dendrortyx barbatus, Geotrygon albifacies, Campylopterus curvipennis, Amazilia cyanocephala, Thraupis abbas, Phaethornis longuemareus, Campylopterus hemileucurus*, and *Atlapetes albinucha*); 6 are endemic to Mexico (*Dendrortyx barbatus, Arathinga holochlora, Atthis heloisa, Melanotis caerulescens, Geothlypis nelsoni, and Atalpetes albinucha*); and 1 has a restricted range (*Dendrortyx barbatus*).

Most of the species recorded were classified as rare or uncommon, because they were detected in less than 10% of the point counts. The other bird species were classified either as common (15-20), or fairly common (10-15%). These categories were used as in Chiapas in all the habitats. The most important common species in terms of number were *Columba fasciata*, and *Chlorospingus ophthalmicus*, and were recorded in three of the four habitats (CF, NSC and Inga).

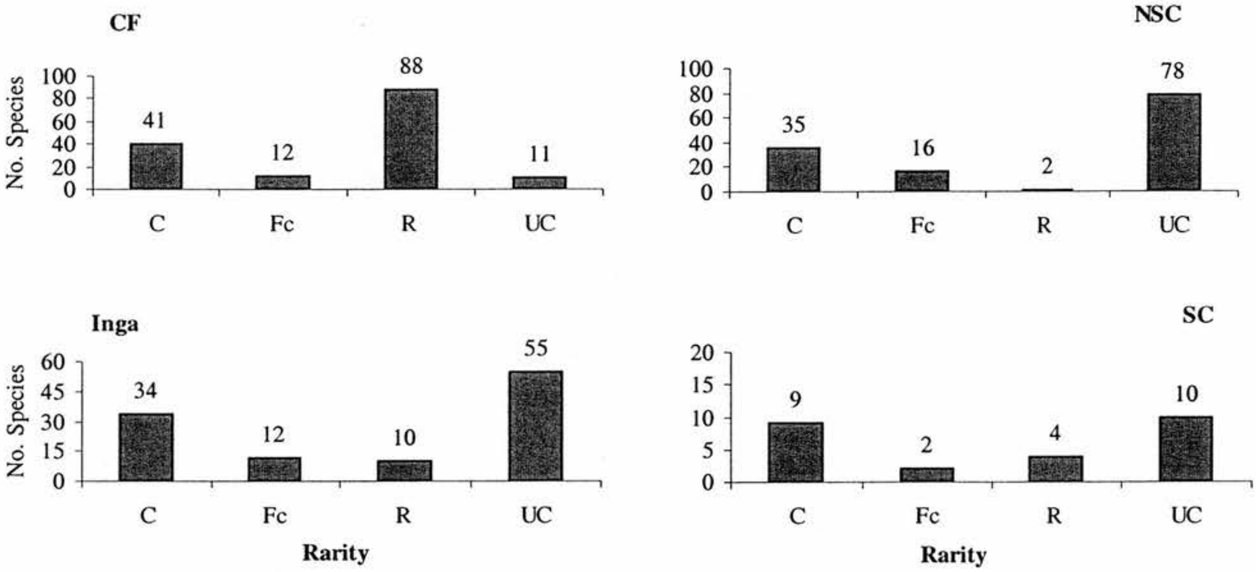

Figure 6.23 Distribution of the bird species based on their level of rarity in the four habitats in Barranca Grande.

The bird communities in the area included 10 species considered to be of conservation concern in Mexico by the Secretary in charge of the administration of natural resources (SEMARNAP 2001). Such species were *Dendrortyx barbatus*, *Aratinga holochlora*, *Pionus senilis*, *Glaucidium brasilianum*, *Atthis heloisa*, *Amazona albifrons*, *Aratinga nana*, *Bolborhynchus lineola*, *Melanotis caerulescens*, and *Icterus graduacauda*. It has to be pointed out that this list is currently under revision for the Secretaria del Medio Ambiente in Mexico.

6.11 Interpretation and preliminary discussion

This chapter has described and analysed the composition and relative abundance of bird communities in four habitats (CF, NSC, Inga and NS) located in Central Veracruz.

The habitats with the highest tree diversity and complexity structure were CF and NSC; the main difference between these two habitats is the substitution of the shrub layer by coffee plants NSC. The next habitat, in terms of complexity of vegetation structure, is Inga. Finally SC lacks trees.

Canopy cover and the level of complexity of vegetation structure (which is related to the number of strata) are important because they influence the species distribution through the different habitats. Most of the bird species were found concentrated in the midstory canopy. The vegetation structure is also important because it increases the availability of the sites for refuge and foraging.

The use of both methods increased the possibility of sampling most of the species. As in Chiapas, the areas with the highest biodiversity were the most conserved habitats (CF and NSC). These habitats were also similar in species composition, in terms of total species as in captured adults. Juveniles were not sharing the CF habitat with adults, both groups were captured together in NSC. However the highest density of juveniles was found in the Inga habitat. The positive relation between the patch size and diversity was stronger in CF and Inga. The numbers of migratory species was also similar between these three habitats; however the number of individuals was higher in the NSC.

In relation to the forest restriction, the pattern was similar to the areas in Chiapas. Forest interior species had a preference for unaltered habitats while the species classified as forest generalists had a higher density in the more disturbed habitats.

The study site in Veracruz can be considered more disturbed and consequently as less conserved than the study areas in Chiapas. In Barranca Grande the patches of coffee plantations and others crop (mainly sugar trees) are larger than the forest patches. However the shade coffee plantations, as a part of the landscape mosaic, provide the bird population with a buffer area around the forest, which is mainly used as a corridor with sites for foraging or shelter.

CHAPTER 7

Implications of Cloud Forest Transformation on the conservation of Bird Diversity: Discussion

7.1 Introduction

Human settlement and related activities, such as forestry and agriculture, have altered the natural landscape, resulting in a mosaic of fragmented habitats and this is clearly demonstrated on all the study sites of this research. The creation of habitat patches adversely affects the original flora and fauna and natural biodiversity can be indirectly affected by agroecosystems. On the other hand, highly productive agroecosystems in favourable areas can indirectly foster natural biodiversity by making it unnecessary to farm marginal or fragile areas, or to clear new forest areas for agriculture. In tropical countries natural biodiversity is often associated with the extent and quality of forested area (Pieri *et al.*, 1995). Yet the indirect links between agroecosystem productivity and sustainability and the conservation of habitats for natural biodiversity are important at a global level.

However, the human landscape may directly contribute to the extinction of species within habitat islands by slanting the ecosystem balance in favour of species that are highly adaptable to changing conditions. For example, the increased amount of human-dominated landscape allows certain species to grow phenomenally, which can result in harm to species that rely exclusively on forest interior habitats.

Tropical deforestation is considered to be one of the main factors contributing to observed population declines of both migrant and resident species. As in many areas of the Neotropics, the substitution of cloud forests by coffee plantations has increased in Southern Mexico. This kind of agroecosystem has been the traditional land use system in the study areas. Recent studies have shown that resident and migrant bird diversity and abundance is often very high in habitats that have suffered a moderate degree of disturbance. Yet over the last 20-25 years, human population growth has resulted in a higher land demand, which in turn results in higher rates of deforestation. Habitat mosaics that occur on a shorter cycle (as opposed to traditional 20-30 year cycle) dominate the landscape.

7.2 Objectives

This final chapter presents a synthesis of the findings of the study and explores some of resulting implications. It discusses the corresponding impacts of change in land use on understory bird populations. There were five principal aims:

- To assess the findings of chapters 5 and 6, which evaluate and compare the composition of the understory bird community in four different habitats of three study sites, assessing the bird species richness in each of the sites.
- To evaluate the ecological findings in terms of distribution of species occurring in the study. This focuses on a numbers of key indicators as trophic guilds, dietary specialisation, trophic-behavioural guilds, use of forest strata, level of restriction to cloud forest and natural shade coffee and its interior, distribution range, endemicity, resident/migratory status, level of rarity, and conservation status.
- To discuss patterns of distribution of adults and juveniles of resident and migratory species in the habitats of the study sites.
- To determine the effects of patch sizes, of the bird community in the three study areas, focusing on the habitat preferences.
- To identify potential conservation and forest management implications of the results.

The ecological findings of chapters 5 and 6 have demonstrated significant changes in bird species richness in habitat mosaics after changes in land use. The first aim will be addressed in this section while the others will be addressed later in this chapter. The original objective was, to describe and compare the composition of the understory bird community occurring in the cloud forest and the different types of coffee plantation (natural shade coffee, Inga shade coffee and sun coffee) within both study sites. This has been achieved by assessing the understory bird species detected and the bird species richness in each of the four surveyed habitats.

7.3 The effects of transformation of land use on understory birds

The data presented in chapters 5 and 6 show a clear pattern in the disturbance-induced modifications that have occurred in understory bird communities over a gradient of land uses. It is evident that clearance of natural forest has driven substantial changes in the species assemblage. The cloud forests of Southern Mexico have relatively rich bird communities. Although some species might have gone undetected, given the sampling methods used and the study period, the species richness of 287 represent a good proportion of the bird species observed in three sites within cloud forests in Mexico according to others studies. Escalona *et al.* (1995) reported 401 bird species, Greenberg *et al* (1997b) reported 250, and Tejeda (Pers Communication) 303 species within the cloud forest and coffee plantations in the South of Mexico see Figure 7.1. They suggested, however, that the reported species richness is not exhaustive, because some of the areas were not well sampled. Each species, or group of species, had its own reaction to forest disturbance according to differences in habitat selection, foraging behaviour and dietary specialisation (adaptability).

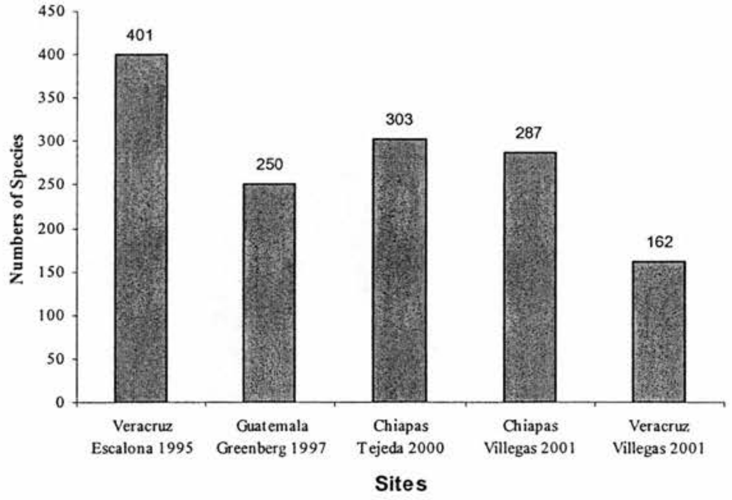

Figure 7.1 Comparison between others studies in numbers of bird species with the present study. (Villegas 2001 corresponds to the present study in Chiapas and Veracruz).

Birds (avian diversity) are a visible form of fauna, and they have captured substantial public interest. As a result, avian diversity has been the subject of greatest public awareness and more research attention regarding the impacts of coffee plantations on biodiversity than other forms of wildlife. Bird populations and diversity are also interconnected with less widely appreciated (but important) forms of biodiversity such as insect populations (an important food source for birds). Birds also have a vital role in pollination and plant dispersal. However, although there is evidence and ecological theory to suggest that bird numbers and biodiversity are higher in shaded coffee systems, especially in traditional systems, the hard data are remarkably scant, which demands caution in drawing conclusions.

Species richness and abundance in the study sites were found to change over the perturbation gradient while analysis of species composition revealed groupings of species by land use. A number of bird species appeared to have a ubiquitous distribution over the habitats with a few thriving at great abundance in coffee plantations. There were, however a number of species that were found in the CF and NSC but were absent in Inga and SC. This indicates that, in the absence of large areas of continuous natural forest, many keystone species like Horned Guan, *Oreophasis derbianus*, Great Curassow, *Crax rubra*, Resplendent Quetzal, *Pharomachrus mocinno*, and Highland Guan, *Penelopina nigra* species would be lost. However the available empirical literature and data from the present study suggest that shaded coffee, when produced by traditional coffee systems, supports a richness of bird species that is comparable to richness found in some natural forest.

7.3.1. Bird fauna in coffee plantations

Comparing the results obtained in this study with others in coffee plantations; Greenberg *et al.* (1997a) found 104 to 107 bird species in a commercial polyculture coffee system in Chiapas. Martínez and Peters (1996) found 136 to 184 bird species in traditional coffee plantations in Veracruz and Chiapas using just point counts. In comparison, more than 200 were founded in the two areas in Chiapas, and 144 found in Barranca Grande in this study using mist nets and point counts. (Figure 7.2)

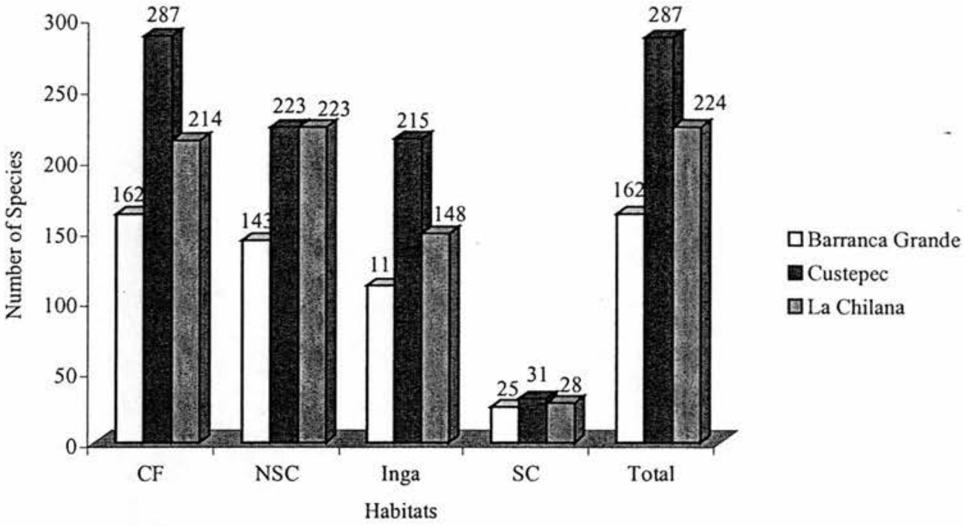

Figure 7.2 Number of species per habitat in each one of the study sites.

Aguilar-Ortiz in 1982 showed the bird species richness (136) of a traditional coffee plantations to be comparable to that of an adjacent remnant of cloud forest (138 species) near the site of the present study site in Central Veracruz. However the sample effort in the present research was greater than the 1982 study and also the combination of two survey techniques resulted a high richness in this area of central Veracruz (Figure 7.3).

The Migratory Bird Centre of the Smithsonian Institute has reported data on bird populations for coffee *fincas* in Peru. They studied unshaded plantations, shaded coffee monoculture and diverse shaded (traditional) coffee systems. Only 70 species of birds (mostly small seed-eating species common on agricultural land) were observed in unshaded plantations. Diversity was higher in shaded monoculture, where 170 bird species were observed, including species commonly found in light woodlands and secondary forests. In diverse shaded plantations they observed nearly 240 species, including some species normally found in original forests. Moguel and Toledo (1999) compiled findings from several sources and found that avian diversity in traditional shaded coffee systems was actually greater than in natural cloud forests, humid oak-pine forests, oak forests, and pine forests.

In the present study, in the three study sites, the number of species found in CF was higher than the number of species in the shade coffee. The reason for the differences in species numbers between the shaded coffee plantations results, may be because in the Moguel and Toledo study there was a presence and proximity of patches of tropical rain forest; by contrast, in the present study, there was just a mixture of CF fragments and coffee plantations.

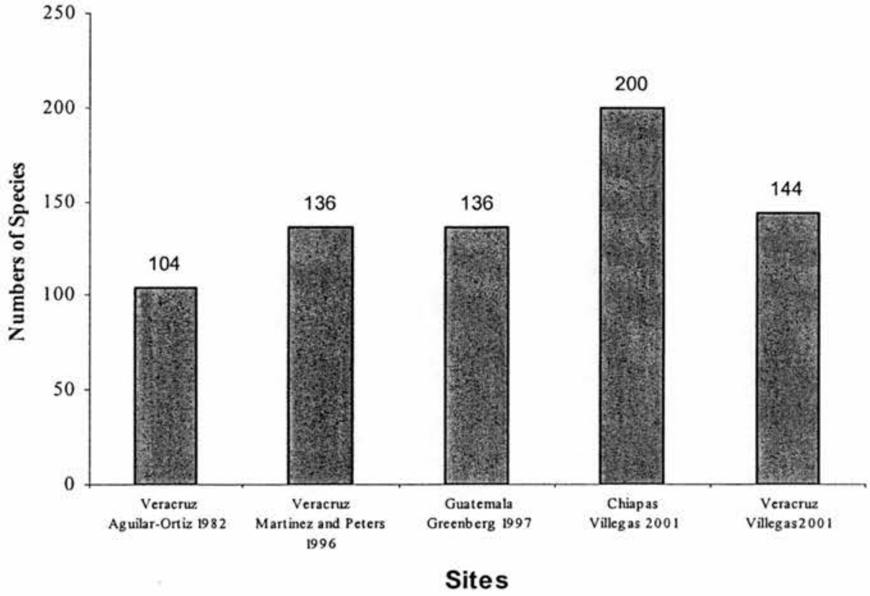

Figure 7.3 Comparison between other studies with the present study in number of bird species using shade coffee plantation. (Villegas 2001 corresponds to the present study in Chiapas and Veracruz).

Other published data also suggest that species richness drops dramatically in less shaded, and less diverse environments. Martínez and Peters (1996) found 50 bird species in a shaded monoculture environment and only 6 to 12 species in unshaded monoculture environments. Wunderle (1998), in a study evaluating the use birds make of different vegetative strata of 14 coffee plantations in the Dominican Republic, identified 24 species of birds, 19 of which he was able to observe well enough to establish adequate sample sizes. Of these 19 species, 13 were permanent residents, five were nearctic migrants, and one species was a neotropical migrant. Wunderle observed 18 of the 19 species foraging at median heights that were significantly above the median maximum height of the coffee plants. The shade overstory was an important foraging site for a vast majority of the birds. Eight of the 19 species foraged exclusively in the overstory or the canopy, but not in the coffee bushes.

In the present study, the *Inga* trees were a very popular foraging platform, being used by 85% of the birds observed. It was similar to the Dominican Republic study where Wunderle (1998) noted that *Inga* leaves act as hosts for a variety of invertebrates, including grasshoppers, lepidopteran larvae, spiders, beetles, butterflies, and microlepidoptera. These invertebrates are attracted away from coffee shrubs and other productive crops by the *Inga* leaves and themselves attract birds that prey on them. However, if chemical pesticides are used, insect numbers are lowered and the tree canopy will host lower numbers of birds.

Wunderle and Latta (1996) also found a significant negative correlation between median avian foraging height and abundance in sun coffee point counts. Thus, they concluded that birds that forage at a greater height in the vegetation are likely to be less abundant in unshaded coffee plantations. In the study areas the coffee plants themselves were relatively unpopular foraging platforms, probably because of the low insect infestation rates of coffee plants. In the 1996 study, Wunderle and Latta found invertebrate abundance levels in coffee plants to be three times lower than on native, moist broadleaf forest. Wunderle and Latta (1996) found that birds did not favour planted crops disproportionately in relation to their relative abundance in the plantations. In the present study in Barranca Grande, frugivores utilised citrus, avocado and guava trees, but only in direct proportion to their abundance on the plantation. This suggests that farmers can enhance a plantations attractiveness to birds by providing plant species that fruit and flower out of synchrony with each other, thus providing food resources for longer periods during the year.

Coffee compares in an intermediate manner to forest fragments in terms of providing diverse habitat for birds. Estrada *et al.* (1997) showed that pastures, followed by non-arboreal crops (jalapeño, corn and bananas) were the poorest habitats for bird species, when sample size was accounted for. The habitats showing greatest species diversity were the forests, followed by cocoa, coffee, live fence, mixed, citrus, and allspice. In comparison in the present study, natural shade coffee plantations were the most similar to natural habitats. These findings also offer evidence to support the argument that some agricultural habitats offer improved habitat and resource alternatives for birds. Comparison of species richness between agroecosystems and undisturbed forest has also been carried out with other taxa, such as mammals, reptiles and insects. Some of these studies have supported the findings with birds. Gallina *et al.* (1996) studied how changes in the arboreal strata affect different guilds of mammals and stressed the conviction that biodiversity is not necessarily incompatible with a productive coffee system. The same study identified the following mammal species on four coffee plantations in Xalapa, Veracruz: 4 marsupials, 2 edentata, 1 rabbit, 4 large and midsize rodents, and 13 carnivores. The vegetation in four coffee plantations was also analysed and determined that mammal diversity increases with the diversity or complexity of the vegetation. Samples one and four showed the most complexity, and sample three showed the least complexity. So it may be a suggested that the pattern of birdlife is complementary to other animal life but at lesser level of biodiversity.

Gallina *et al.* (1996) added that a diverse coffee agrosystem is an important habitat alternative for mammals. The shade coffee agrosystem is one of the few productive systems capable of sustaining a highly diverse mammalian and bird community, in spite of the transformation of the original vegetation, by maintaining arboreal strata for the coffee shade, thus providing good sources of food, shelter, nests, and protection for the birds. The 1996 results and the present study results note further that, not only is the vegetation structure important, but also the "patchiness of the habitat," that is to say the variations in vegetation and topography of the environment. Thus, the more variety the habitat offers, the greater animal species diversity it can support.

Given the diversity of the cloud forest and coffee plantations in Mexico and the logistical complications of fieldwork in some cloud forest localities, bird studies in different habitat types are still far from complete. More comprehensive studies of the bird communities of the coffee plantations would undoubtedly result in further species recorded. It is important to stress that a comprehensive study of a bird community has to include an array of survey methods, which take into account the diversity of social systems, home ranges, patchiness, seasonality, and degrees of detectability of the tropical bird fauna (Terborgh *et al.*, 1990; Robinson *et al.*, 2000). Due to the geographical position of the cloud forest and coffee plantation studies, this bird community included species of tropical affinity (Thicket Tinamou, *Crypturellus cinnamomeus*, Brown jay, *Cyanocorax morio*), species of boreal affinity (American Tree-Creeper, *Certhia americana*), and species typical of the cloud forest and from middle elevation habitats, (Horned Guan, *Oreophasis derbianus,* Resplandencent quetzal*, Pharomachrus mocinno* , and Great Curassow, *Crax Rubra*) a pattern reflected in other studies (Navarro 1992; Escalona *et al.*, 1995).

Given the history of the anthropogenic impact on the cloud forest and its further habitat mosaics in the study areas, it would not be surprising if some species are close to being locally extinct (*e.g.* Kattan *et al.*, 1994). Therefore, the bird community in the present study, even in the largest forest fragments, might not strictly represent the original pool of bird species. However, given the spatial scale of this research, this does not detract from conclusions being reached on the effects of habitat mosaics on the bird communities in southern Mexico.

Results of the present research and other studies (e.g. Greenberg *et al.*, 1997a) demonstrate that shade coffee plantations can vary greatly in their suitability as habitat for birds. The majority of birds found in the Greenberg study were characteristic of forest edge, second-growth, semi-open areas, plantations, and other disturbed habitats (Howell and Webb, 1995). In the present study birds typical of cloud forest were less common but, when present, typically were more abundant on the traditional shade coffee plantations (e.g. Ochre-bellied Flycatcher, *Mionectes oleagineus,* White-breasted Wood-Wren, *Henicorhina leucosticta*). Many of the 13 species that were never observed on the Inga in Custepec (e.g. Collared Trogon, *Trogon collaris*, Emerald Toucanet *Aulacorhynchus pras inus*, Ruddy Foliage-gleaner *Automolus rubiginosus,* Highland Guan *Penelopina nigra*, Horned Guan *Oreophasis derbianus*,) are typically found in Cloud Forest suggesting that NSC may provide a more suitable alternative habitat for such birds than does Inga.

Although this study was based on three different sites, the results probably apply more broadly. First, the three *fincas* (Custepec, La Chilana and Barranca Grande) are representative of others in the region (Veracruz and Chiapas), in terms of type of plantation, and management. Second, the fincas in Chiapas are adjacent to each other and have similar elevation to the *finca* in Veracruz and also are surrounded by the same landscapes. Thus, differences between the *fincas* are not confounded by differences in elevation (Greenberg *et al.*, 1997a) or surrounding habitat. The results were consistent over time (between and within seasons) and are consistent with other studies (e.g. Wunderle and Latta, 1996; Greenberg *et al.* 1997a, b) that have demonstrated increased abundance and diversity of birds on structurally more complex agroforestry systems. Finally the three coffee *fincas* included in this study used different management practices (use of chemicals, planting and pruning of shade trees, etc.) that affected the structural and floristic diversity of the vegetation (i.e. shade trees, epiphytes). These differences in vegetation probably account for much of the difference in bird abundance and diversity between the *fincas* and also are likely to influence the overall biological diversity in the three systems (Perfecto *et al.*, 1996). Several aspects of the plantation systems were particularly important influences on diversity. Agricultural habitats can provide important alternative habitats for many species when natural habitats are lost (Rappole and Warner, 1980; Vannini, 1994; Schelhas and Greenberg, 1996). The NSC habitats included in this study had a greater abundance and diversity of shade trees, more epiphytes, and were more heterogeneous in distribution of foliage than the more uniform in Inga. Differences in both floristic and structural diversity of the vegetation probably contributed to the greater abundance (twice as many birds) and diversity (e.g. birds of Cloud Forest) of birds on the NSC. Inga, the most important shade tree on the three plantations, provides resources (food) for a variety of birds (Wunderle and Latta, 1996; Greenberg *et al.* 1997b) and probably attracts many birds to shade coffee plantations.

As a corollary, the habitat with most species richness was CF mainly because it contained a more complex structure with many strata, that provide food, refuges against predators, and nest places for the birds. The second habitat was NSF with similar structural complexity to that of CF, in contrast with SC that presents just lower layers.

Cloud Forest	>	Natural Shade Coffee	>	Inga Shade Coffee	>	Sun Coffee

Figure 7.4 Ranking of bird species richness over a gradient of disturbance.

7.4 Species area relationships

In the present study, the linear regression between number of species and patch area that was observed is inconsistent with the assumption of the equilibrium theory of island biogeography that diversity is independent of area. On other hand Cohen (1998) suggests that patch area, on average, accounts for approximately 10% of the variation in the population size and diversity of bird, a moderate to small effect. Furthermore, the tendency for population size of individual species to be higher in larger rather than smaller areas suggests that density compensation is not a uniform phenomenon.

The slightly positive regression between number of species and area, observed in the present study, may possibly be biased. Nevertheless there are several lines of reasoning for arguing that biased estimation of effect sizes is unlikely to account entirely for the patterns observed in this research. Firstly, the methods used to discover studies that report data on the relationship between bird population and patch area are unbiased, for individual species (Begg, 1994; Greenhouse and Iyengar, 1994). For faunas, the absence in the literature of studies with both small sample sizes and small effect sizes suggests that a bias exists against publishing statistically non-significant values of the correlation between faunal density and area. Consequently, the selection of all published studies, regardless of sample size, taxa, or the nature of the habitat patch, should be a sufficient guard against unforeseen bias. Secondly, for studies of birds based on point counts, the radius of detection of many species may be greater than the radius of small patches. Therefore, the region sampled, a circle determined by the location of the sample point and a species radius of detection, may not be entirely forested.

As a result, there might be a tendency to underestimate densities on small patches, generating a positive bias in estimates of the correlation between bird population and patch area (Haila 1988; Haila *et al.*, 1993). Even in studies such as those of Haila (1981, 1983) and Haila *et al.* (1983, 1987), in which density estimates were made using transects that covered the entire area of small patches, correlations between population and patch area remained positive.

Thirdly, a large proportion of the effect size estimates obtained in the present study was based on point count and mist nets methods that rely on detecting singing birds. If there is a systematic bias for particular bird species, or species in general, to be more or less detectable as a function of patch area, then the patterns reported could simply reflect such a bias. However, the literature suggests that point counts tend to underestimate abundance, which means that the detectability of calling or singing birds does not always depend on patch area (Connor and Mc Coy 1979; McShea and Rappole *et al.* 1998).

Fourthly, Haila (1988) also indicated that, because small patches contain more species that forage in regions outside the putative habitat patch than do large patches, density estimates that do not account for this additional foraging area tend to be overestimates. Therefore, Haila (1988) claimed that the null hypothesis for the relationship between size and patch area should be negative, Haila's argument would imply that the effect sizes found in this research might be underestimates.

Fifth, the repeatability of estimates within species in both the sign of the correlation and its magnitude suggests that the effect sizes estimated are largely attributes of each species rather than idiosyncratic measures heavily dependent on site characteristics and study methodology. The high repeatability observed also argues that it is unlikely that non-independence of species within studies could account for this study result, since similar estimates of effect sizes were obtained regardless of the species composition of the fauna in which a species was embedded.

Finally, after excluding the studies by Engbring and Ramsey (1989) and Engbring *et al.* (1986, 1990) that have average patch areas at least two to three orders of magnitude greater than all other studies, no effect of spatial scale was observed in which a study is performed on the correlation between bird population and patch area for species. This result also supports the contention that the size effect estimates in this study are not systematically biased. In contrast, Bowers and Matter (1997) conclude that for mammals, density-area relationships are scale dependent, tending to be negative at small spatial scales. On the other hand, the coefficient of variation in patch areas within this study was positively related to the correlation between population size and area. This indicates that variation in the magnitude of the correlation (r) is partly due to the idiosyncrasies of individual studies.

The overall positive regression between bird population size and patch area could arise from a number of mechanistic explanations acting individually or in concert, and the mechanisms may differ among species. Predation risk may be higher on small patches, keeping the densities of prey populations low (Denno *et al.*, 1981; Ambuel and Temple, 1988; Askins *et al.*, 1987; Rolstad and Wegge, 1987; Moller, 1988, 1991; Paton, 1994), or animals may be less likely to disperse from large patches, keeping densities high (Raupp and Denno, 1979; Foster and Gaines, 1991). Habitat quality could be positively correlated with patch area, permitting higher density populations to persist (Ambuel and Temple, 1983; 1988; 1991, 1995, Raupp and Denno, 1979; Denno *et al.*, 1981; Moller, 1991, 1996). Andren (1994) found that positive correlations between density and patch area were more likely to occur in patch systems embedded in highly fragmented landscapes. Evidence is mounting that the movement hypothesis may explain the positive correlation between population density and patch area (Risch, 1981; Kareiva, 1983; Foster and Gaines, 1991). A better understanding of the mechanistic causes of the observed overall positive correlation between bird population density and patch area requires further field studies designed to test the potential role of these alternative mechanisms. In a fragmented landscape the presence of patches with vegetation structure inside the mosaic (which may be natural forest or natural shade coffee plantations) is important, because they facilitate the movement of birds between patches, increasing the number of bird species in the patches with the highest area. These patches provide more choices of food and shelter than the small ones.

A substantial difference among sites was observed between population diversity and area. On average, bird diversity displayed a large positive regression with area see figure 5.6 and 6.5. The average effect size for Custepec is considerably less than that for La Chilana and Barranca Grande. The results parallel those reported by Bowers and Matter (1997) in their review of density area and relationships in mammals. However, small vertebrate and invertebrate groups show varying patterns between population size of individuals species and area occupied. Foster and Gaines (1991) suggest that at least for small mammals, greater numbers of individuals establish and hold territories on large patches, resulting in lower population densities on large than on small patches. Presumably, small mammal populations on small patches are composed of a greater proportion of transient or sub-adult individuals that are nonterritorial, hence permitting greater numbers of individuals to coexist temporarily on small patches (Dooley and Bowers, 1996).

Alternatively, mammals may have a greater tendency than insects and birds to use resources outside their putative habitat patches (Laurance 1990). Such resources would be more abundant and accessible near small patches because of their greater perimeter-to-area ratio (Dooley and Bowers, 1996). Mammalian studies show smaller coefficients of variation in patch areas and smaller effect sizes than do birds or insects. All of these explanations could account for the low average effect size observed for mammals. The results do not appear to parallel those reported by Schoener (1986) for spiders and lizards on Bahamian islands. Schoener reported higher positive correlation between the abundance of several lizard species and island area than for several species of spiders. But, when expressed as population densities (abundance divided by island area), rather than abundance, correlation for all species, both lizards and spiders, were negative. On the other hand, Diamond (1975) and Jaenike (1978) also found that the correlation between population density and patch area was positive, on average, for birds and insects. Bender *et al.* (1998) performed a meta-analysis of the relationship between animal population density and patch area for species of birds, mammals, and insects. Their study focused on assessing the effect of habitat loss on population density at different spatial scales and in regions with differing proportions of suitable habitat. They report somewhat different effect sizes for each taxon, but these differences can be attributed to their smaller data set (n = 98 species for Bender *et al.*, 1998), in contrast with the large data set of the present study (n= 287 species).

Finally, if a goal of biological conservation is to maintain populations of individual species that are at least larger than some minimum viable population size, the observation that bird populations are, on average, positively correlated with patch area, argues that a single large nature preserve is more likely to achieve this goal than several small preserves of equal total area. For bird species, the correlation between population and patch area was observed to be independent of the overall density of the species, which suggests that rare or uncommon species are as likely to have high positive correlation as are more abundant species. However, the high variability in effect size estimates among species within taxa, combined with the considerable repeatability in effect sizes was estimated within species, argues that the area dependence of the population density of individual species also varies considerably among species. As a result, the mean effect size within taxa will be an inadequate representation of the effect size for any particular species. Therefore, which conservation strategy is most effective will depend on the biology of the species in question, on the sign and magnitude of the correlation between its population density and area, and on many other biological and practical considerations.

7.5 Trophic guilds on the habitat mosaic

The data presented in Chapter 5 and 6 show the impacts in the distributions of trophic guilds within habitats. The original research objective addressed in this section was to evaluate the ecological findings, in terms of distribution of species occurring in the study areas, by trophic guilds. In this study, as in others, for example Johns (1992), the relative frequency of trophic groups in the perturbed habitats (in this case coffee plantations) is a better indicator of the disturbance-habitat mosaic regime. In the coffee plantation habitat studied, the impact of the environmental conditions on the understory is more pronounced when the canopy is located farther from the ground in perturbed and regenerated areas. In the understory of the natural and Inga coffee patches, the insectivorous birds activity increases as regeneration proceeds, which is explained by their physiological and ecological links with the forest interior (Orians, 1969; Karr and Freemark, 1983). In Custepec, La Chilana and Barranca Grande, most ant-followers try to avoid perturbed areas and were more common in forest patches. However they have been found using coffee plantations (NSC and Inga), being especially sensitive to changes in the landscape. Bierregaard (1990) and Johns (1992) also found the same preference for less perturbed areas.

Canopy insectivorous birds showed greater variation in the use of lower strata in the forest and coffee patches for the three habitats and can also be used as indicators of regeneration of habitats. In Barranca Grande, some birds of the family Tyrannidae (common and more diverse in disturbed patches; Johns, 1992) were captured mainly in NSC, and a few were present in the CF patches. In La Chilana and Custepec this group was equal common in all the habitats except sun coffee. Even less sensitive to anthropogenic disturbance are the gleaning insectivores. In this study (in the three sites) they were more frequently captured in shade coffee plantations (NSC and Inga) than in CF patches. At Manu some of these species captured in the regenerating fields were encountered mainly in forest patches habitats (Robinson and Terborgh, 1990). This is apparently an artifact of the limited portion of the vegetation profile that is sampled by ground level mist nets.

Frugivores represent 20% of the species at Custepec, 23% la Chilana and the 15% in Barranca Grande. These are higher values compared to other studies in Central America (17.2% at La Selva; Blake *et al.*, 1990), Panama (15.2 %; Karr 1982), Colombian Amazon (10%; Andrade and Rubio-Torgler, 1994), and Peru (14% at Manu; Robinson and Terborgh, 1990). The higher abundance of the frugivores depends on the fruit of small plants of the Melastomataceae family, which are associated with perturbed habitats (Levey, 1988; Thiollay, 1992). This may result from the high occurrence of coffee plantations in those areas occupied in Barranca Grande 50 years before, in La Chilana 5 years early and Custepec more than 90 years before this study began. Their higher abundance in the forest may also be an artifact of placing some undestory nets near the forest edge. Small frugivores, however, seemed more common in these study areas than in large patches of forest.

In the present research nectarivorous birds were caught in the forest understory patches. In Custepec and La Chilana they were more frequently caught in coffee plantation patches (NSC and Inga) due the abundance of clumps of *Heliconia*. The *Heliconia* species are always slightly related and are more abundant in secondary habitats. The relative scarcity of nectarivores in Barranca Grande, is probably due to the lower productivity of undisturbed cloud forest and understory (Gentry and Emmons, 1987). Granivores may indicate severe large-scale disturbance in the forest ecosystems because of their dependence on grasses. Their slight presence in CF patches mist netting captures at La Chilana and Custepec suggests that even under high intensity disturbance regimes such as agroecosystems, the small scale of disturbance does not allow invasion of these species. By contrast, granivores were very common in mist net samples in Barranca Grande.

7.5.1 More common trophic guilds

For the three study areas, the bird individuals were concentrated in bird species feeding on insects and fruits (53%) and seeds and fruits (29%). The differences in the guild structure of these bird communities suggest that the bird communities in the cloud forest and coffee plantations contain fewer specialised birds. In a tropical forest of north-east India (Raman *et al.*, 1998), the species richness in specialised guilds such as frugivores, bark-feeders, and canopy insectivores, increased with increasing forest successional age. In contrast, omnivores did not show any pattern in their study. The low importance of specialised species in the habitat mosaics of the south of Mexico might be the result of the historical occurrence of human disturbance (going back several thousand years). This disturbance might have favoured species making use of a wider range of resources at the expense of specialised species.

Vegetation structure and the types and availability of food resources strongly influence the guild structure of a community (May, 1982; Holmes and Recher, 1986; Borges and Stouffer, 1999). In general, bird species that include insects as an important item in their food constitute the predominant group in the bird community of the three areas studied here. In particular, bird species feeding mainly on fruits and insects were found to be the most important in terms of their contribution to the relative abundance and number of individuals of the community.

If the trophic guild is further categorised by feeding behaviour strategy, the gleaning arboreal insectivores constitute the most important guild by number of species. The guilds with the largest number of individuals detected were the arboreal frugivore-insectivores and the gleaning arboreal insectivore-frugivores. The arboreal and the terrestrial granivore-frugivores were also important guilds within the bird community in terms of number of individuals. Although there were significantly fewer understory insectivores in small patches, the microclimate hypothesis, which states that sedentary understory insectivores react more unfavorably to microclimate fluctuations in forest patches than more mobile species that are frequently exposed to different microclimates, was not tested by the present observations.

With respect to the habitat specificity, some understory insectivorous species may have disappeared from patches because of the reduction or disappearance of some critical habitat elements, such as army ant swarms. However, the small patches where sometimes army ant swarms were observed, were also lacking army ant-following bird species, and a number of bird species missing from small fragments feed on invertebrate resources that were not significantly different between forest and patches sites. Thus, this habitat specificity is tentatively rejected because the presence of some birds species may depend on the patch size alone.

Dispersal, crucial in the colonisation of habitat islands, may be the key mechanism that makes it more likely that small and short-lived bird species will go extinct as a result of habitat fragmentation compared with large and long-lived species. Likewise, the limited dispersal capabilities of understory insectivores may be the most important factor in their sensitivity to habitat mosaics. At the study sites, the presence of a bird species in the coffee plantations around forest patches appeared to be, from field observations only, the best determinant of its occurrence in smaller patches. If verified statistically, this would be in agreement with the limited dispersal hypothesis. In Custepec, 15 insectivorous species were caught significantly more times than in la Chilana and Barranca Grande patches. Thus the ability to move through and possibly forage in other habitats around forest patches may link small populations that would otherwise be isolated and vulnerable to edge effects and stochastic events. This mobility may greatly enhance effects and thus improve the survival chances of forest-dependent organisms in forest fragments, as has been observed in previous studies (Stouffer and Bierregaard, 1995; Paton, 1994). In addition, forest bird species frequently detected in the matrix surrounding forest fragments are also likely to be more tolerant of ecological changes in patches, such as those resulting from edge effects, and may be more capable of occasionally foraging and even nesting in shade coffee habitats near patches.

Although forest fragmentation and other forms of habitat disturbance may reduce the breeding success of most forest bird species, possibly as a result of increased nest predation of all species, more sedentary species may be less able than other birds to commute through nonforest from their breeding territories to small patches containing sufficient resources. Such regular commuting from nesting areas to foraging areas that are unsuitable for nesting has been observed in frugivorous bats in Mexican lowland tropical forest fragments (M. Evelyn, unpublished data). Increased mobility increases the chances of renesting in patches of shade coffee if conditions become more favorable, making it less likely that more fragile species will become locally extinct. In addition, forest bird species that are likely to move through nonforest habitats are more likely to use those habitats occasionally for foraging and nesting, mitigating the effects of fragmentation. More research comparing the movement, foraging, and breeding patterns of understory insectivores and other guilds in both forest patches of various sizes and in shade coffee plantations is needed to reveal the actual mechanisms of the disappearance of understory insectivores. Meanwhile, better integration of agricultural/human-dominated habitats into conservation strategies, such as linking forest fragments with shade coffee plantations, may make deforested areas more hospitable to understory insectivores and other fragmentation-sensitive groups by enabling them to disperse between forest fragments and prevent local extinction.

7.6 Use of forest strata, level of restriction to forest interior and conservation status

The findings in the previous chapters have demonstrated that marked changes occurred in the bird species assemblages and in their habitat preferences. The original research objective for this section was to assess the composition of the understory bird community occurring in the four different habitats, in terms of distribution of species by: use of forest strata; level of restriction to cloud forest and its interior; distribution range; endemicity; level of rarity and conservation status.

7.6.1 Use of forest strata and restriction to forest

The midstory included the largest number of bird species, but in general the use of forest strata by birds was distributed in terms of the number of species and individuals in the main types of habitats in the three areas. In an undisturbed tropical forest, most of the primary productivity occurs in the canopy (Medellín and Equihua, 1998). Therefore, a larger numbers of species would be expected to occur in the upper strata of the forest. The distribution of the bird species in the forest strata might suggest that productivity is concentrated in the upper middle of the forest. Based on this idea and in spite of the historical and present levels of disturbance occurring in the cloud forest from the three areas, it might still be possible to find preserved features of a primary forest in disturbed areas.

Forest interior and generalist birds were more numerous in terms of number of species, but in terms of relative abundance, forest generalist and forest border birds were far more important than forest interior. The predominance of forest generalist species occurring in these forest habitats might be a response of the bird community to a regime of forest perturbation, where species making use of a wider range of habitats (coffee plantation) are favoured over habitat-restricted species, such as forest interior or forest border species. Furthermore, the historical fragmentation of cloud forest may have reduced the extent of interior forest, directly affecting those bird species depending on forest interior habitats.

Several species restricted to the cloud forests of southern and southeastern Mexico were detected in this study, restricted to or using preferentially the cloud forest and NSC. The species include: *Penelopina nigra* (Highland Guan), *Bolborhynchus lineola* (Barred Parakeet), *Abeillia abeillei* (Emerald-chinned Hummingbird), the *Eupherusa* Hummingbirds, *Lampornis viridipallens* (Green-throated Mountain-gem), *Pharomachrus mocinno* (Resplendent Quetzal), *Crax rubra* (Crax Guan), *Oreophasis derbianus* (Horned Guan) *Anabacerthia variegaticeps* (Scaly-throated Foliage-gleaner), and *Chlorophonia occipitalis* (Blue-crowned Chlorophonia). Even when these species are characteristic of forest interior, some of them were recorded in the NSC habitat.

The estimated density in large patches (in CF and NSC habitats) was higher in the forest interior than the edge. In contrast, in small patches there was no difference in the estimated density between interior and edge. This may be simply a result of sampling methods combined with differences in the proportion of habitat that is classified as edge, interior-edge, or forest interior on small vs. large patches. Forest-interior and interior-edge habitats constitute a larger proportion of habitat in large patches, and forest-edge habitat constitutes a smaller proportion of habitat in large patches. The change in the abundance of each habitat as a function of patch area, combined with the fact that point counts are usually conducted either in the centre or at least some minimum distance from the forest edge, could result in a greater proportion of the habitat sampled in large patches being forest-interior habitat and a smaller proportion being forest-edge habitat. In turn this could lead to higher estimates of the density of forest-interior and lower estimates for forest-edge species on large patches.

7.6.2. Distribution range and conservation issues

In Chiapas, there were several species at the edge of their altitudinal ranges, this may be due a change in the landscape as a result of the recent meteorological events in the area (Hurricane Mitch). The populations of a bird species occurring at the edge of its geographic and/or altitudinal distribution range found in this research are the populations that ultimately affect the distribution range of the species. This means that, the expansion or contraction of the distribution range of a species is highly dependent on the dynamics of the populations living at the edge of the distribution range. Howe (1984), and Kattan *et al.* (1994) have reported that bird species occurring at the edge of their distribution range are more vulnerable to fragmentation.

Rarity

Rare species consisted of birds that have low population levels. In this study, such species included 3 raptors, 4 cracids, 2 woodpeckers, 2 trogons (*Dendrortyx barabtus*, *Columba flavirostris*, *Geotrygon montana*, *Pionus senilis*, *Ciccaba virgata*, *Momotus momota*, *Aulacorhynchus prasinus*, and *Pteroglosus torquatus)*. Some rare species in CF and NSC were common in Inga. These species included all the 22 species associated with secondary growth, plus a few others that are known to inhabit the lowland tropical rain forest preferentially, and its associated secondary growth (*e.g. Chloroceryle americana*, *Pitangus sulphuratus*, *Cyanocitta formosa*, Brown Jay, *Cyanocorax morio*, American Tree-Creeper, *Certhia americana*, Canyon Wren, *Catherpes mexicanus*, White-collared Seedeater, *Sporophila torqueola*, Yellow-faced Grassquit, *Tiaris olivacea*). Summer visitors (which became rare because their preferred habitat is elsewhere), and transient species were also rare within the study areas. If those birds that are large for their guilds (and thus, likely to exist at low population densities) are considered as truly rare species, such species constituted about 21% (34/290) of the bird community in these areas, a similar proportion to the Amazonian mature floodplain forest (10%) studied by Terborgh *et al.* (1990). These bird species can be considered as rare and merit special attention in conservation planning, because rarity has been acknowledged as a predictor of vulnerability and a precursor to extinction (Terborgh *et al.* 1990).

The level of rarity found in the bird communities of the study areas (72%) was higher than the levels of rarity reported in studies in the cloud forest of the Centra Cordillera l of Colombia, in Northeastern of Hidalgo and in an Amazonian mature floodplain forest. In the Colombian cloud forest, 34% (92/273) of the bird species were considered rare in terms of abundance (Kattan, 1992), in the Amazonian floodplain forest, 42% (134/319) of the bird species were considered as rare (Terborgh *et al.*,1990), in Northeastern of Hidalgo (Martinez, 2001) 60% of these species were rare. However the proportion of rare species in the cloud forest studied was similar to the proportion (68%) reported for the Atlantic forest (Goerck, 1997).

The influence of bird species living more commonly in coffee plantations on the high level of rarity in these bird communities might mean that the high level of rarity reflects levels of perturbation in the cloud forest. Alternatively, the influence on rarity of bird species preferentially using the lowland tropical rain forest, as well as the influence of some migrants, might well be the result of the geographical location of this cloud forest. In other words a high level of rarity may be an inherent feature of bird communities in the cloud forest.

Conservation status and endemicity

About 12% of the bird species recorded are considered of conservation concern by the Secretary in charge of the administration of natural resources in Mexico. Some of the listed species, are considered only because they are endemic to Mexico, such as Bumblebee Hummingbird, *Atthis heloisa* and Blue Mockingbird, *Melanotis caerulescens*. However, the population parameters for these species estimated by this study, suggests some of these species might be excluded from the list of species of conservation concern. The populations of these Mexican endemics attained densities of more than 38 birds/km^2, which can be considered a relatively high density by Neotropical standards.

In general endemicity is important in Mexico, the bird species richness has been estimated at about 1074 species, with 107 endemic to the country (Escalante *et al.*, 1998). According to the results, in Chiapas the level of endemicity was higher than in Veracruz. This endemicity is explained because the intermix of two biogeographic regions (Neartic and Neotropical) and the complex topography of the region. The area with a large number of endemic species are called "biodiversity hotspot" (Goerk,1997), it is important to take it into consideration for plans in order to maintain the most biological diversity in the area.

7.7 Resident and migratory species

In this section the aims are to evaluate the ecological finding in terms of patterns of distribution of resident and migratory species occurring in the different habitats of the study sites. Results from cluster analysis suggest that CF and NSC, were the habitats with greatest similarity in composition of migratory species, followed closely by Inga. The differences may be related to the species detectability. On the other hand, similarity in species composition between the three main habitats (CF, NSC, Inga) explain the non preferences of the migratory birds for particular habitats in the study areas. Results of this and other studies (Calvo and Blake 1998; Greenberg, *et al.* 1997a; Greenberg, *et al.* 1997b) demonstrate that shaded coffee plantations provide habitats for some forest residents and migrants. Some migrant species preferred secondary habitats (coffee plantations) to primary forest stands. Primary ecosystems were found to be important for endemic species, in the case of cloud forest, and forest specialists (Table 7.1). The number of birds per point was related to seasonality and habitat type.

Table 7.1 Differences in habitat preference between migratory and resident species.

Species	CF	NSC	Inga	SC
Migratory	✔	✔	✔	✗
Resident/endemic	✔	✔	✗	✗

Inga had fewer species numbers of forest specialists compared with NSC and CF. A great number of bird species observed in Inga shade coffee were typical of disturbed areas (Howell and Webb 1995). However natural shade coffee showed a great similarity with cloud forest in both sites in Chiapas. These results suggest that these two habitats were similar in diversity, species composition and mean bird abundances. This pattern is opposite to the findings of Greenberg (1997b) who found that planted shade and traditional coffee (natural shade coffee) in eastern Chiapas had the greatest similarity in the number and abundance of bird species, which was higher, compared with primary forest. The apparent difference from the present study is possibly related to the highly patchy distribution of natural shade coffee plantations in the three sites. Coffee plantations are part of a mosaic of different-aged stands of cloud forest. Coffee patches are often less than 1ha in size, surrounded by cloud forest, which may increase the chance of recording forest species in the coffee stands.

Resident bird species dominated the bird communities within the study areas, a situation that might have been influenced by the census period (although the survey period did include several months of the winter migratory season, October to

December, in all three areas). This evidence suggests that, despite not covering the entire period for wintering species, a large proportion of Neotropical migrant species were detected. A judging by the proportion reported in other cloud forest localities in Mexico (Hutto, 1992; Villaseñor and Hutto, 1995; Escalona *et al.*, 1995; Gram and Faaborg, 1997). For instance, in this research 17% (48/290) of the bird species detected were Neotropical migrants (winter visitors or transient migrants), whereas in El Cielo Biosphere Reserve in the Eastern Sierra Madre, Gram and Faaborg (1997) reported a proportion of 22% (15/69) of migrant species. Of the species they detected in El Cielo, all of them were detected in the habitats in Barranca Grande in Veracruz.

In relation to pattern of distribution for adults and juveniles, the results in the 3 study areas suggest that juveniles are occupying perturbed areas instead of natural forest. The reason for this habitat selection could be explained because adults are establishing in the cloud forest thus Juveniles have to move to the surrounding territories. However, the duration of this study was only one and half year and this is not enough time to take this assumption.

7.7.1. Migratory species

Analysis of the seasonal patterns of occurrence of Neotropical migrants in the study area provided evidence of the importance of the study areas as a wintering site. For some winter visitors, such as Wilson's Warbler, *Wilsonia pusilla*, Yellow-rumped Warbler, *Dendroica coronata*, and Townsend's Warbler, *D. townsendi*, the region appears to be an important wintering ground, as suggested by the high abundance of individuals detected. However, although some winter visitors may be abundant in the region, a larger proportion of individuals seem to prefer more southern wintering grounds, as suggested by the significant influx of individuals into the study area as the spring migration approached, presumably of individuals that wintered further south, moving northwards during the spring migration. Such species included Wilson's Warbler, *W. pusilla*, Black-throated Green Warbler, *Dendroica virens*, Black-and-white Warbler, *Mniotilta varia*, Blue-grey Gnatcatcher, *Polioptila caerulea*, Nashville Warbler, *Vermivora ruficapilla*, Blue-headed Vireo, *Vireo solitarius*, Hermit Warbler, *Dendroica occidentalis*, and Yellow-bellied Sapsucker, *Sphyrapicus varius*, in order of abundance. On the other hand, in species such as Ruby-crowned Kinglet, *R. calendula*, Yellow-rumped Warbler, *Dendroica coronata*, and Townsend's Warbler, *D. townsendi*, the lack of an increase in their abundance during the spring migration might well be due to the use of a different migration route (trans-Gulf migration) by the populations wintering south of the study area, particularly in the case of Yellow-rumped Warbler, *D. coronata* and Townsend's Warbler, *D. townsendi*. In the case of Ruby-crowned Kinglet, *R. calendula*, since the study area is located close to the southern most wintering distribution of the species, no important increase in abundance would be expected during the spring migration in the study area.

Most Neotropical migrants are quite flexible in their choice of winter habitat, and can occupy regions that are only marginally used by the forest birds that breed in the tropics. Although migrant birds fit into a smaller geographical range in winter, their needs are fewer. Free from the constraints of breeding that tie them down in summer, they need only find sufficient food for the day, and avoid predation. Migratory songbirds heavily use disturbed habitats, such as pastures with scattered trees and in particularly those coffee plantations that grow coffee shrubs in the shade of tall trees, like in the study areas of this research. Neotropical migrants may be less sensitive to habitat degradation in pristine tropical forests than to the quality of habitat available to them in the more disturbed landscapes of the Neotropics, such as pastures, agricultural fields, and coffee plantations. In this case, the best way to sustain populations of many migrant songbirds in the tropics may be to encourage the development of shaded plantations, as opposed to other methods of coffee cultivation, and the preservation of wooded stream corridors in agricultural landscapes, which would also help water quality. Cloud forests need to be conserved, but perhaps with more attention on the habitat requirements of residents for breeding and nesting, than for winter migrants.

Migratory bird select habitats non-randomly during migration (Moore *et al.*, 1990; Hutto, 1995; Winker, 1995). Evidence suggests habitat quality (and hence availability of food resources) as the basis of this habitat selectivity (Simons *et al.*, 2000). Some studies have also suggested that the energetic status of birds, sex-age class of birds, and predation risk play an important role in habitat selection during migration stopover (Moore and Aborn, 2000; Woodrey, 2000; Petit, 2000).

The fact that migratory species showed an irregular use of habitats and that they had low relative abundance might suggest that the cloud forests of those regions are not very important for migratory birds, or alternatively, that the areas have become unimportant for such species due to fragmentation and habitat mosaics. Transient migrants seemed not to be forest dependent because they used the largest continuous vegetation or agroecosystems and they all appeared not to be restricted to the forest interior in the present research study areas. Askins *et al.* (1992) showed evidence that a decrease in the use of moist forest by winter visitors, in two adjacent islands in the U.S. Virgin Islands, was due to degradation and destruction of forest. Similarly, Rappole *et al.* (1992) suggested that deforestation of tropical forests has reduced the abundance of some Neotropical migrants in the wintering grounds.

7.8 Sampling techniques: point counts and mist-net

The use of population size as a measure of the health of a species has been a very common tool of ornithologists for many years (Lack, 1954, 1966; Hutchinson, 1978). Methods for surveying population size are detailed in Ralph and Scott (1981), the excellent compendium by Cooperrider and others (1986), and the manual by Koskimies and Vaisanen (1991). Many types of counting techniques are available to estimate relative abundance and population trends. Probably the most widely used are modifications of unlimited distance point counts (Blondel and others 1981), conducted at a series of counting stations. These often represent the best compromise between economy of collection effort and precision and accuracy of the estimates of population trends or population indeces (Verner 1985).

Points counts and mist nets were a good combination of techniques for detecting richness in habitat in this study because the areas were occupied by a wide variety of birds, including a number of Neotropical migrants that have exhibited population declines in central North America or throughout their range (DeGraaf and Rappole, 1995), such as yellow-billed cuckoo (*Coccyzus americanus*), Bell's vireo, ovenbird, common yellowthroat, and orchard oriole.

The rate of captures using mist nets for the present study, in the three study sites, was successful. The three areas presented higher captures rates of individuals and species within habitat patches in natural forest and shade coffee plantations. This pattern seems to be general in tropical forest areas (Levey, 1988; Bierregaard, 1990; Blake *et al.*, 1990; Johns, 1992), presumably due to high species movements between habitats and not necessarily to a higher number of specialized edge species in each site. In this research there were some differences in capture rates and avifaunal composition between the habitats. Custepec and La Chilana were similar in composition and rate of captures, in contrast Barranca Grande was different because it presented less numbers of captures and mainly those species of perturbed areas.

An important proportion of species, reported for the whole study, was captured in the coffee plantation forming a habitat mosaic (62 species, 54%). Out of the total sampled, 23 species were found only in coffee plantations. This figure is higher than the Colombian Amazon (47%; Andrade and Rubio-Torgler, 1994), Manu (32%; Terborgh, 1986), Para in Brasil (42%; Novaes, 1980), Guatemala (40%; Greenberg, 1997), and Dominican Republic (36%; Wanderle, *et al.* 2000). This finding may due to the fact that, even though coffee cultivation suffers high intensity disturbance, more birds used these patches because they are intersperesed with natural forest patches.

The abundance of some typical birds of secondary growth suggests that small scale coffee plantation patches provide enough suitable habitat for invader species. The doves *Columbina spp.*, were present in the samples in this study, and *Crotophaga sulcirostris* and *Cyanocorax inca* were not as abundant in Custepec and La Chilana as in Barranca Grande where the species are more common. Similarly the avifauna of the secondary vegetation at Custepec and La Chilana is less rich in species than in Barranca Grande. The results suggests that the presence of invader birds (birds that show preference for perturbed areas) in great numbers in Barranca Grande is indicative of the presence a high proportion of perturbed areas in contrast with Custepec and La Chilana which were surrounded by large patches of continuous forest and are localised in the buffer zone of a Biosphere Reserve.

7.8.1. Advantages of the use of both techniques

The most common method of collecting demographic data is capturing birds with constant effort mist nets and point count techniques, these methods can often be modified to better survey cryptic or uncommon birds. The use of standardised methods will enable comparisons with other studies. The quality of the data, however, is at least as important, and depends upon the continued dedication and training of the observers, cooperation of various agencies and investigators, and the rapid and accurate compilation of results. Mist-net capture data result a good estimates (estimates with small bias) of adult and juvenile survival, provided that transients and non-transients can be distinguished. In the absence of any distinction between these two classes, survival estimates will be substantially biased. The double-capture criterion (two or more captures in the same breeding season, at least 7 days apart) appears to be a good means to make this distinction. However that was not developed in depth in the present study because it was for a year and half period of capture and for demographic studies a long term period is needed.

The present study includes few comparisons with tropical studies in the analyses (only 4 studies). These studies also sample bird species abundance by two methods that combine point counts and mist nets, as the present study, while most of the temperate and boreal studies of birds used point count or mist net methods (Bond, 1957; Haila, 1981, 1983; Haila *et al.,* 1983, 1987; Askins *et al,*. 1987; Blake and Karr,1987; Moller 1987).

Point counts and mist nets were used for this study but both have biases as sampling methods for avian communities (Bibby *et al.*, 1992; Remsen and Good, 1996; Rappole *et al.*, 1998). Remsen and Good (1996) argued that constant-effort mist net sampling protocols do not allow comparison of relative abundance of species from capture data because of many confounding variables such as differences among species in net avoidance, proportion of territorial individuals and floaters, vertical distributions within the habitat, and flight frequencies or distances. Point counts also have some drawbacks as measures of abundance because they tend to miss or underestimate certain species, particularly those with low densities or secretive, skulking habits (Bibby *et al.* 1992, Rappole *et al.* 1998).

The combination of techniques provides consistency between studies and researchers that would like to use point counts during the breeding season to track population trends or determine associations between birds and their habitats. The purpose of using both techniques in this study was to develop the components of point count methodology sufficiently to: (1) provide trend data for monitoring population changes; and (2) predict population responses to habitat manipulations. Population trends from lands managed by government agencies will permit agency-specific evaluations of population health and status. Point count data that can be associated with habitat measures can be pooled across many programmes to test hypotheses regarding bird-habitat relationships (e.g., Ruggiero and Thomas, 1991) and to validate existing bird-habitat models. Comparisons of bird-habitat relationships across different regions require the use of standardised collection techniques. Managers who are using point counts to develop bird-habitat models are willing to use standardised techniques. Point count methodology has applicability in seasons, climates, and circumstances beyond those we discuss. Point counts have been used in both the tropics and temperate areas to monitor wintering migrants (Hutto *et al.*, 1986; Blake, 1992). Point count methodology is applied in Latin America, but sometimes needs modifications. For example, in hot weather and in the non-breeding season, detectability declines more rapidly during the course of the day.

Another technique very popular is spot mapping, which is arguably considered the most accurate measure of avian density, but it is time and labour intensive relative to point counts (Bibby *et al.*, 1992; Dobkin and Rich, 1998). Several studies have compared spot mapping and point counts as measures of avian species richness, relative abundance, and density (DeSante, 1981, 1986; Szaro and Jakle 1982; Dobkin and Rich, 1998). Generally, these studies have found that point counts produce errors in actual density estimates, but that with repeated visits, point counts provide acceptable measures of species richness and relative abundance, with lower effort than spot mapping. Dobkin and Rich (1998) recommended fixed-radius point counts with at least two visits per site for breeding season surveys and their study, as well as that of Szaro and Jakle (1982). Finally, Rappole *et al.* (1998) found that weaknesses of point count and mist net sampling methods each tended to be offset by strengths of the other method, so that a combination of the two methods provided a more reliable assessment of the avian community than either method did alone.

In this study, abundance was calculated from points count from all detections of 25 m or less from the observer. Such measurement of density is standard for point counts (Reynolds *et al.*, 1980) but, because birds move into the count area from outside during the count period, the effective distance sampled is unknown and therefore, absolute density cannot be accurately calculated and these birds were not included (Hutto *et al.*, 1986). Thus, these density estimates are in reality another measure of relative abundance. Abundance measures in this study were in general agreement (between the two sampling techniques), at least for the more common species. Nevertheless, the most common species in point counts for the three areas and in all the habitats in this study were in the majority of cases also the most commonly captured species.

Sometimes, however, abundance measures differed greatly between point counts and mist net sampling. For example, Blue-gray Gnatcatcher, *Polioptila caerulea*, Streaked Flycatcher, *Myodynastes maculatus*, ovenbirds, *Seiurus aurocapillus*, and common yellowthroats, *Geothlypis trichas* were more commonly captured than expected based on their abundance from point counts. Low abundance on point counts relative to capture rates may be due to secretive or skulking habits, in the case of ovenbirds and common yellowthroats. Several species that were not captured in mist nets were relatively common in point counts. These included red-bellied woodpeckers, eastern kingbirds, song sparrows, common grackles, and red-winged blackbirds. Several other species were also rarely captured, although they were relatively common in point counts. These species included eastern wood-pewee, *Contopus virens*, cedar waxwing, *Bombycilla cedrorum*, indigo bunting, *Passerina cyanea*, brown-headed cowbird, *Molothrus ater*, orchard oriole, *Icterus spurius*, and Baltimore oriole, *Icterus galbula*. These rarely captured species tend to remain high in the canopy or are associated with adjacent marshy or forested habitats that were not sampled with mist nets in this research.

Although differences in methods confound direct comparison, overall avian species richness and abundance in this study compare favourably to species richness and/or abundance measures from Kansas floodplain forests (Zimmerman and Tatschl, 1975) and from different successional forest stages in Illinois (Karr, 1968), Arkansas (Shugart and James, 1973), South Carolina (Buffington *et al.*, 1997), Massachusetts (Swift *et al.*, 1984), and Nova Scotia (Morgan and Freedman, 1986; Zimmerman and Tatschl, 1975). In the tropics Greenberg (1997a), Bierregaard and Stouffer (1997), Estrada *et al* (1994), and Kattan *et al* (1994) studied the composition of birds using different techniques and found that avian abundance was higher using a combination of techniques than just one. Those studies, along with the current study, suggest the interesting possibility that avian abundance, and perhaps species richness, may be higher in successional stages (habitat mosaic) than in more mature forests. The relationship between change of land use and avian species richness and abundance along the cloud forest in the South of Mexico merits further investigation, particularly in light of the declining availability of early successional habitats (Hesse 1996).

It is argued that the use of several techniques, rather than providing redundant and duplicated information, offers complementary information that would not otherwise be available. An example of the power of a multi-level, integrated approach is the ability to track abundance of non-breeders (floaters). Point counts can potentially track the number of breeders, but floaters are an important component of avian demography, yet are hard to observe in the field due to their secretive nature. Mist-netting allowed us to track the total number of adults (whether breeding or not), but by itself could not tell us which were breeders. Putting both together (total adult abundance and breeder abundance) allows inference about non-breeder abundance.

7.9 Management perspectives

In regions where deforestation has drastically affected original forests, coffee agroecosystems, mainly natural shade coffee, may be the best alternative for bird conservation. Moreover, coffee plantations can operate as conservation sites complementary to protected areas (Moguel and Toledo, 1999). This is the case of El Triunfo Biosphere reserve where the buffer zone presents extensive coffee plantations, which undoubtedly are playing an important role as faunal refuges and contributing to maintaining regional ecological processes. No buffer zone comparable to Chiapas exist in Veracruz.

However, the benefits of coffee cultivation to the conservation of biodiversity can not be fully understood without clear notions on the role of this ecosystem on single species population (e.g. demographic patterns, populations dynamics); and at landscape level (e.g. size and shape of plantations, distance to forest). Concern has recently emerged about the inability of commercial and highly manipulated plantations to sustain native flora and fauna. Without the food and shelter that overstory trees can provide, many organisms avoid coffee plantations. Traditional plantations typically support many species that provide a multi-stratal canopy (Moguel and Toledo, 1999). Also, various wild type herbs and shrubs densely populate the forest floor. Biotic diversity is vastly greater in shade than sun plantations. For example: Nestel *et al.* (1993) identified almost twice as many macro-Coleoptera; Perfecto and Snelling (1995) noticed more foraging ants, and Perfecto *et al.* (1997) recorded more beetles, ants and non-formicid hymenopterans in shaded systems. Wunderle and Latta (1998) witnessed fewer birds foraging in modern than shade plantations and Greenberg *et al.* (1997) observed more birds in shaded sites and that those birds resided in the overstory.

From the database and observations on the use of different types of habitat by different species, it is suggested that disturbance patches such as shade coffee plantations embedded in a large forest areas increase overall diversity by allowing forest species to use these disturbed patches and coexist with open habitat species. Although Inga communities locally have a smaller habitat structural complexity than NSC and CF patches (due to fewer vegetation layers and lianas), they increase habitat heterogeneity at the landscape scale by drastically modifying the otherwise continuous forest structure with a changed use land. The fact that nearly all forest bird species were also present in the shade coffee patches agrees with Malcolm (1991) and Greenberg (1997b). The observations of this study show that there were very few bird species specialising in primary forest. This agrees with the study of Greenberg (1997), in suggesting that most small birds seem to be adapted in general to secondary forests or to ecosystems with relatively high disturbance rates.

However, we must be aware of the fact that many opportunistic species depend on the forest for their long-term survival (Medellin and Redford, 1992). Diversity seems to be promoted by a small numbers of patches up to 2 ha in area. In these areas, primary productivity is brought to ground level making additional resources available to those understory birds that are normally restricted to using the few resources produced on the ground. A follow up study is necessary to look at actual resource availability and use in forest, open habitats and oldfields; and to pursue studies analysing the bird diversity and community structure in the larger (> 200 ha) coffee plantations habitats.

The idea of controlled agricultural activities is ecologically risky because of the difficulty in implementing adequate control over land use. However, if properly regulated, a scheme of agricultural patches within an overall forest matrix may also serve as an important element to maintain good relations between conservationists and coffee producers within a framework of sustainable development. Additionally, such practices might provide valuable information on control mechanisms for agricultural pests through maintaining predator and competitor presence nearby in the surrounding forest. The resulting structure of clearings embedded in a large forest matrix seems to promote bird diversity and local abundance in shade coffee plantations.

Application of regional-scale habitat analyses to conservation ecology represents an important step forward, because it places management decisions within the landscape context and thus avoids local policies that fail to recognise critical linkages among populations. In particular, indices of patch importance may prove to be useful in guiding habitat preservation efforts and designation of critical habitats, as well as the design of dispersal and demographic studies. For example, in this study, one habitat area had high importance indices across all analyses. The region of central Veracruz was not previously considered important, because it contains relatively few large habitat areas. However, the analysis highlighted Veracruz as a "stepping stone", linking with bird populations in southern Mexico. These northerly populations may exist as "demographic sinks" (Pulliam, 1988), but nonetheless could act as buffers against collapse of source populations caused by disturbance or disease (Thomas *et al.,* 1996).

The importance of regional and landscape scale analyses is even greater in situations in which multiple agencies manage habitats throughout a species range. For example, market forces may induce forest managers to harvest timber from a small region of habitat, thinking that the patch is of little ecological importance. However, a high per area index for the same patch might lead managers to recognise the role of the patch as a crucial link within a broader region composed of several management jurisdictions. Alteration of the patch based on nonspatial, economic perspectives could jeopardise conservation goals among many agencies. Within a jurisdiction, such as a national forest, managers might re-allocate harvests to patches that have small per area indices in order to preserve the connectivity value of the entire habitat network. Alternatively, one or more agencies may trade land or extracted resources to accomplish management goals while maintaining network fidelity.

It is important to emphasise that the results are not restricted to single-species studies. Habitat patches that have high importance over a wide range of scales may represent important dispersal habitat for many species at once. Differences in management techniques between the Chiapas and Veracruz sites can have direct and indirect impacts on birds (Kattzeff, 1994; Vannini, 1994; Calvo and Blake, 1998). More intensive use of herbicides in Barranca Grande means that understory vegetation (no coffee plants) is absent for long periods in NSC, Inga and SC and may be the reason for lower numbers of bird diversity found there. Many birds in this area typically forage on the ground or low in the understory, and the elimination of low vegetation may reduce foraging sites and insect abundance (Nestel *et al.*, 1993; Greenberg *et al.*, 1997a). Major differences in the shade management techniques between the coffee plantations in the three study areas probably affected bird populations as well. For example, bird abundance in Veracruz showed a significant decrease in resident birds in comparison to Chiapas maybe because of the structure of Inga plantation management (several tropical fruit trees are also inside of canopy). In contrast, no decline was noted in Chiapas where Inga was used as a shade and there were only coffee plants inside the canopy. Based on this and other studies (e.g. Mullie *et al.*, 1991; Greenberg 1997a,) the use of agrochemicals probably has significant effects on the avifauna in shade coffee plantations, but such effects remain difficult to quantify. Major differences in shade management techniques between the three fincas probably affected bird populations as well. Another example, between the Inga and NSC is the pruning of shade trees. Such differences in pruning affect the seasonal distribution of foliage and contribute to differences observed between the habitats. Distribution and abundance of foliage can influence foraging patterns, abundance, and nesting success of birds (Martin, 1993). Severe pruning of large branches may even affect the likelihood of cavity nesters (e.g. woodpeckers) finding suitable sites for nest construction, with consequent impacts on secondary cavity nesters as well.

The conservation implications, as Greenberg *et al.* (1997a) and Calvo and Blake (1998) concluded, are that the use of pesticides and extensive trimming of shade are two management techniques that can reduce abundance of birds on coffee plantations. Thus, any reductions in these activities might potentially benefit bird populations in shade coffee plantations. To accomplish this, coffee growers must be provided with information about how alternative management techniques (e.g. pruning, types of shade trees) may help conserve biodiversity without reducing the economic returns from the coffee. Coffee is a commodity that influences the prosperity and economic stability of Southern Mexico. Thus, persuading farmers to maintain natural shade coffee *fincas* in the interest of conservation can only be accomplished by demonstrating that such farms are economically viable.

Finally, the findings contribute to the debate and growing concerns about the real role that agroecosystems (shade coffee plantations in particular) can play in biodiversity conservation. The data from the mist nets study suggest that habitat mosaics of shade coffee plantations mimic, from the avifauna standpoint, the gap-phase dynamics of the natural forest. Crop fields are interspersed in the forest and second growth is allowed to occur.

CHAPTER 8

Conclusions and Recommendations

8.1 Conclusion

The results of this research in southern Mexico support the common perception that increasing habitat fragmentation will cause an increasing need to manage and conserve regional mosaic landscapes. Agroecosystem patches and continuous forest have decidedly different impacts on the conservation of bird populations. The most important tool required for conservation and management is therefore, the knowledge of how to manipulate fragmented landscapes. Because birds play a integral role in tropical forest and are arguably the best studied group of organisms in these forests, they provide a excellent medium through which to understand faunal response to habitat fragmentation. Furthermore, managed forest patches are particularly well suited to providing extensive habitats for long distance migrants. Managed forest patches, individually and as mosaic, support a high density of migrants. They can provide seasonal resources for residents and migrants and may be important in the buffer zone adjacent to large patches of continuous forest, where mobile forest birds can find breeding habitats. Finally, they enhance the local avifaunal diversity by providing habitats in coffee plantations for forest edge species in areas that otherwise would support only open field species. The increase in bird diversity occurs at even the lower levels of tree density in sun coffee but reaches its apex in the diverse agroforestry systems associated with coffee production.

This study has found some particularly sensitive groups of species, and suggests also that a number of seemingly vulnerable species are more resilient than previously supposed. Also traditional coffee plantations may be reasonably effective forest surrogates for some faunal groups (e.g., Terborgh, 1989; Robbins *et al.*, 1992; Perfecto *et al.*, 1996). The extensive habitat heterogeneity in traditional coffee systems is probably one of the major reasons why they serve as good substitutes for natural forest compared to maize fields and pasture (Terborgh, 1989). In the areas studied, coffee is grown under the cover of various species of large shade trees, and the understory often contains a diverse assemblage of herbaceous plants. Factors such as humidity, light, and ground cover in coffee groves make these systems much more analogous to a natural forest than are pastures and sun coffee plantations. In fact, from aerial photographs of this region, it is hard to distinguish coffee groves from natural forest. One of the limitations on traditional coffee groves serving as reservoirs of biodiversity is that they may not represent large enough forest tracts to support some vertebrate species. However, this is a problem associated with fragment size, rather than the suitability of coffee per se.

Most of the coffee plantation patches support only a few of the most specialised forest bird species, however, particularly those that have large territories or home ranges or are the target for hunting. The ecological differences between agroecosystem patches and forest are large, and the response to these differences will have major implications for the future of biological conservation in these kinds of habitat in the tropics in future decades. One response is to say that forest patches are empty forests, biologically fragmented or depauperate and altered to the point where they are best considered biological ghosts and ignored (Greenberg, 1997). It is sometimes said that articulating any value for biodiversity conservation to these degraded systems is dangerous, because it justifies the destruction of large fragments of continuous forest and siphons away resources for higher priority areas. On the other hand, there is the argument that the efforts to increase forest cover in agricultural lands are essential and are complementary to efforts in protected area management. The implementation of proper land stewardship, environmental protection and soil management arguably benefits resident and migratory birds populations, making natural allies between agencies and groups of people working on both progressive rural development and bird conservation.

In other words it is clear that the changing tropical landscape is having dramatic effects on bird diversity and abundance. Deforestation and forest fragmentation will undoubtedly lead to the loss of endemic forest birds, as habitats are lost or invaded by species of secondary growth. Yet some managed ecosystems appear to have the potential to support high bird diversity, including a high proportion of forest specialists.

8.1.1 Summary conclusions

- Induced changes in understory birds caused by disturbance were evident in measures of species diversity, abundance and composition. A classification of species composition by site and land use clearly demonstrates the level of disturbance.
- Habitat fragments and their biotas cannot be understood without knowing the habitats surrounding them.
- Specific bird species can be used to indicate levels of perturbation. Nevertheless, information regarding the impact of perturbation on bird diversity cannot necessarily be used to imply the reaction of other taxa to similar disturbance levels.
- A landscape of forest remnants, second growths, and human activity is not devoid of biological activity. Some species of understory birds commonly found in primary forest will be found throughout highly disturbed areas. Such habitat mosaics may serve a number of conservation purposes.
- The mosaic of land uses found in the south of Mexico contains a rich bird fauna. However, the changes caused by perturbation revealed in this study show that natural forest patches are essential in the maintenance of species diversity.
- Improved natural forest management, which provides sustainable livelihoods for local forest communities while also conserving biodiversity and maintaining natural shade coffee patches, is therefore essential in the maintenance of species diversity.
- There is some indication that assemblages of frugivorous birds in cloud forest are robust to human impact, provided that landscapes are not severely modified. Frugivores also appear to move quite readily through tall, complex shade coffee plantations. This would seem to augur well for artificial succession, but the rate and trajectory of forest regeneration will certainly be affected by many other factors.

- The fragmentation and transformation of cloud forest ecosystems in the south of Mexico does not seem to generate the same patterns in assemblages of understory birds at low, middle, and high altitudes. These differences may have important consequences for conservation and management of the ecosystem along a perturbation gradient.
- The species area relationship can be used to determine and predict the number of species a given patches is likely to support, while incidence function can be used to determine the probability that a given species will be present in patches of certain size.
- Even small patches (< 20ha) of cloud forest and shade coffee plantations can support a significant fraction of local and migratory avifuana.
- The relatively high species diversity in small patches is probably due in part to movements between habitats.

8.2 Recommendations and conservation implications

The relatively high diversity of understory birds in the study areas could be due to a combination of historical and current land-use patterns within and around the forest. Most of the surrounding land is used for agriculture, especially traditional shaded coffee plantations. These plantations are a valuable habitat for many vertebrate species, and may have played an important role in decreasing extinction rates of Mexican avifauna. To serve in this capacity, plantations must afford suitable foraging areas and provide essential breeding habitat, thus increasing biodiversity.

Songbirds have become the most visible indicators of the consequences of the changes causes by human activities. Songbirds serve as a kind of barometer of the general state of the environment and a ready reminder of the underlying need for conservation and biodiversity. People see birds, count them, and care about them. What is good for birds bodes well for other animals. Songbirds link conservation efforts on different continents and command economic attention through ecotourism and their undeniable benefits for the forest products industry. Clearly, it is not possible just to say *no* to agriculture or even habitat fragmentation. However, studies like this can help to people be more aware of what is gained and what is lost

8.3 Future Research

The ultimate goal of applied ecological research is to gather knowledge of ecosystem functions and to use that knowledge to manage the forest ecosystem in a sustainable way. It is evident that the increase of the population and consequently the human impact in biodiversity requires extensive research. A focus of inventories on both the forest and in the disturbed habitat components will be crucial in the lack of information in the knowledge of many species in their habitats. This perhaps will not fill the gaps in knowledge, but will provide researchers tools to understand the losses in species.

Future research, with specific reference to this study, would be useful in a variety of directions. The study tested not only whether traditional coffee plantations are as bird species-rich in total as the forests, but also whether the numeric relationships between different taxa are similar, which could indicate that shade-coffee plantations are not merely rapidly filling and unstable sinks for certain pressured taxa (migrant songbirds) but do in fact hold stable ecological relationships similar to larger forest systems. Is important the implementation of long term bird studies focusing in endangered, and migratory bird species and in the knowledge of the habitats for the juveniles and adults birds species.

Selection of appropriate tree species, particularly native species, and managing the shade level for highest coffee quality may offset production losses by higher prices in the expanding markets of organic and special coffees. The study of coffee quality and benefits for birds and other fauna as a function of environmental and management factors deserves greater attention in the future. Future research should provide the information to develop a list of recommended trees that are of value to both birds and people for different regions. The diversity of potential supplementary shade trees will vary with region, lower and sites at higher elevations and latitudes.

Shade coffee presents a tremendous opportunity for both conservation and economic gain, in that such a relatively benign form of agriculture has been and continues to be so significant an economic engine for the Latin American and Caribbean region.

when these activities are undertaken, and to take steps, to minimise the harmful impacts on songbird populations. To do this a better understanding of the natural variability and resilience of their numbers overall is required.

To maintain high diversity, it is recommend that future management of the Custepec, La Chilana and Barranca Grande areas should include shaded coffee agroecosystems, which are important assets for the conservation and management of the avifauna. Economic and technical incentives should also be given to private landowners to maintain forest cover and shaded coffee plantations in the areas surrounded this new and valuable forest.

The most effective conservation strategies for those regions have to be directed to the conservation of the largest cloud forest fragments surrounding by shade coffee plantations. The following recommendations can help to develop management strategies:

- Establishing networks of wildlife habitat in non-farmed areas and connecting these with larger protected areas.
- Integrating perennial plants into farming systems to mimic natural habitats such as forests.
- To maximise biological diversity, shade trees of coffee plantations should be taxonomically and structurally diverse, provide shade over the fincas over the years and support epiphytes, lichens, mosses, and parasitic plants assemblage.
- Tree pruning should be kept at a minimum.
- Snags and dead limbs should be maintained as much as possible.
- Natural re-growth and evergreen trees should be used as much as possible.
- Increasing agricultural productivity on lands already being farmed to reduce further conversion of land to agriculture.
- Modifying resource management in crop fields as coffee plantation to enhance their value as wildlife habitat.
- Establishing protected areas near farming zones and involves local communities in maintaining them by demonstrating benefit.

Most tropical forests are fragmented and much research attention has been given to questions related to the maintenance of biodiversity within these "islands" of forest. This study suggests the need to approach this issue from a landscape perspective. This leads us to examine not just the forest fragments, but also the agricultural matrix in which these fragments are embedded. Some tropical agroecosystems have a high floristic diversity and complex structure, which resemble that of forests. These agroecosystems help maintain biodiversity at the landscape level, decrease the probability of species extinction in the fragments by allowing the movement of individuals between fragments, and at the same time, represent an economic alternative for rural communities in the tropics. Also in the future, the development of investigations into the function of biodiversity in terms of pest regulation in the coffee plantations will be crucial in the bird conservation. The basic idea is that the higher the diversity of organisms in the plantation, the more control mechanisms there will be and the lower the possibility for a pest outbreak. This will also provide some incentive for farmers to maintain diverse shaded coffee plantations.

The evaluation of the capacity of shade coffee plantations as refuges and nesting sites will contribute to the understanding of the dynamics of birds in habitats with human disturbance. This kind of data was not obtained in this study but may enhance the assessment of anthropogenic impact on bird diversity in southern of Mexico.

The major findings of the present study were that natural shaded coffee plantations contain extraordinarily high levels of biodiversity, and that the shaded plantations (NSC and Inga) act as high-quality matrices that allow the establishment and movement of fauna through forest patches. Both findings will be important in the management of the agroecosystems in terms of increasing the bird conservation in fragmented landscapes. Regarding the current situation in southern Mexico, shade coffee plantations are playing an important role in diversity conservation and can be seen to provide a key habitat to connect isolated forest patches.

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APPENDIX I

Keys for the bird groups are based on the following criteria: trophic guild, dietary specialization, trophic behaviour, use of forest strata, restriction to a particular area, distribution range, conservation status, endemicity, rarity and resident or migratory status.

Trophic guild

O = Omnivore
S = Scavenger
P = Predator
PC = Primary consumer

Dietary specialization

A = Arthropods
B = Birds
C = Carrion
F = Fruits
Fi = Fish
Fl = Flowers
I = Insects
In = Invertebrates
L = Leaves
M = Mammals
N = Nectar
P = Plants
R = Reptiles
Ro = Rodents
S = Seeds
Sa = Sap
Sn = Snails
V = Vertebrates

Trophic-behavioural guild

C = Carrion
F-A = Arboreal frugivore
F-F-A = Arboreal folivore-frugivore
F-I-A = Arboreal frugivore-insectivore
F-N-A = Arboreal frugivore-nectarivore
G-A = Arboreal granivore
G-F-A = Arboreal granivore-frugivore
G-F-E = Forest edge-dwelling granivore-frugivore
G-F-T = Terrestrial granivore-frugivore
G-F-U = Understory granivore-frugivore
G-I-A = Arboreal granivore-insectivore
G-T = Terrestrial granivore
G-U = Understory granivore
I-A-D = Diurnal aerial insectivore
I-A-N = Nocturnal aerial insectivore
I-A-G = Gleaning arboreal insectivore
I-A-S = Sallying arboreal insectivore
I-B-S = Surface bark-dwelling insectivore
I-C-G = Cliff-gleaning insectivore
I-F-A-G = Gleaning arboreal insectivore-frugivore
I-F-A-S = Sallying arboreal insectivore-frugivore
I-F-B-I = Interior bark-dwelling insectivore-frugivore
I-F-T-G = Gleaning terrestrial insectivore-frugivore
I-F-U-G = Gleaning understory insectivore-frugivore
I-N-A-G = Gleaning arboreal insectivore-nectarivore
I-T-G = Gleaning terrestrial insectivore
I-U-G = Gleaning understory insectivore
N-I = Nectarivore-insectivore
P = Piscivore
O-A = Arboreal omnivore
O-T = Terrestrial omnivore
R-D = Diurnal raptor
R-N = Nocturnal raptor
S = Sap

Use of forest strata

A = All strata
C = Canopy
DD = Data deficient
M = Midstory
M-C = Midstory and Canopy
NA = Not applicable
U = Understory
U-M = Understory and Midstory

Restriction to forest interior

B = Border
G = Generalist
I = Interior
VM = Vegetation Matrix

Restriction to cloud forest

NR = Non-restricted
R = Restricted

Distribution range

C = Core distribution
M = Marginal distribution

Endemicity

M = Mexico
MA = Middle America
NE = Non endemic
RR = Restricted-range species

Resident/Migratory status

NA = Not applicable
R = Resident
R-W = Resident and Winter visitor
S = Summer visitor
T = Transient
T-W = Transient and Winter visitor

Rarity

C = Common
U = Uncommon
F = Fairly common
R = Rare

Conservation status

CC = Conservation concern
NT = Non threatened

APPENDIX II

List of plant species recorded around the point counts located in the cloud forest patches, natural shade coffee and Inga shade coffee plantation at the two sites (Custepec, La Chilana and Barranca Grande).

Cloud Forest

Family	Species	Stratum
Fagaceae	*Quercus salicifolia*	Tree, Shrub
Aquifoliaceae	*Ilex beliscensis*	Tree
Asteraceae	*Vaccinium leucocephala*	Tree
	Verbesina arborea	Tree
	Siegesbeckia agrestis	Tree
	Senecio greenmanii	Tree
Melastomataceae	*Miconia argentea*	Tree, Shrub
	Tibouchina longiflora	Herbaceous
	Miconia mexicana	Herbaceous, Shrub
	Conostegia volcanalis	Shrub
Rubiaceae	*Chioccoca filipes*	Shrub
	Chioccoca alba	Shrub
	Pinarophyllon flavum	Herbaceous
	Gonzalagunia chiapensis	Shrub
	Boubardia dictioneura	Shrub, Herbaceous
	Chormelia brachypoda	Shrub
	Chormelia protacta	Shrub
	Simira rhodoclada	Shrub
	Godmania descuifolia	Shrub
Meliaceae	*Guarea trompillo*	Tree
	Trichilia cuneata	Tree
	Guarea grandifolia	Tree
	Trichilia hirta	Tree, Shrub
	Guarea glabra	Tree
Araliaceae	*Dendropanax populifolius*	Shrub
	Oreopanax peltatus	Tree, Shrub
Euphorbiaceae	*Acalypha firmula*	Herbaceous
	Omphalea oleifera	Tree
	Alchornea latifolia	Shrub
Poaceae	*Lasciasis procerrima*	Herbaceous
	Lasciasis nigra	Herbaceous
	Andropogon glomeratus	Herbaceous
	Isachne arondiacea	Herbaceous
Gesneriaceae	*Achimenes candida*	Shrub, Herbaceous
Adiantaceae	*Adiantopsis radiata*	Herbaceous
	Adiantum princeps	Herbaceous, Tree
	Pteris quadriaurita	Herbaceous
Polypodiaceae	*Pleopeltis astrolepis*	Herbaceous
	Pteridium aquilinum	Herbaceous
	Blechnum occidentalis	Herbaceous
Cyperaceae	*Cyperus matudae*	Shrub, Herbaceous

Family	**Species**	**Stratum**
Borraginaceae	*Cordia ferruginea*	Tree
Clethraceae	*Clethra obliquinervia*	Tree
	Clethra matudae	Tree
Fabaceae	*Pithecellobium cojoba*	Tree, Shrub
	Caliandra grandiflora	Tree, Shrub
	Lonchocarpus salvadorensis	Tree
	Poeppigia procera	Tree
	Macherium riparium	Tree
	Desmodium helerii	Tree
	Platymiscium pinnatum	Tree
	Calliandra magdalenae	Shrub
	Pitecellobium dulce	Shrub
	Hymenea courbaril	Shrub
	Phoebe chapensis	Shrub
	Shyzolobium parahybum	Tree
Lauraceae	*Nectandra coriaceae*	Tree
	Phoebe trinervis	Tree
	Phoebe chiapensis	Tree
	Litsea glauscencens	Tree
Annonaceae	*Rollinia jirmenezii*	Tree, Shrub
	Desmopsis lanceolata	Shrub
Comelinaceae	*Tradescantia mexicana*	Shrub
	Tripogandra serrulata	Herbaceous
Zapotaceae	*Chrysophyllum mexicanum*	Tree, Shrub
	Achras zapota	Tree
	Sideroxylon copiri	Tree
	Pauteria zapota	Tree
Acanthaceae	*Justicia inaequalis*	Tree, Shrub
	Barleria micans	Tree, Shrub
Hammamelidaceae	*Liquidambar styraciflua*	Tree
Celastraceae	*Rhacoma standleyi*	Tree
Amaranthaceae	*Iresine celosia*	Tree
Apocinaceae	*Mandevilla subsagitata*	Shrub
	Tonduzia longifolia	Shrub
Loganiaceae	*Buddleia americana*	Shrub
Musaceae	*Heliconia adflexa*	Herbaceous
Phytolacaceae	*Phytolaca rivinioides*	Herbaceous
Comelinaceae	*Tradescantia zanonia*	Tree
Theaceae	*Terstroemia tepezapote*	Shrub
	Terstroemia lineata	Shrub
Myrtaceae	*Eugenia chiapensis*	Tree
	Eugenia biflora	Herbaceous
Ulmaceae	*Celtis caudata*	Shrub, Tree
	Ulmus mexicana	Tree
	Trema micrantha	Tree
Clusiaceae	*Rheedia edulis*	Tree, Herbaceous
Urticaceae	*Myriocarpa longipes*	Tree, Shrub
	Urera alceifolia	Shrub
	Bochmeria caudata	Shrub

Family	Species	Stratum
	Phenax hirtus	Shrub
Arecaceae	*Geonoma selerii*	Herbaceous
	Chamaedora quetzalteca	Shrub
	Chamaedora pinatifrons	Shrub
Zingiberaceae	*Costus spicatus*	Herbaceous
Piperaceae	*Piper yzabalanum*	Shrub
	Piper auritum	Herbaceous
Tiliaceae	*Heliocarpus donnell smithii*	Tree
	Belotia mexicana	Tree
Sterculiaceae	*Stercilia mexicana*	Tree, Shrub
Malvaceae	*Malvaviscus lanceolata*	Shrub
Thelypteraceae	*Thelypteris imbricata*	Herbaceous
Begoniaceae	*Begonia calderonii*	Herbaceous
Sapindaceae	*Exothea paniculata*	Shrub
	Cupania macrophylla	Tree
	Cupania dentata	Tree, Shurb
Miristaceae	*Virola guatemalensis*	Tree, Shrub
Combretaceae	*Terminalia amazona*	Tree
Moraceae	*Brasimun alicastrum*	Tree
	Cecropia obtusifolia	Tree
	Ficus glabrata	Tree
	Trophis chorizanta	Tree
Burseraceae	*Bursera simaruba*	Tree
Bignoniaceae	*Roseadendron donnell smithii*	Tree
Betulaceae	*Carpinus caroliniana*	Shrub
Solanaceae	*Lycianthes tricolor*	Shrub
Sterculaceae	*Guazuma ulmifolia*	Shrub
Smilacaceae	*Smilax dominguensis*	Herbaceous

Natural shade coffee

Family	Species	Stratum
Asteraceae	*Siegesbeckia agrestis*	Shrub, Herbaceous
	Eupatorium deleoides	Herbaceous
	Verbesina arborea	Shrub
	Titonia diversifolia	Herbaceous
Rubiaceae	*Coffea arabiga*	Shrub, Herbaceous
	Hamelia erecta	Herbaceous
	Hamelia potens	Shrub, Herbaceous
	Calypohyllum candidissimum	Tree
	Rondeletia ovandensis	Tree
	Faramea occidentalis	Tree
	Pinarophyllon flavum	Herbaceous
	Zanthoxylum microcarpum	Herbaceous
Meliaceae	*Thrichilia havanensis*	Shrub
	Guarea glabra	Tree
	Thrichilia hirta	Tree
	Guerea grandifolia	Tree
Ruthaceae	*Croton drago*	Tree
Araliaceae	*Dendropanax populifolius*	Shrub

Family	Species	Stratum
	Oreopanax peltatus	Tree
Cyperaceae	*Cyperus matudae*	Herbaceous
Euphorbiaceae	*Acalypha firmula*	Herbaceous
	Omphalea oleifera	Tree
Annonaceae	*Astronium graveolens*	Tree
Poaceae	*Lasciasis nigra*	Herbaceous
	Lasciasis procerrima	Herbaceous
	Panicum maximum	Herbaceous
Adiantaceae	*Adiantopsis radiata*	Herbaceous
	Adiantum princeps	Shrub, Herbaceous
	Pteris quadriaurita	Herbaceous
Fabaceae	*Lonchocarpus salvadorensis*	Tree
	Calliandra magdalenae	Shrub
	Schizolobium parahybum	Tree
	Inga fagifolia	Tree
	Inga calderonii	Tree
	Inga oerstediana	Tree
	Inga paterno	Tree
	Inga radians	Tree
	Hymenaea courbaril	Tree
	Canavalia dura	Tree
	Senna spectabilis	Shrub
	Marcherium riparium	Shrub
	Acacia pringleii	Shrub
	Poeppigia procera	Tree
	Erytrina mexicana	Shrub
Lauraceae	*Nectandra coriaceae*	Shrub
	Litsea glauscenscens	Shrub
	Persea americana	Tree
	Phoebes chiapensis	Tree
Comelinaceae	*Tradescantia mexicana*	Shrub
	Tradescantia zanonia	Herbaceous
	Tradescantia prusiantha	Herbaceous
Passifloraceae	*Passiflora membranaceae*	Herbaceous
Zapotaceae	*Chrysophyllum mexicanum*	Tree, Shrub
	Achras zapota	Tree
	Dipholis minutiflora	Shrub
Apocinaceae	*Aspidosperma megalocarpon*	Tree
	Stemmadenia donnell smithii	Tree
	Stemmadenia galeottiana	Tree
Musaceae	*Heliconia adflexa*	Shrub, Herbaceous
	Musa paradisiaca	Shrub
Urticaceae	*Urera alceifolia*	Herbaceous
	Bochmeria ulmifolia	Shrub
Moraceae	*Cecropia obtusifolia*	Tree
	Ficus padifolia	Tree
	Ficus glabrata	Tree
	Brosimum alicastrum	Tree

Inga shade coffee

Family	Species	Stratum
Fabaceae	*Inga micheliana*	Tree
	Inga laurina	Tree, Shrub
	Calliandra houstoniana	Shrub
	Inga sapioniodes	Tree
	Inga oerstediana	Tree
	Crotalaria longistrata	Herbaceous
	Calliandra magdalenae	Shrub, Herbaceous
	Demodium helleri	Shrub
Tiliaceae	*Belotia mexicana*	Tree
	Heliocarpus apendiculatus	Tree
	Bidens odorata	Herbaceous
Rubiaceae	*Coffea arábiga*	Shrub
	Pinarophyllon flavum	Herbaceous
Asteraceae	*Senecio cobanensis*	Shrub, Herbaceous
	Tithonia diversifolia	Shrub
	Verbesina polypleura	Shrub
	Senecio greenmanii	Shrub
	Siegesbeckia agrestis	Herbaceous
Urticaceae	*Bochmeria urtaceifolius*	Herbaceous
	Urera alceifolia	Herbaceous
	Bochmeria ulmifolia	Shrub, Herbaceous
Cyperaceae	*Cyperus matudae*	Herbaceous
Polypodiaceae	*Polypodio aquilinum*	Herbaceous
Adiantaceae	*Adiantopsis radiata*	Herbaceous
	Adiantum princeps	Herbaceous
	Adiantum frutescens	Herbaceous
Comelinaceae	*Tradescantia mexicana*	Herbaceous
	Tradescantia plusiantha	Herbaceous
	Tradescantia zanonia	Herbaceous
Phytolacaceae	*Phytolaca rivinoides*	Herbaceous
Convolvulaceae	*Ipomea lindelii*	Herbaceous
Poaceae	*Menis minutiflora*	Herbaceous
	Panicum maximum	Shrub, Herbaceous
	Lasciasis nigra	Herbaceous
	Lasciasis procerrima	Herbaceous
	Andropogon bicornis	Herbaceous
Meliaceae	*Trichilla hirta*	Tree, Shrub
Ulmaceae	*Trema micrantha*	Tree
	Ulmus mexicana	Tree
Amarilidaceae	*Yuca elephantipes*	Tree
Caprifoliaceae	*Sambucus mexicana*	Shrub, Herbaceous
Polemoniaceae	*Laeselia glandulosa*	Herbaceous
Araceae	*Monstera acuminata*	Herbaceous
Verbenaceae	*Lantana camora*	Herbaceous
Lamiaceae	*Stachys lindeni*	Herbaceous
	Hiptis urticoides	Herbaceous
Moraceae	*Cecropia peltata*	Tree
	Cecropia obtusifolia	Shrub

Family	Species	Stratum
Musaceae	*Heliconia adflexa*	Tree
Fagaceae	*Quercus laurina*	Tree
Solanaceae	*Solanum chiapasense*	Herbaceous
	Solanum verbascifolium	Shrub, Herbaceous
	Solanum nigrescens	Herbaceous
	Solanum wendlandii	Herbaceous
	Lycianthes tricolor	Shrub
	Datura candida	Shrub
	Datura arborea	Shrub
	Juonulloa mexicana	Herbaceous
Cucurbitaceae	*Cucúrbita pepo*	Herbaceous
	Melotrhia pendula	Herbaceous
Malvaceae	*Hibiscus bifurcatus*	Shrub
Piperaceae	*Piper auritum*	Herbaceous
Euphorbiaceae	*Euphorbia scabrella*	Herbaceous
Asplenidaceae	*Aplenium monantes*	Herbaceous
Crassulaceae	*Bryophyllum pinnatum*	Herbaceous
Commelinaceae	*Commelina* sp	Herbaceous
	Tradescantia sp	Herbaceous

APPENDIX III

Number of bird species per family in all the sites in Custepec.

Family	CF	NSC	Inga	SC
Tinamidae	2	2	1	0
Accipitridae	6	3	3	0
Falconidae	2	2	0	0
Cracidae	6	1	1	0
Phasianidae	3	0	0	0
Columbiadae	12	7	5	0
Psittacidae	9	5	3	0
Cuculidae	8	3	2	2
Strigidae	1	1	1	0
Caprimulgidae	3	1	1	0
Trochilidae	29	12	8	1
Trogonidae	4	0	0	0
Momotidae	5	1	1	0
Buconidae	1	0	0	0
Ramphastidae	2	3	3	0
Picidae	9	6	5	0
Furnariidae	4	0	0	0
Dendrocolaptidae	7	3	3	0
Formicariidae	2	0	0	0
Tyrannidae	36	22	17	7
Vireonidae	12	5	2	1
Corvidae	3	2	2	2
Troglodytidae	11	3	3	0
Muscicapidae	17	0	0	0
Mimidae	3	1	1	1
Turdidae	5	5	4	1
Ptilogonatidae	1	0	0	0
Parulidae	36	31	23	5
Thraupidae	10	8	7	0
Emberizidae	7	5	5	0
Icteridae	8	7	7	2
Fringillidae	3	2	2	2

Number of bird species per family in all the sites in La Chilana.

Family	CF	NSC	Inga	SC
Tinamidae	1	2	1	0
Accipitridae	3	5	3	0
Falconidae	2	2	1	0
Cracidae	7	6	3	0
Phasianidae	1	2	0	0
Columbiadae	8	9	5	0
Psittacidae	3	7	2	0
Cuculidae	4	7	2	0
Strigidae	2	1	1	0

Family	CF	NSC	Inga	SC
Caprimulgidae	2	2	0	0
Trochilidae	16	24	11	3
Trogonidae	4	4	1	0
Momotidae	5	5	4	0
Buconidae		1	0	0
Ramphastidae	2	2	1	0
Picidae	6	8	3	0
Furnariidae	3	5	0	0
Dendrocolaptidae	5	5	2	0
Formicariidae	1	1	1	0
Tyrannidae	38	32	24	7
Vireonidae	7	9	3	1
Corvidae	2	3	2	2
Troglodytidae	7	8	6	0
Muscicapidae	6	12	1	2
Mimidae	3	3	3	1
Turdidae	3	3	2	1
Bombycillidae	1	1	0	0
Ptilogonatidae	1		1	0
Parulidae	33	29	27	8
Thraupidae	8	9	9	0
Emberizidae	4	7	3	0
Icteridae	7	3	4	0
Fringillidae	2	2	2	1

APPENDIX IV

Relative abundances of the bird species detected in the cloud forest (CF), natural shade coffee (NSC), Inga shade coffee (Inga), and sun coffee (SC) in Custepec and La Chilana. Relative abundances are expressed as the mean number of individuals at 65 surveyed points in each habitat. Species without relative abundance were not detected in the point counts.

Custepec

Common name	Scientific name	Relative abundance			
		CF	NSC	Inga	SC
Thicket Tinamou	*Crypturellus cinnamomeus*	0.050	0.083	0.125	
Slaty-breasted Tinamou	*Crypturellus boucardi*	0.034	0.043		
White-breasted Hawk	*Accipiter chionogaster*	0.040	0.047		
Common Black-Hawk	*Buteogallus anthracinus*	0.068	0.079		
Great Black-Hawk	*Buteogallus urubitinga*	0.065	0.076	0.177	
Gray Hawk	*Buteo nitidus*	0.196	0.228	0.185	
Roadside Hawk	*Buteo magnirostris*	0.255	0.296	0.213	
Ornate Hawk-Eagle	*Spizaetus ornatus*	0.019			
Barred Forest-Falcon	*Micrastur ruficollis*	0.087	0.101		
Collared Forest-Falcon	*Micrastur semitorquatus*	0.078		0.133	
Plain Chachalaca	*Ortalis vetula*	1.937	2.250	1.771	
White-bellied Chachalaca	*Ortalis leucogastra*	1.085	1.260	1.103	

Common name	**Scientific name**	**Relative abundance**			
		CF	**NSC**	**Inga**	**SC**
Highland Guan	*Penelopina nigra*	0.031	0.036	0.085	
Crested Guan	*Penelope purpurascens*	0.081	0.181	0.064	
Horned Guan	*Oreophasis derbianus*	0.006			
Great Curassow	*Crax rubra*	0.040	0.101	0.024	
Spotted Wood-Quail	*Odontophorus guttatus*	0.183	0.228		
Singing Quail	*Dactylortyx thoracicus*	0.140	0.155	0.181	
northern Bobwhite	*Colinus virginianus*	0.078	0.134	0.246	
Rock Dove	*Columba livia*	1.060	1.293	1.115	
Red-billed Pigeon	*Columba flavirostris*	0.936	1.210	0.821	
Band-tailed Pigeon	*Columba fasciata*	0.696		0.733	
White-winged Dove	*Zenaida asiatica*	0.494			
Mourning Dove	*Zenaida macroura*	0.858		1.111	
Inca Dove	*Columbina inca*	0.964	1.224	1.248	
Common Ground-Dove	*Columbina passerina*	0.802	0.849		
Ruddy Ground-Dove	*Columbina talpacoti*	0.392	0.455	0.507	
Maroon-chested Ground-Dove	*Claravis mondetoura*	0.190	0.202	0.173	
White-tipped Dove	*Leptotila verreauxi*	0.836	0.787	0.612	
White-faced Quail-Dove	*Geotrygon albifacies*	0.743	0.939	0.543	
Ruddy Quail-Dove	*Geotrygon montana*	0.777	0.751	0.825	
Green Parakeet	*Aratinga holochlora*	0.479	0.556		
Pacific Parakeet	*Aratinga nana*	0.833	1.069		
Orange-fronted Parakeet	*Aratinga canicularis*	0.709	0.730	0.644	
Barred Parakeet	*Bolborhynchus lineola*	0.168		0.229	
Orange-chinned Parakeet	*Brotogeris jugularis*	0.149		0.109	
White-crowned Parrot	*Pionus senilis*	0.479	0.491	0.181	
White-fronted Parrot	*Amazona albifrons*	0.249	0.242		
Mealy Parrot	*Amazona farinosa*	0.364	0.423		
Yellow-naped Parrot	*Amazona auropalliata*	0.242	0.256	0.266	
Black-billed Cuckoo	*Coccyzus erythropthalmus*	0.096	0.105	0.374	
Mangrove Cuckoo	*Coccyzus minor*	0.168	0.224	0.173	
Squirrel Cuckoo	*Piaya cayana*	0.367	0.628	0.612	
Striped Cuckoo	*Tapera naevia*	0.277	0.332		
Pheasant Cuckoo	*Dromococcyx phasianellus*	0.187	0.267	0.193	
Lesser Ground-Cuckoo	*Morococcyx erythropygus*	0.121		0.097	
Lesser Roadrunner	*Geococcyx velox*	0.140			
Groove-billed Ani	*Crotophaga sulcirostris*	0.047	0.148	0.229	1.920
Ferruginous Pygmy-Owl	*Glaucidium minutissimum*	0.134	0.159	0.181	
Chuck-will's-widow	*Caprimulgus carolinensis*	0.218	0.296	0.113	2.909
Buff-collared Nightjar	*Caprimulgus ridgwayi*	0.246	0.260		
Whip-poor-will	*Caprimulgus vociferus*	0.289	0.321	0.270	4.072
Rufous Sabrewing	*Campylopterus rufus*	0.286	0.188	0.161	
Violet Sabrewing	*Campylopterus hemileucurus*	0.749	0.737	0.632	
Green Violet-Ear	*Colibri thalassinus*	0.168	0.209	0.370	
Green-breasted Mango	*Anthracothorax prevostii*	0.084	0.090		
Emerald-chinned Humm.	*Abeillia abeillei*	0.864	0.502	0.906	
Black-crested Coquette	*Lophornis helenae*	0.090	0.141	0.612	
Fork-tailed Emerald	*Chlorostilbon canivetii*	0.084		0.467	
Broad-billed Hummingbird	*Cynanthus latirostris*	0.053	0.061	0.241	
Blue-throated Goldentail	*Hylocharis eliciae*	0.354	0.383		
White-eared Hummingbird	*Hylocharis leucotis*	0.071	0.043	0.093	
White-bellied Emerald	*Amazilia candida*	0.389	0.722	0.431	

Common name	Scientific name	Relative abundance			
		CF	NSC	Inga	SC
Azure-crowned Hummingbird	*Amazilia cyanocephala*	0.152	0.246	0.189	
Berylline Hummingbird	*Amazilia beryllina*	0.196	0.293	0.254	
Blue-tailed Hummingbird	*Amazilia cyanura*	0.435	0.296	0.366	
Rufous-tailed Hummingbird	*Amazilia tzacatl*	0.081	0.141	0.254	
Buff-bellied Hummingbird	*Amazilia yucatanensis*	0.264	0.531	0.503	4.247
Cinnamon Hummingbird	*Amazilia rutila*	0.112	0.426	0.318	
Green-fronted Hummingbird	*Amazilia viridifrons*	0.162	0.231		
Stripe-tailed Hummingbird	*Eupherusa eximia*	0.121			
Greenthroated MountainGem	*Lampornis viridipallens*	0.233		0.600	
Amethyst-throated Humm.	*Lampornis amethystinus*	0.193	0.173	0.225	
Blue-throated Hummingbird	*Lampornis clemenciae*	0.224	0.260	0.290	
Garnet-throated Humm.	*Lamprolaima rhami*	0.765	0.758	0.676	
Magnificent Hummingbird	*Eugenes fulgens*	0.270	0.477	0.712	
Long-billed Starthroat	*Heliomaster longirostris*	0.071	0.679	0.338	
Plain-capped Starthroat	*Heliomaster constantii*	0.118	0.386		
Sparkling-tailed Humm.	*Tilmatura dupontii*	0.233			
Ruby-throated Hummingbird	*Archilocus colubris*	0.171	0.311	0.370	
Wine-throated Hummingbird	*Atthis ellioti*	0.131	0.137	0.334	2.792
Violaceous Trogon	*Trogon violaceus*	0.230	0.383	0.254	
Mountain Trogon	*Trogon mexicanus*	0.656	0.870	0.600	
Collared Trogon	*Trogon collaris*	0.671	0.780	0.628	
Resplendent Quetzal	*Pharomachrus mocinno*	0.165	0.116	0.089	
Tody Motmot	*Hylomanes momotula*	0.715	0.592	0.555	
Blue-throated Motmot	*Aspatha gularis*	1.107	1.250	1.280	
Blue-crowned Motmot	*Momotus momota*	0.494	0.726	1.123	
Russet-crowned Motmot	*Momotus mexicanus*	0.103	0.300	0.274	
Turquoise-browed Motmot	*Eumomota superciliosa*	0.202	0.343		
White-necked Puffbird	*Notharchus macrorhynchos*	0.326			
Emerald Toucanet	*Aulacorhynchus prasinus*	0.280	0.242	0.254	
Collared Aracari	*Pteroglossus torquatus*	0.258	0.105	0.402	
Acorn Woodpecker	*Melanerpes formicivorus*	0.460	0.773	0.849	
Golden-fronted Woodpecker	*Melanerpes aurifrons*	0.283	0.426	0.543	
Yellow-bellied Sapsucker	*Sphyrapicus varius*	0.236	0.314	0.531	
Hairy Woodpecker	*Picoides villosus*	0.255			
Smoky-brown Woodpecker	*Veniliornis fumigatus*	0.348	0.751	0.716	
Golden-olive Woodpecker	*Piculus rubiginosus*	0.258	0.368		
northern Flicker	*Colaptes auratus*	0.230	0.311	0.491	
Lineated Woodpecker	*Dryocopus lineatus*	0.177	0.307	0.584	
Pale-billed Woodpecker	*Campephilus guatemalensis*	0.342	0.520	0.205	
Rufous-breasted Spinetail	*Synallaxis erythrothorax*	0.196		0.254	
Spectacled Foliage-Gleaner	*Anabacerthia variegaticeps*	0.311	0.506	0.173	
Ruddy Foliage-Gleaner	*Automolus rubiginosus*	0.429	0.600	0.841	
Tawny-throated Leaftosser	*Sclerurus mexicanus*	0.333	0.618		
Ruddy Woodcreeper	*Dendrocincla homochroa*	0.473	0.549		
Olivaceous Woodcreeper	*Sittasomus griseicapillus*	0.221	0.256	0.141	
Barred Woodcreeper	*Dendrocolaptes certhia*	0.326	0.390	0.217	
Ivory-billed Woodcreeper	*Xiphorhynchus flavigaster*	0.404	0.347	0.121	
Spotted Woodcreeper	*Xiphorhynchus erythropygius*	0.382	0.206	0.097	
Streak-headed Woodcreeper	*Lepidocolaptes souleyetii*	0.199	0.177		
Spot-crowned Woodcreeper	*Lepidocolaptes affinis*	0.485		0.085	
Barred Antshrike	*Thamnophilus doliatus*	0.159		0.060	

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		CF	NSC	Inga	SC
Scaled Antpitta	*Grallaria guatimalensis*	0.389	0.585	0.145	
Paltry Tyrannulet	*Zimmerius vilissimus*	0.183	0.437		
N. Beardless-Tyrannulet	*Camptostoma imberbe*	0.103	0.321	0.133	
Greenish Elaenia	*Myiopagis viridicata*	0.162	0.253	0.165	
Yellow-bellied Elaenia	*Elaenia flavogaster*	0.075			
Ochre-bellied Flycatcher	*Mionectes oleagineus*	0.109	0.321	0.173	0.989
northern Bentbill	*Oncostoma cinereigulare*	0.267	0.191	0.286	
Common Tody-Flycatcher	*Todirostrum cinereum*	0.103	0.347	0.350	
Eye-ringed Flatbill	*Rhynchocyclus brevirostris*	0.112	0.094	0.370	
Yellow-olive Flycatcher	*Tolmomyias sulphurescens*	0.134	0.112	0.314	
Royal Flycatcher	*Onychorhynchus coronatus*	0.190	0.444	0.137	
Belted Flycatcher	*Xenotriccus callizonis*	0.171	0.119		
Tufted Flycatcher	*Mitrephanes phaeocercus*	0.354	0.289	0.600	
Yellow-bellied Flycatcher	*Empidonax flaviventris*	0.354	0.152	0.390	
Acadian Flycatcher	*Empidonax virescens*	0.357	0.376	0.052	
Alder Flycatcher	*Empidonax alnorum*	0.295	0.282	0.382	
	Empidonax affinis	0.140	0.144	0.229	2.269
Black Phoebe	*Sayornis nigricans*	0.047	0.116	0.274	1.396
Bright-rumped Attila	*Attila spadiceus*	0.071	0.199	0.394	
Dusky-capped Flycatcher	*Myiarchus tuberculifer*	0.134	0.358	0.173	
Ash-throated Flycatcher	*Myiarchus cinerascens*	0.221	0.441	0.660	
Nutting's Flycatcher	*Myiarchus nuttingi*	0.115	0.213	0.407	
Great Crested Flycatcher	*Myiarchus crinitus*	0.208	0.256	0.443	
Brown-crested Flycatcher	*Myiarchus tyrannulus*	0.218	0.090	0.185	
Great Kiskadee	*Pitangus sulphuratus*	0.233	0.329	0.334	2.734
Boat-billed Flycatcher	*Megarynchus pitangua*	0.174	0.563	0.817	3.200
Social Flycatcher	*Myiozetetes similis*	0.199	0.249	0.423	2.792
Streaked Flycatcher	*Myiodynastes maculatus*	0.441	0.491		
Sulphur-bellied Flycatcher	*Myiodynastes luteiventris*	0.330	0.433	0.314	
Piratic Flycatcher	*Legatus leucophaius*	0.553		0.475	
Tropical Kingbird	*Tyrannus melancholicus*	0.239	0.614	0.205	
Cassin's Kingbird	*Tyrannus vociferans*	0.211	0.307	0.463	
Western Kingbird	*Tyrannus verticalis*	0.348	0.448	0.555	
Eastern Kingbird	*Tyrannus tyrannus*	0.090	0.242	0.644	
Gray-collared Becard	*Pachyramphus major*	0.793	0.368	0.402	
Rose-throated Becard	*Pachyramphus aglaiae*	0.168	0.303		
Masked Tityra	*Tityra semifasciata*	0.155	0.332	0.491	
Green Jay	*Cyanocorax yncas*	0.047	0.300	1.405	
Black-throated Jay	*Cyanolyca pumilo*	0.413	0.433	0.479	4.130
Unicolored Jay	*Aphelocoma unicolor*	0.488			
Band-backed Wren	*Campylorhynchus zonatus*	0.454	0.813	0.761	
Giant Wren	*Campylorhynchus chiapensis*	0.746	0.668	0.785	
Rufous-naped Wren	*Campylorhynchus rufinucha*	0.211	0.296	0.733	
Spot-breasted Wren	*Thryothorus maculipectus*	0.314	0.296	0.757	
Rufous-and-white Wren	*Thryothorus rufalbus*	0.516	0.477		
Banded Wren	*Thryothorus pleurostictus*	0.706		0.684	
Plain Wren	*Thryothorus modestus*	0.059	0.159	0.419	
Southern House Wren	*Troglodytes musculus*	0.354	0.531	0.407	2.792
Rufous-browed Wren	*Troglodytes rufociliatus*	0.482	0.628	0.523	
White-breasted Wood-Wren	*Henicorhina leucosticta*	0.246	0.491	0.306	
Gray-breasted Wood-Wren	*Henicorhina leucophrys*	0.404	0.311	0.443	

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		CF	**NSC**	**Inga**	**SC**
Long-billed Gnatwren	*Ramphocaenus melanurus*	0.342			
Blue-gray Gnatcatcher	*Polioptila caerulea*	1.604	1.073	1.538	1.338
White-lored Gnatcatcher	*Polioptila albiloris*	0.724	0.300	0.592	
Eastern Bluebird	*Sialia sialis*	0.339	0.267	0.559	2.676
Brown-backed Solitaire	*Myadestes obscurus*	0.597	0.516	0.773	
Slate-colored Solitaire	*Myadestes unicolor*	0.174	0.202	0.797	
Orange-billed Night-Thrush	*Catharus aurantiirostris*	0.283	0.585	0.286	
Ruddy-capped Night-Thrush	*Catharus frantzii*	0.628	0.480	0.563	
Spotted Nightingale-Thrush	*Catharus dryas*	0.693	0.867	0.632	
Swainson's Thrush	*Catharus ustulatus*	0.528	0.722	0.451	
Hermit Thrush	*Catharus guttatus*	0.581			
Wood Thrush	*Hylocichla mustelina*	0.473	0.412	0.427	
Black Robin	*Turdus infuscatus*	0.671	0.621	0.568	
Mountain Robin	*Turdus plebejus*	0.973	0.632		
Clay-colored Robin	*Turdus grayi*	0.572	0.553	0.628	
White-throated Robin	*Turdus assimilis*	0.867	0.733	0.841	
Rufous-collared Robin	*Turdus rufitorques*	0.560	0.509	0.600	
Gray Catbird	*Dumetella carolinensis*	0.706	0.672	0.906	4.945
Tropical Mockingbird	*Mimus gilvus*	0.351	0.339		
Blue-and-white Mockingbird	*Melanotis hypoleucus*	0.087	0.159	0.274	
Cedar Waxwing	*Bombycilla cedrorum*	0.392	0.383	0.362	
Gray Silky-Flycatcher	*Ptilogonys cinereus*	0.081	0.051		
Bell's Vireo	*Vireo bellii*	0.252		0.604	
Solitary Vireo	*Vireo solitarius*	0.696	0.643	0.644	
Yellow-throated Vireo	*Vireo flavifrons*	0.267	0.311	0.411	
Warbling Vireo	*Vireo gilvus*	0.404	0.386		
Brown-capped Vireo	*Vireo leucophrys*	0.361	0.368	0.338	
Philadelphia Vireo	*Vireo philadelphicus*	0.274	0.401	0.620	5.177
Red-eyed Vireo	*Vireo olivaceus*	0.724	0.769	0.716	2.443
Yellow-green Vireo	*Vireo flavoviridis*	0.361	0.354	0.266	
Lesser Greenlet	*Hylophilus decurtatus*	0.258	0.300		
Chestnutsided Shrike-Vireo	*Vireolanius melitophrys*	0.115	0.213		
Green Shrike-Vireo	*Vireolanius pulchellus*	0.124	0.224	0.708	
Rufous-browed Peppershrike	*Cyclarhis gujanensis*	0.311		0.237	
Golden-winged Warbler	*Vermivora chrysoptera*	0.783	0.661	0.805	
Tennessee Warbler	*Vermivora peregrina*	0.902	0.690	0.781	
Nashville Warbler	*Vermivora ruficapilla*	0.569	0.661	0.543	3.839
Crescent-chested Warbler	*Vermivora superciliosa*	0.765	0.621	0.753	
Yellow Warbler	*Dendroica petechia*	0.193	0.256	0.507	
Magnolia Warbler	*Dendroica magnolia*	0.103	0.300	0.278	1.920
Cape May Warbler	*Dendroica tigrina*	0.183	0.141	0.237	
Yellow-rumped Warbler	*Dendroica coronata*	0.165	0.148	0.507	
Black-throated Gray Warbler	*Dendroica nigrescens*	0.115	0.083		
Townsend's Warbler	*Dendroica townsendi*	0.326	0.253	0.294	
Hermit Warbler	*Dendroica occidentalis*	0.199	0.358	0.173	
Blackthroated Green Warbler	*Dendroica virens*	0.961	0.795	0.495	2.734
Golden-cheeked Warbler	*Dendroica chrysoparia*	0.513	0.462	0.330	
Blackburnian Warbler	*Dendroica fusca*	1.343	0.870	1.103	
Grace's Warbler	*Dendroica graciae*	0.205	0.213	0.221	
Black-and-white Warbler	*Mniotilta varia*	0.650	0.549	0.543	
American Redstart	*Setophaga ruticilla*	0.488	0.383	0.632	

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		CF	**NSC**	**Inga**	**SC**
Prothonotary Warbler	*Protonotaria citrea*	0.532			
Worm-eating Warbler	*Helmitheros vermivorus*	0.413	0.289	0.310	
Ovenbird	*Seiurus aurocapillus*	0.385	0.408	0.439	
northern Waterthrush	*Seiurus noveboracensis*	0.622	0.524	0.584	
Louisiana Waterthrush	*Seiurus motacilla*	0.180	0.209		
Kentucky Warbler	*Oporornis formosus*	0.584	0.553	0.555	7.912
Mourning Warbler	*Oporornis philadelphia*	0.417	0.397	0.334	
MacGillivray's Warbler	*Oporornis tolmiei*	0.317	0.278		
Common Yellowthroat	*Geothlypis trichas*	0.348	0.350	0.229	
Gray-crowned Yellowthroat	*Geothlypis poliocephala*	0.298	0.347		
Hooded Warbler	*Wilsonia citrina*	0.351	0.271	0.326	
Wilson's Warbler	*Wilsonia pusilla*	0.936	1.026	1.171	5.119
Pink-headed Warbler	*Ergaticus versicolor*	0.737	0.600		
Painted Redstart	*Myioborus pictus*	0.348		0.451	
Slate-throated Redstart	*Myioborus miniatus*	0.827	0.708	1.002	
Fan-tailed Warbler	*Euthlypis lachrymosa*	0.311		1.051	
Golden-crowned Warbler	*Basileuterus culicivorus*	1.169	1.116	0.797	
Rufous-capped Warbler	*Basileuterus rufifrons*	0.199	0.293	0.278	
Chesnut-capped Warbler	*Basileuterus delattrii*	0.174	0.184		
Golden-browed Warbler	*Basileuterus belli*	0.678	0.571	0.664	
Yellow-breasted Chat	*Icteria virens*	0.320	0.448	0.660	4.596
Olive Warbler	*Peucedramus taeniatus*	0.187			
Red-legged Honeycreeper	*Cyanerpes cyaneus*	0.252	0.531	0.628	3.956
Blue-crowned Chlorophonia	*Chlorophonia occipitalis*	0.370	0.386		
Scrub Euphonia	*Euphonia affinis*	0.438	0.531	0.443	
Yellow-throated Euphonia	*Euphonia hirundinacea*	0.159	0.415	0.829	
Blue-hooded Euphonia	*Euphonia elegantissima*	0.218	0.365	0.233	
Blue-gray Tanager	*Thraupis episcopus*	0.258	0.350	0.282	
Yellow-winged Tanager	*Thraupis abbas*	0.233	0.217	0.491	
Red-crowned Ant-Tanager	*Habia rubica*	0.196	0.372	0.246	1.978
Hepatic Tanager	*Piranga flava*	0.121	0.260	0.467	
Summer Tanager	*Piranga rubra*	0.162	0.311		
Western Tanager	*Piranga ludoviciana*	0.152	0.213	0.394	
Flame-colored Tanager	*Piranga bidentata*	0.799	0.535		
White-winged Tanager	*Piranga leucoptera*	0.211	0.343	0.225	
Common Bush-Tanager	*Chlorospingus ophthalmicus*	0.410	0.397	0.423	
Grayish Saltator	*Saltator coerulescens*	0.426			
Black-headed Saltator	*Saltator atriceps*	0.233	0.206	0.229	
Yellow Grosbeak	*Pheucticus chrysopeplus*	0.547			
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	0.211	0.332	0.274	
Blue Bunting	*Cyanocompsa parellina*	0.345	0.339		
Blue Grosbeak	*Guiraca caerulea*	0.479	0.484	0.563	
Indigo Bunting	*Passerina cyanea*	1.390	0.527	0.704	
Varied Bunting	*Passerina versicolor*	0.491	0.571	0.491	
Painted Bunting	*Passerina ciris*	0.435			
Dickcissel	*Spiza americana*	0.538	0.480	0.503	
Yellow-throated Brush-Finch	*Atlapetes gutturalis*	0.345	0.361	0.467	
Chestnut-capped Brush-Finch	*Atlapetes brunneinucha*	0.323	0.441	0.346	
Prevost's Ground-Sparrow	*Melozone biarcuatum*	0.187			
Blue-black Grassquit	*Volatinia jacarina*	0.068			
White-collared Seedeater	*Sporophila torqueola*	0.081	0.181		

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Slaty Finch	*Haplospiza rustica*	0.432	0.441		
Cinnamonbellied Flowerpier.	*Diglossa baritula*	0.432	0.404	0.447	
Rusty Sparrow	*Aimophila rufescens*	0.071	0.235	0.563	4.014
Lincoln's Sparrow	*Melospiza lincolnii*	0.143	0.289		
Rufous-collared Sparrow	*Zonotrichia capensis*	0.112	0.130		
Yellow-eyed Junco	*Junco phaeonotus*	0.180			
Red-winged Blackbird	*Agelaius phoeniceus*	0.003			
Melodious Blackbird	*Dives dives*	0.211	0.246	0.326	2.618
Great-tailed Grackle	*Quiscalus mexicanus*	0.016			
Bronzed Cowbird	*Molothrus aeneus*	0.040			
Bar-winged Oriole	*Icterus maculialatus*	0.190	0.220	0.246	
Orchard Oriole	*Icterus spurius*	0.059	0.069		
Yellow-backed Oriole	*Icterus chrysater*	0.081	0.094	0.495	
Streak-backed Oriole	*Icterus pustulatus*	0.177	0.253	0.443	
Altamira Oriole	*Icterus gularis*	0.137	0.155		
northern Oriole	*Icterus galbula*	0.286	0.267	0.487	4.363
Yellow-billed Cacique	*Amblycercus holosericeus*	0.242	0.282	0.173	
Black-headed Siskin	*Carduelis notata*	0.009	0.058	0.608	1.513
Hooded Grosbeak	*Coccothraustes abeillei*	0.016		0.121	2.618
House Sparrow	*Passer domesticus*	0.009			

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Common Name	Scientific Name	Relative Abundance			
		CF	NSC	Inga	SC
Thicket Tinamou	*Crypturellus cinnamomeus*	0.15	0.04	0.09	
Slaty-breasted Tinamou	*Crypturellus boucardi*		0.03		
White-breasted Hawk	*Accipiter chionogaster*		0.05		
Common Black-Hawk	*Buteogallus anthracinus*		0.08		
Great Black-Hawk	*Buteogallus urubitinga*	0.69	0.10	0.30	
Gray Hawk	*Buteo nitidus*	0.38	0.23	0.54	
Roadside Hawk	*Buteo magnirostris*			0.44	
Ornate Hawk-Eagle	*Spizaetus ornatus*		0.06		
Barred Forest-Falcon	*Micrastur ruficollis*	0.71	0.24		
Collared Forest-Falcon	*Micrastur semitorquatus*	0.73	0.11	0.27	
Plain Chachalaca	*Ortalis vetula*	1.71	3.52	2.01	
White-bellied Chachalaca	*Ortalis leucogastra*	0.66	2.17	1.19	
Highland Guan	*Penelopina nigra*	0.36	0.10		
Crested Guan	*Penelope purpurascens*	0.52	0.10	0.27	
Horned Guan	*Oreophasis derbianus*	0.03			
Great Curassow	*Crax rubra*	0.07	0.04		
Singing Quail	*Dactylortyx thoracicus*		0.16		
northern Bobwhite	*Colinus virginianus*		0.15		
Rock Dove	*Columba livia*		0.81		
Red-billed Pigeon	*Columba flavirostris*	0.36	0.40		
Band-tailed Pigeon	*Columba fasciata*	1.08			
Inca Dove	*Columbina inca*	1.09	0.98		
Common Ground-Dove	*Columbina passerina*		0.84		
Ruddy Ground-Dove	*Columbina talpacoti*	0.35	0.76	0.76	
White-winged Dove	*Zenaida asiatica*	0.91		0.41	
Mourning Dove	*Zenaida macroura*	0.73		0.32	

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		CF	NSC	Inga	SC
Maroon-chested Ground-Dove	*Claravis mondetoura*		0.29		
White-tipped Dove	*Leptotila verreauxi*	0.65	0.88	0.78	
White-faced Quail-Dove	*Geotrygon albifacies*	1.28	0.33	0.85	
Ruddy Quail-Dove	*Geotrygon montana*		0.99		
Green Parakeet	*Aratinga holochlora*		0.58		
Pacific Parakeet	*Aratinga nana*		0.79		
Orange-fronted Parakeet	*Aratinga canicularis*		0.42		
White-crowned Parrot	*Pionus senilis*	1.12	0.51	0.12	
White-fronted Parrot	*Amazona albifrons*	0.72	0.38	0.52	
Mealy Parrot	*Amazona farinosa*		0.32		
Yellow-naped Parrot	*Amazona auropalliata*	0.94	0.28		
Black-billed Cuckoo	*Coccyzus erythropthalmus*		0.19		
Mangrove Cuckoo	*Coccyzus minor*		0.19		
Squirrel Cuckoo	*Piaya cayana*	0.38	0.54	0.78	2.47
Striped Cuckoo	*Tapera naevia*	0.30			
Pheasant Cuckoo	*Dromococcyx phasianellus*	0.32	0.41		1.12
Lesser Ground-Cuckoo	*Morococcyx erythropygus*		0.20		
Lesser Roadrunner	*Geococcyx velox*		0.33		3.82
Groove-billed Ani	*Crotophaga sulcirostris*	0.86	0.21	0.89	5.84
Ferruginous Pygmy-Owl	*Glaucidium brasilianum*			0.28	
Least Pygmy-Owl	*Glaucidium minutissimum*	0.32	0.26		
Mottled Owl	*Ciccaba virgata*	0.23			
Chuck-will's-widow	*Caprimulgus carolinensis*		0.16		
Whip-poor-will	*Caprimulgus vociferus*	0.32			
Buff-collared Nightjar	*Caprimulgus ridgwayi*		0.23		
Common Potoo	*Nyctibius jamaicensis*	0.16			
Rufous Sabrewing	*Campylopterus rufus*		0.43		
Violet Sabrewing	*Campylopterus hemileucurus*	0.53	0.90	0.22	
Green Violet-Ear	*Colibri thalassinus*	0.47	0.30	0.66	
Emerald-chinned Humm.	*Abeillia abeillei*	0.36	0.59	0.36	
Black-crested Coquette	*Lophornis helenae*		0.28		
Broad-billed Hummingbird	*Cynanthus latirostris*	0.22	0.23		
Blue-throated Goldentail	*Hylocharis eliciae*	0.41	0.42		
White-eared Hummingbird	*Hylocharis leucotis*	0.26	0.29	0.25	
White-bellied Emerald	*Amazilia candida*		0.46		
Azure-crowned Hummingbird	*Amazilia cyanocephala*	0.36	0.61	0.80	
Berylline Hummingbird	*Amazilia beryllina*		0.46		
Blue-tailed Hummingbird	*Amazilia cyanura*		0.95		5.17
Rufous-tailed Hummingbird	*Amazilia tzacatl*	0.28	0.39	0.69	4.27
Buff-bellied Hummingbird	*Amazilia yucatanensis*	0.61	0.78	1.10	3.15
Cinnamon Hummingbird	*Amazilia rutila*	0.65	0.45		
Green-fronted Hummingbird	*Amazilia viridifrons*		0.42		
Greenthroated MountainGem	*Lampornis viridipallens*		0.26		
Amethyst-throated Humm.	*Lampornis amethystinus*		0.37		8.54
Blue-throated Hummingbird	*Lampornis clemenciae*	0.51	0.31		
Garnet-throated Humm.	*Lamprolaima rhami*	0.82	0.80	0.84	
Magnificent Hummingbird	*Eugenes fulgens*	0.34	0.61	0.27	
Sparkling-tailed Humm.	*Tilmatura dupontii*		0.26		
Ruby-throated Hummingbird	*Archilocus colubris*	0.50	0.48	0.62	
Wine-throated Hummingbird	*Atthis ellioti*	0.40	0.33		
Violaceous Trogon	*Trogon violaceus*	0.77	0.34		

Common Name	Scientific Name	Relative Abundance			
		CF	NSC	Inga	SC
Mountain Trogon	*Trogon mexicanus*	0.97	0.68		
Collared Trogon	*Trogon collaris*	0.42	0.77	0.54	
Resplendent Quetzal	*Pharomachrus mocinno*	0.33	0.17		
Tody Motmot	*Hylomanes momotula*	0.11	0.70	0.51	
Blue-throated Motmot	*Aspatha gularis*	0.25	0.99	0.25	
Blue-crowned Motmot	*Momotus momota*	0.10	1.02	0.58	
Russet-crowned Motmot	*Momotus mexicanus*	0.80	0.20	0.52	
Turquoise-browed Motmot	*Eumomota superciliosa*	0.58	0.46	0.43	
White-necked Puffbird	*Notharchus macrorhynchos*		0.63		
Emerald Toucanet	*Aulacorhynchus prasinus*	0.60	0.48	0.25	
Collared Aracari	*Pteroglossus torquatus*	0.81	0.50		
Acorn Woodpecker	*Melanerpes formicivorus*		0.74		
Golden-fronted Woodpecker	*Melanerpes aurifrons*	0.52	0.45	0.30	
Yellow-bellied Sapsucker	*Sphyrapicus varius*	0.26	0.29		
Hairy Woodpecker	*Picoides villosus*	0.36	0.49		
Smoky-brown Woodpecker	*Veniliornis fumigatus*		0.47		
Golden-olive Woodpecker	*Piculus rubiginosus*		0.37		
Lineated Woodpecker	*Dryocopus lineatus*	0.30	0.19		
Pale-billed Woodpecker	*Campephilus guatemalensis*	0.31	0.66	0.26	
Spectacled Foliage-Gleaner	*Anabacerthia variegaticeps*	0.29	0.36		
Ruddy Foliage-Gleaner	*Automolus rubiginosus*	0.35	0.39		
Tawny-throated Leaftosser	*Sclerurus mexicanus*		0.44		
Ruddy Woodcreeper	*Dendrocincla homochroa*		0.64		
Olivaceous Woodcreeper	*Sittasomus griseicapillus*	0.41	0.26		
Barred Woodcreeper	*Dendrocolaptes certhia*	0.91	0.34		
Ivory-billed Woodcreeper	*Xiphorhynchus flavigaster*	0.38	0.40		
Spotted Woodcreeper	*Xiphorhynchus erythropygius*	0.29	0.17	0.40	
Streak-headed Woodcreeper	*Lepidocolaptes souleyetii*	0.38	0.22		
Spot-crowned Woodcreeper	*Lepidocolaptes affinis*	0.28	0.41		
Barred Antshrike	*Thamnophilus doliatus*		0.20		
Scaled Antpitta	*Grallaria guatimalensis*	0.41			
Paltry Tyrannulet	*Zimmerius vilissimus*	0.24	0.19	0.49	
N. Beardless-Tyrannulet	*Camptostoma imberbe*	0.85	0.12		
Greenish Elaenia	*Myiopagis viridicata*	0.71	0.17		
Yellow-bellied Elaenia	*Elaenia flavogaster*	0.23	0.14		
Ochre-bellied Flycatcher	*Mionectes oleagineus*	0.78	0.14		
northern Bentbill	*Oncostoma cinereigulare*	0.83	0.39	0.83	
Common Tody-Flycatcher	*Todirostrum cinereum*	0.76		0.43	
Eye-ringed Flatbill	*Rhynchocyclus brevirostris*	0.92	0.22	0.53	
Stub-tailed Spadebill	*Platyrinchus cancrominus*	0.27		0.37	
Yellow-olive Flycatcher	*Tolmomyias sulphurescens*	0.63	0.28	0.30	
Royal Flycatcher	*Onychorhynchus coronatus*	0.27	0.37		
Belted Flycatcher	*Xenotriccus callizonis*	0.36		0.38	
Tufted Flycatcher	*Mitrephanes phaeocercus*	0.50	0.48		
Eastern Wood Pewee	*Contopus virens*	0.40		0.21	
Tropical Pewee	*Contopus cinereus*	0.30		0.45	
Yellow-bellied Flycatcher	*Empidonax flaviventris*	0.38	0.49	0.29	
Acadian Flycatcher	*Empidonax virescens*	0.36	0.57		2.47
Alder Flycatcher	*Empidonax alnorum*	0.18	0.31	0.29	2.02
Willow Flycatcher	*Empidonax traillii*	0.16			
White Throated Flycatcher	*Empidonax albigularis*	0.17		0.31	

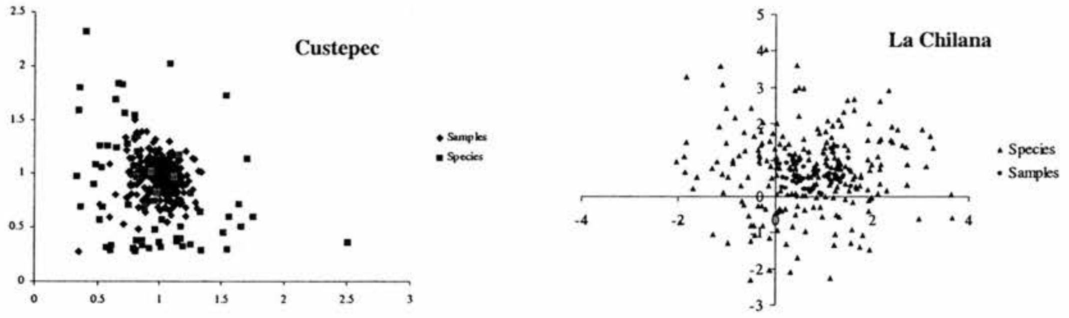
Common Name	Scientific Name	Relative Abundance			
		CF	NSC	Inga	SC
Pine Flycatcher	*Empidonax affinis*	0.34	0.47		
Black Phoebe	*Sayornis nigricans*	0.27	0.26	0.25	
Bright-rumped Attila	*Attila spadiceus*	0.31	0.37	0.44	
Dusky-capped Flycatcher	*Myiarchus tuberculifer*	0.57	0.42	0.99	7.19
Ash-throated Flycatcher	*Myiarchus cinerascens*	0.45	0.29	0.54	2.47
Nutting's Flycatcher	*Myiarchus crinitus*	0.44			
Great Crested Flycatcher	*Myiarchus nuttingi*		0.22		
Brown-crested Flycatcher	*Myiarchus tyrannulus*	0.12	0.47		
Great Kiskadee	*Pitangus sulphuratus*	0.41	0.33	1.38	15.28
Boat-billed Flycatcher	*Megarynchus pitangua*	0.39	0.21	0.60	4.27
Social Flycatcher	*Myiozetetes similis*	0.32	0.17	1.60	1.12
Streaked Flycatcher	*Myiodynastes maculatus*	0.16	0.60	1.17	
Sulphur-bellied Flycatcher	*Myiodynastes luteiventris*				
Piratic Flycatcher	*Legatus leucophaius*		0.46		
Tropical Kingbird	*Tyrannus melancholicus*	0.32	0.23	1.82	
Cassin's Kingbird	*Tyrannus vociferans*	0.30	0.39	0.49	
Western Kingbird	*Tyrannus verticalis*	0.27	0.42		
Eastern Kingbird	*Tyrannus tyrannus*	0.18	0.41	0.76	
Gray-collared Becard	*Pachyramphus major*	0.20	0.21	0.43	
Rose-throated Becard	*Pachyramphus aglaiae*	0.26	0.33	0.45	
Masked Tityra	*Tityra semifasciata*	0.14	0.37	0.58	
Green Jay	*Cyanocorax yncas*	0.24	0.46	1.90	
Black-throated Jay	*Cyanolyca pumilo*	0.09	0.46		
Unicolored Jay	*Aphelocoma unicolor*	0.18	0.49	1.25	
Band-backed Wren	*Campylorhynchus zonatus*	0.16	0.50	0.47	
Giant Wren	*Campylorhynchus chiapensis*	0.21	0.54	0.38	
Rufous-naped Wren	*Campylorhynchus rufinucha*	0.18	0.32		
Spot-breasted Wren	*Thryothorus maculipectus*	0.34	0.35	0.62	
Plain Wren	*Thryothorus modestus*		0.11		
Banded Wren	*Thryothorus pleurostictus*			0.44	
Southern House Wren	*Troglodytes musculus*	0.35		0.55	
Rufous-browed Wren	*Troglodytes rufociliatus*		0.43		
White-breasted Wood-Wren	*Henicorhina leucosticta*	0.48	0.52	0.22	
Gray-breasted Wood-Wren	*Henicorhina leucophrys*		0.63		
Long-billed Gnatwren	*Ramphocaenus melanurus*		0.34		
Blue-gray Gnatcatcher	*Polioptila caerulea*	0.11	0.63	0.55	2.02
White-lored Gnatcatcher	*Polioptila albiloris*		0.51		1.57
Eastern Bluebird	*Sialia sialis*		0.42		
Omao	*Myadestes occidentalis*	0.41			
Brown-backed Solitaire	*Myadestes obscurus*		0.66		
Slate-colored Solitaire	*Myadestes unicolor*	0.07	0.44		
Orange-billed Night-Thrush	*Catharus aurantiirostris*	0.08	0.48		
Ruddy-capped Night-Thrush	*Catharus frantzii*	0.18	0.43		
Spotted Nightingale-Thrush	*Catharus dryas*		0.72		
Swainson's Thrush	*Catharus ustulatus*		0.55		
Wood Thrush	*Hylocichla mustelina*	0.12	0.51		
Clay-colored Robin	*Turdus grayi*	0.09	0.67	1.00	1.57
White-throated Robin	*Turdus assimilis*	0.30	0.58	0.49	
Rufous-collared Robin	*Turdus rufitorques*	0.26	0.51	0.15	
Gray Catbird	*Dumetella carolinensis*	0.85	1.20	1.65	
Tropical Mockingbird	*Mimus gilvus*	0.78	0.36	0.50	

Common Name	Scientific Name	Relative Abundance			
		CF	NSC	Inga	SC
Blue-and-white Mockingbird	*Melanotis hypoleucus*	0.76	0.30		
Cedar Waxwing	*Bombycilla cedrorum*	0.58	0.26		
Bell's Vireo	*Vireo bellii*	0.26	0.31	0.90	
Solitary Vireo	*Vireo solitarius*	0.45	0.38	1.26	1.35
Yellow-throated Vireo	*Vireo flavifrons*		0.19		
Warbling Vireo	*Vireo gilvus*	0.17	0.57		
Philadelphia Vireo	*Vireo philadelphicus*	0.98	0.25		
Red-eyed Vireo	*Vireo olivaceus*	0.24	0.83	0.80	
Yellow-green Vireo	*Vireo flavoviridis*	0.09	0.20		
Green Shrike-Vireo	*Vireolanius pulchellus*		0.28		
Rufous-browed Peppershrike	*Cyclarhis gujanensis*	0.54	0.20		
Golden-winged Warbler	*Vermivora chrysoptera*	0.67	1.05	0.77	
Tennessee Warbler	*Vermivora peregrina*	0.29	0.92	0.88	2.25
Nashville Warbler	*Vermivora ruficapilla*	0.52	0.63	1.44	1.12
Crescent-chested Warbler	*Vermivora superciliosa*	0.67	0.77	0.84	
Yellow Warbler	*Dendroica petechia*	0.80	0.34	1.42	
Magnolia Warbler	*Dendroica magnolia*	0.35	0.44	1.30	2.25
Yellow-rumped Warbler	*Dendroica coronata*	0.68	0.26		
Black-throated Gray Warbler	*Dendroica nigrescens*		0.29		
Townsend's Warbler	*Dendroica townsendi*	0.66	0.40		
Hermit Warbler	*Dendroica occidentalis*	0.54	0.28		
Blackthroated Green Warbler	*Dendroica virens*	0.50	0.67	0.65	
Golden-cheeked Warbler	*Dendroica chrysoparia*	0.45	0.76	1.17	
Blackburnian Warbler	*Dendroica fusca*	0.98	0.39	0.37	
Black-and-white Warbler	*Mniotilta varia*	0.65	0.66	1.19	
American Redstart	*Setophaga ruticilla*	0.51	0.43	0.72	4.27
Ovenbird	*Seiurus aurocapillus*	0.89	0.24	1.06	
northern Waterthrush	*Seiurus noveboracensis*	0.49	0.43		
Louisiana Waterthrush	*Seiurus motacilla*	0.46		0.60	
Kentucky Warbler	*Oporornis formosus*	0.85	0.57	0.72	1.80
Mourning Warbler	*Oporornis philadelphia*	0.82	0.60	0.65	
MacGillivray's Warbler	*Oporornis tolmiei*	0.52		1.10	
Common Yellowthroat	*Geothlypis trichas*	0.78	0.67	0.87	
Gray-crowned Yellowthroat	*Geothlypis poliocephala*	0.69	0.25	0.50	
Hooded Warbler	*Wilsonia citrina*	1.01	0.25	0.04	
Wilson's Warbler	*Wilsonia pusilla*	0.60	1.01	1.80	4.27
Painted Redstart	*Myioborus pictus*	0.76	0.46	0.50	
Slate-throated Redstart	*Myioborus miniatus*	0.93	0.90	0.63	
Fan-tailed Warbler	*Euthlypis lachrymosa*	0.89		0.17	
Golden-crowned Warbler	*Basileuterus culicivorus*	0.50	0.68	0.87	
Rufous-capped Warbler	*Basileuterus rufifrons*	0.35	0.39	0.45	
Golden-browed Warbler	*Basileuterus belli*	0.45	0.36	0.49	
Yellow-breasted Chat	*Icteria virens*	0.88	0.65	1.06	2.70
Red-legged Honeycreeper	*Cyanerpes cyaneus*	0.25	0.39	1.09	
Blue-crowned Chlorophonia	*Chlorophonia occipitalis*	0.33	0.55	1.03	
Scrub Euphonia	*Euphonia affinis*	0.52	0.48	0.72	
Yellow-throated Euphonia	*Euphonia hirundinacea*	0.81	0.31	0.48	
Blue-gray Tanager	*Thraupis episcopus*	0.57	0.50	0.55	
Yellow-winged Tanager	*Thraupis abbas*	0.40	0.45	0.56	
Red-crowned Ant-Tanager	*Habia rubica*	0.64	0.38	0.34	

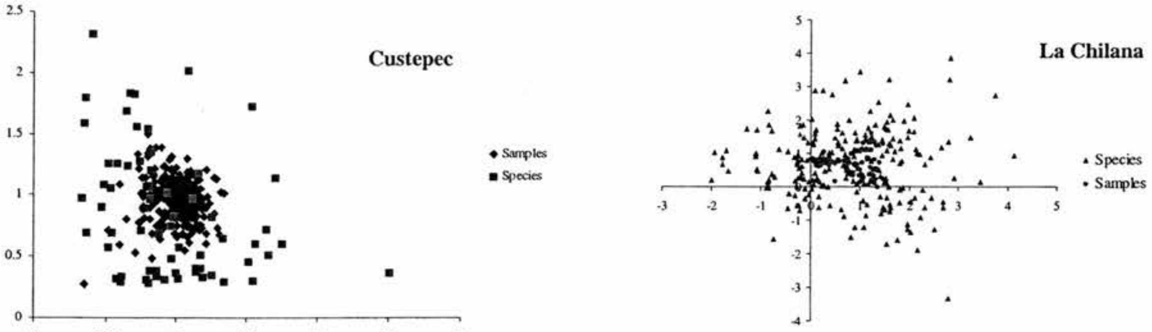
Common Name	**Scientific Name**	**Relative Abundance**			
		CF	**NSC**	Inga	**SC**
Red-Throated Ant-Tanager	*Habia fuscicauda*	0.62		0.70	
Hepatic Tanager	*Piranga flava*	0.36		0.99	
White-winged Tanager	*Piranga leucoptera*	0.22		0.57	
Summer Tanager	*Piranga rubra*	0.05	0.31	1.13	
Western Tanager	*Piranga ludoviciana*		0.29		
Flame-colored Tanager	*Piranga bidentata*		0.73		
Common Bush-Tanager	*Chlorospingus ophthalmicus*	0.21	0.26	0.66	
Grayish Saltator	*Saltator coerulescens*	0.30	0.53	0.43	
Black-headed Saltator	*Saltator atriceps*	1.07	0.34	0.75	
Rose-breasted Grosbeak	*Pheucticus ludovicianus*		0.46		
Yellow Grosbeak	*Pheucticus chrysopeplus*	0.42		1.11	
Blue Grosbeak	*Guiraca caerulea*	0.37	0.63		
Indigo Bunting	*Passerina cyanea*	0.32	0.82	0.61	
Varied Bunting	*Passerina versicolor*			0.75	
Painted Bunting	*Passerina ciris*	0.37		1.25	
Dickcissel	*Spiza americana*	0.29	0.60	0.70	
Yellow-throated Brush-Finch	*Atlapetes gutturalis*	0.42		0.41	
Chestnut-capped Brush-Finch	*Atlapetes brunneinucha*	0.98	0.40	0.80	
Blue-black Grassquit	*Volatinia jacarina*	0.56	0.34	0.87	1.57
White-collared Seedeater	*Sporophila torqueola*	0.70	0.16	0.72	
Cinnamonbellied Flowerpier.	*Diglossa baritula*	0.51	0.23	0.49	
Rusty Sparrow	*Aimophila rufescens*	0.31		1.03	
Lincoln's Sparrow	*Melospiza lincolnii*	0.24		0.53	
Rufous-collared Sparrow	*Zonotrichia capensis*	0.46		0.56	
Yellow-eyed Junco	*Junco phaeonotus*	0.66		0.44	
Red-winged Blackbird	*Agelaius phoeniceus*	0.47		0.83	
Melodious Blackbird	*Dives dives*	0.30	0.41	0.64	
Orchard Oriole	*Icterus spurius*	0.75		0.69	
Yellow-backed Oriole	*Icterus pustulatus*	0.38		0.37	
Spoted Breasted Oriole	*Icterus pectoralis*	0.20		0.64	
Bar-winged Oriole	*Icterus maculialatus*	0.33	0.28		
Altamira Oriole	*Icterus gularis*	0.38	0.34		
northern Oriole	*Icterus galbula*	0.21	0.31	0.81	
Yellow-billed Cacique	*Amblycercus holosericeus*		0.25		
Black-capped Siskin	*Carduelis atriceps*			0.56	
Hooded Grosbeak	*Coccothraustes abeillei*	0.55	0.20	0.17	4.04

APPENDIX V

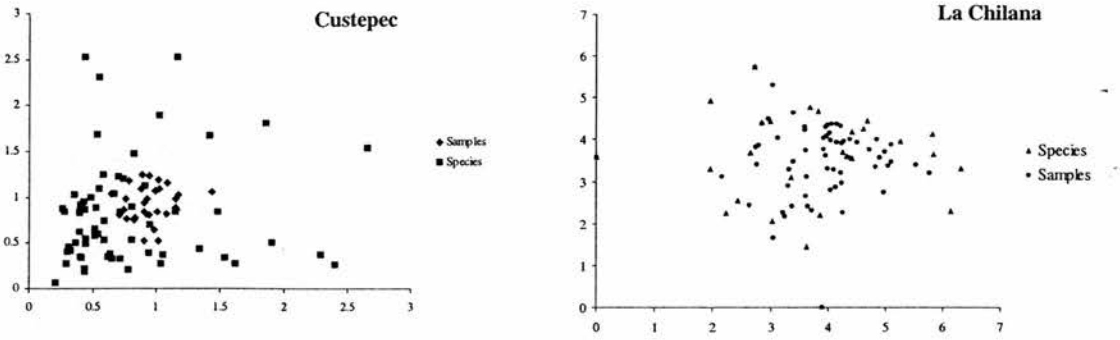
Detrended correspondence analysis (DCA) diagrams, based on the full bird data set and number of samples. A) In CF, the species were densely grouped, B) In NSC the species were grouped, C) In Inga the pattern was much spread out than in the other habitats(CF and NSC), and D) In SC species were distinctively apart from the sites.



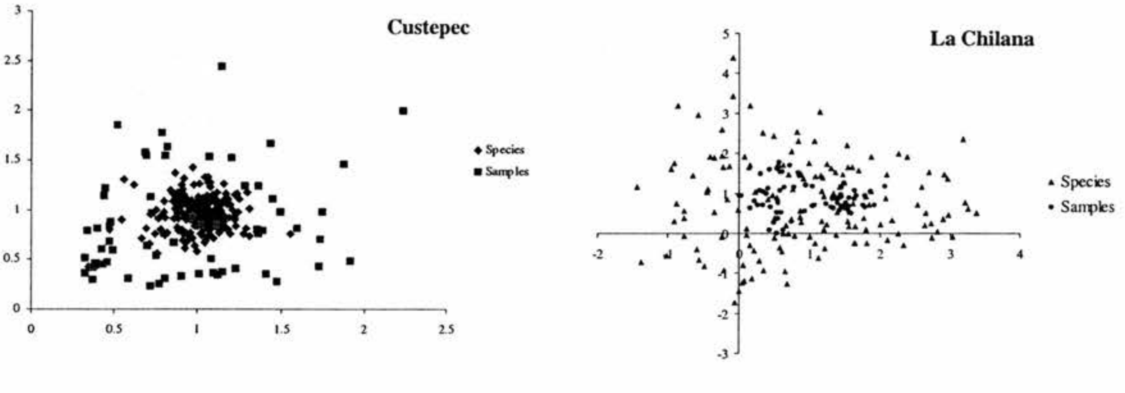
A) Detrended correspondence analysis (DCA) diagram for CF based on the full bird data set and number of samples. In the CF habitats the species were densely grouped



B) Detrended correspondence analysis (DCA) diagram for NSC based on the full bird data set and number of samples. In NSC habitats the species were distinctly grouped.



C) Detrended correspondence analysis (DCA) diagram for Inga based on the full bird data set and number of samples. In La Chilana the pattern is much spread out than in the other habitats (CF and NSC).



D) Detrended correspondence analysis (DCA) diagram for SC based on the full bird data set and number of samples. In this habitat species were distinctively apart from the sites.

APPENDIX VI

Detrended correspondence analysis (DCA) diagrams, based on the full bird data set (triangles in blue) and number of samples (circles in red), showing the spatial relationship between nets and species.

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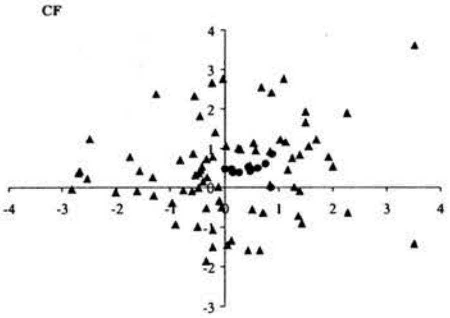
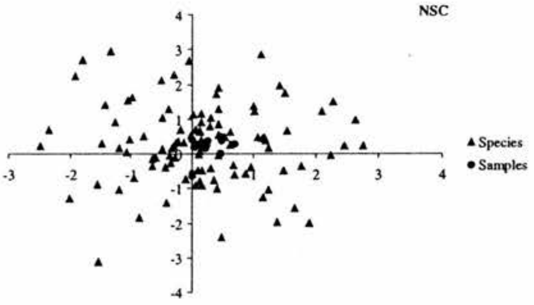
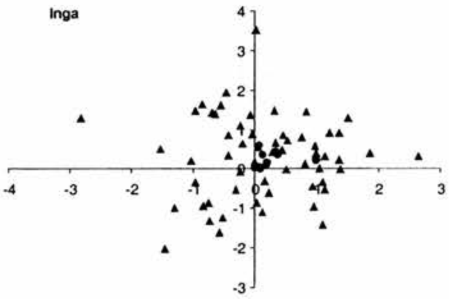
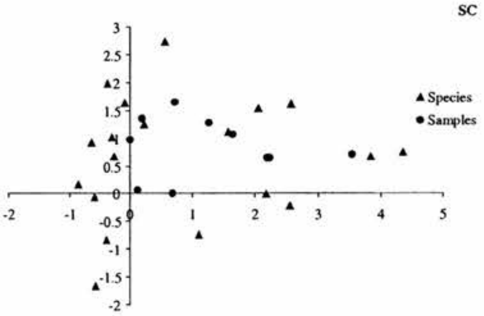
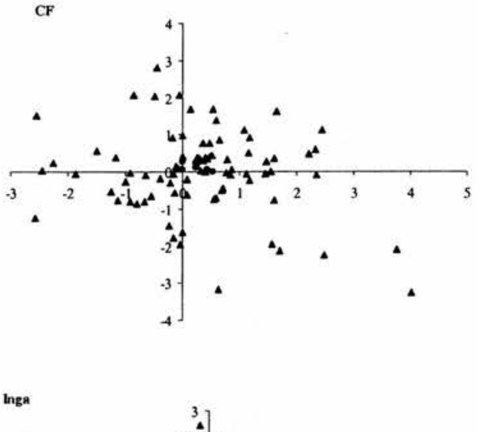


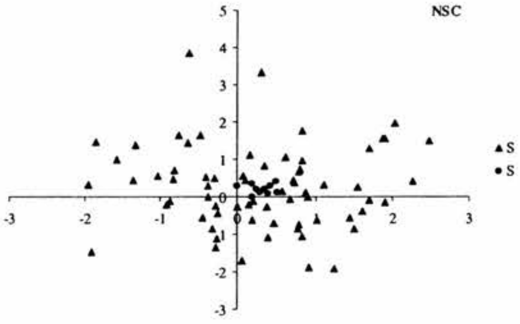


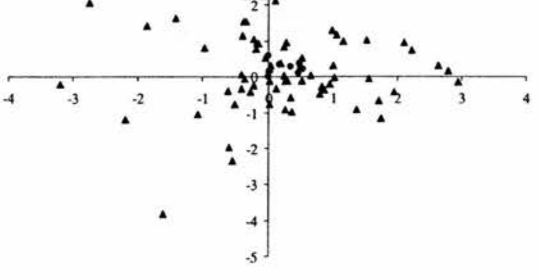


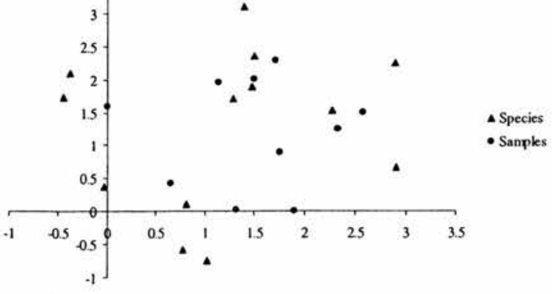


La Chilana









APPENDIX VII

Characteristics of the 288 bird species detected in 4 habitats surveyed at Custepec and La Chilana. Bird were arranged in groups based on the following criterias: trophic guild, dietary specialisation, trophic behavioural use of forest strata, restriction to a particular area, distribution range, conservation status, endemicity rarity and resident or migratory status. The point counts and mist nets database for this study was used.

	Trophic guild	Dietary specialization	Trophic-behavioural guild	Use of forest strata	Restriction to forest interior	Restriction to CF and NSC	Distribution range	Endemicity	Resident/ Migratory status	Rarity	Conservation
Tinamidae											
Crypturellus cinnamomeus	O	In, P	O-T	U	I	NR	C	NE	R	U	NT
Crypturellus boucardi	O	In, P	O-T	U	I	NR	C	NE	R	U	NT
Accipitridae											
Accipiter chionogaster	P	B, M, R,	R-D	M-C	G	NR	C	NE	R	U	NT
Buteo antrhracinus	P	B, M, R,I	R-D	M-C	G	NR	C	NE	R	U	NT
Buteo nitidus	P	B, M, R, I	R-D	M-C	G	NR	C	NE	R	C	NT
Buteo magnirostris	P	B, M, R, I	R-D	M-C	G	NR	C	NE	R	C	NT
Falconidae											
Spizaetus ornatus	P	B, M, R, I	R-D	M-C	G	NR	C	NE	R	C	NT
Micrastur ruficollis	P	B, M, R, I	R-D	M-C	G	NR	C	NE	R	U	NT
Micrastur semitorquatus	P	B, M, R, I	R-D	M-C	G	NR	C	NE	R	U	NT
Cracidae											
Ortalis vetula	PC	L, F	F-F-A	M	B	NR	C	NE	R	R	NT
Ortalis leucogastra	PC	L, F	F-F-A	M	B	NR	C	NE	R	R	NT
Penelope nigra	PC	L, F	F-F-A	M	I	NR	C	NE	R	R	NT
Penelope purpuracens	PC	L, F	F-F-A	M	I	NR	C	NE	R	R	NT
Dendrortyx barbatus	PC	S, L, F	G-F-T	U	G	R	M	MA, M,RR	R	R	CC
Oreophasis derbianus	PC	L, F	F-F-A	M	I	NR	C	NE	R	R	NT
Crax rubra	PC	L, F	F-F-A	M	I	NR	C	NE	R	R	NT
Odontophorus guttatus	P	L, F	F-F-A	M	I	NR	C	NE	R	R	NT
Dactylotyx thoracicus	P	L, F	F-F-A	M	I	NR	C	NE	R	R	NT
Colinus virginianus	PC	L, F	F-F-A	M	I	NR	C	NE	R	R	NT
Columbidae											
Columba flavirostris	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	R	NT
Columba fasciata	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	C	NT
Zenaida asiatica	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	C	NT
Zenaida macroaura	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	C	NT
Columbina inca	PC	F, S, FI	G-F-A	C	G	NR	C	NE	R	C	NT
Columbina passerina	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	R	NT
Columbina talpacoti	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	C	NT
Claravis mondetoura	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	C	NT
Leptotila verreauxi	PC	F, S, FI, L	G-F-T	U	G	NR	C	NE	R	U	NT
Geotrygon albifacies	PC	F, S, FI, L	G-F-T	U	I	R	M	MA	R	F	NT
Geotrygon montana	PC	F, S, FI, L	G-F-T	U	G	NR	C	NE	R	R	NT
Psittacidae											
Aratinga holochlora	PC	S, F	G-F-A	C	I	NR	C	M	R	F	CC
Aratinga nana	PC	S, F	G-F-A	C	I	NR	C	C	R	C	CC
Aratinga canicularis	PC	S, F	G-F-A	C	I	NR	C	C	R	C	CC
Bolborhynchus lineola	PC	S, F	G-F-A	C	I	NR	C	C	R	C	CC
Brotogeris jugularis	PC	S, F	G-F-A	C	I	NR	C	C	R	C	CC
Pionus senilis	PC	S, F	G-F-A	C	G	NR	C	NE	R	R	CC
Amazona albifrons	PC	S, F	G-F-A	C	I	NR	C	C	R	R	CC
Amazona farinosa	PC	S, F	G-F-A	C	I	NR	C	C	R	R	CC
Amazona auropalliata	PC	S, F	G-F-A	C	I	NR	C	C	R	R	CC
Cuculidae											
Coccyzus erythropthalmus	P	I, R, F	O-A	M	G	R	C	NE	R	R	NT
Coccyzus minor	P	I, R, F	O-A	M	G	R	C	NE	R	R	NT
Piaya cayana	P	I, R, F	O-A	M	G	R	C	NE	R	R	NT
Tapera naevia	P	I,R	O-A	M	G	NR	C	NE	R	C	NT
Dromococcyx phasianellus	P	I, R, F	O-A	M	G	R	C	NE	R	R	NT
Morococcyx erythropygus	P	I, R, F	O-A	M	G	R	C	NE	R	R	NT
Geococcyx veloz	P	I, R, F	O-A	M	G	R	C	NE	R	R	NT
Crotophaga sulcirostris	P	I, R, F	O-A	A	G	NR	C	NE	R	C	NT
Strigidae											
Glaucidium brasilianum	P	B, R, I	R-D	DD	I	NR	C	NE	R	R	CC

	Trophic guild	Dietary specialization	Trophic-behavioural guild	Use of forest strata	Restriction to forest interior	Restriction to CF and NSC	Distribution range	Endemicity	Resident/ Migratory status	Rarity	Conservation
Glaucidium minutissimum	P	B, R, I	R-D	DD	I	NR	C	NE	R	R	CC
Caprimulgidae											
Caprimulgus carolinensis	P	I	I-A-N	DD	G	NR	C	NE	R	R	NT
Caprimulgus ridgwayi	P	B, R, I	R-D	DD	I	NR	C	NE	R	R	CC
Caprimulgus vociferus	P	I	I-A-N	U	G	NR	C	NE	R	R	NT
Caprimulgus rufus	P	B, R, I	R-D	DD	I	NR	C	NE	R	R	CC
Trochilidae											
Campylopterus hemileucurus	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Colibri thalassinus	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Anthracothrorax prevostii	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Abeillia abeillei	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Lophornis helenae	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Chlorostilbon canivetii	O	N, I	N-I	M	B	NR	C	NE	R	R	NT
Cynanthus latirostris	O	N, I	N-I	M	G	NR	C	NE	R	R	NT
Hylocharis eliciae	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Hylocharis leucotis	O	N, I	N-I	U-M	B	NR	C	NE	R	R	NT
Amazilia candida	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Amazilia cyanocephala	O	N, I	N-I	U-M	B	NR	C	MA	R	R	NT
Amazilia beryllina	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Amazilia cyanura	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Amazilia tzacatl	O	N, I	N-I	M	B	NR	C	NE	R	C	NT
Amazilia yucatanensis	O	N, I	N-I	M	B	NR	C	NE	R	C	NT
Amazilia rutila	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Amazilia viridifrons	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Eupherusa eximia	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Lampornis viridipallens	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Lampornis amethystinus	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Lampornis clemenciae	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Lamprolaima rhami	O	N, I	N-I	M	B	NR	C	NE	R	R	NT
Eugenes fulgens	O	N, I	N-I	M	B	NR	C	NE	R	U	NT
Heliomaster longirostris	O	N, I	N-I	U-M	B	NR	C	NE	R	R	NT
Heliomaster constabtii	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Tilmatura dupontii	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Archilochus colubris	O	N, I	N-I	U-M	I	NR	C	NE	T	R	NT
Atthis elloiti	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Atthis heloisa	O	N, I	N-I	U-M	I	NR	C	M	R	U	CC
Trogonidae	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Trogon violaceus	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Trogon mexicanus	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Trogon collaris	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Pharomachrus mocino	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Momotidae											
Hylomanes momotula	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Aspatha gularis	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Momotus momota	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Momotus mexicanus	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Eumomota superciliosa	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Ramphastidae											
Aulacorhynchus prasinus	O	F, In, V	O-A	M	I	NR	M	NE	R	R	NT
Pteroglossus torquatus	O	F, In, V	O-A	M	I	NR	M	NE	R	R	NT
Picidae											
Melanerpes formicivorus	O	I, F	I-F-B-I	M-C	B	NR	C	NE	R	C	NT
Melanerpes aurifrons	O	I, F	I-F-B-I	M	B	NR	C	NE	R	C	NT
Sphyrapicus varius	PC	Sa	S	M	B	NR	C	NE	T-W	U	NT
Picoides villosus	O	I, F	I-F-B-I	M	I	NR	C	NE	R	R	NT
Veniliornis fumigatus	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Piculus rubiginosus	O	I, F	I-F-B-I	M-C	G	NR	C	NE	R	U	NT
Colaptes auratus	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Dryocopus lineatus	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Campephilus guatemalensis	O	I, F	I-F-B-I	M	I	NR	C	NE	R	R	NT
Dendrocolaptidae											
Synallaxis erythrothorax	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Anabacerthia variegaticeps	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Automulus rubiginosus	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Scleurus mexicanus	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Dendrocincla homochroa	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Sittasomus griseicapillus	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Dendrocolaptes certhia	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Xiphorhynchus flavigaster	P	In	I-B-S	U-M	G	NR	C	NE	R	U	NT
Xiphorhynchus	P	In	I-B-S	M	G	NR	C	NE	R	C	NT

	Trophic guild	Dietary specialization	Trophic-behavioural guild	Use of forest strata	Restriction to forest interior	Restriction to CF and NSC	Distribution range	Endemicity	Resident/ Migratory status	Rarity	Conservation
erythropygius											
Lepidocolaptes souleyetii	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Lepidocolaptes affinis	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Thamnophilus doliatus	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Tyrannidae											
Grallaria guatimalensis	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Zimmerius vilissimus	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Camptostoma imberbe	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Myiopagis viridicata	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Elaenia flavogaster	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Mionectes oleagineus	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Oncostoma cinereigulare	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Todirostrum cinereum	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Rhynchocyclus brevirostris	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Tolmomyias sulphurescens	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Onychorhynchus coronatus	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Xenotriccus callizonis	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Mitrephanes phaeocercus	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Empidonax flaviventris	P	I	I-A-S	U-M	G	NR	C	NE	T-W	U	NT
Empidonax virescens	P	I	I-A-S	M	G	NR	C	NE	T	C	NT
Empidonax alnorum	P	I	I-A-S	DD	I	NR	C	NE	T-W	R	NT
Empidonax affinis	P	I	I-A-S	DD	I	NR	C	NE	T-W	R	NT
Sayornis nigricans	P	I	I-A-S	U-M	G	NR	C	NE	R	C	NT
Attila spadiceus	O	I, F	I-F-A-S	DD	I	NR	M	NE	R	R	NT
Myiarchus tuberculifer	O	I, F	I-F-A-S	M	G	NR	C	NE	R	C	NT
Myiarchus cinerascens	O	I, F	I-F-A-S	M	G	NR	C	NE	R	C	NT
Myiarchus nuttingi	O	I, F	I-F-A-S	M	G	NR	C	NE	R	C	NT
Myiarchus crinitus	O	I, F	I-F-A-S	DD	G	NR	C	NE	R	C	NT
Myiarchus tyrannulus	O	I, F	I-F-A-S	M	G	NR	C	NE	R	C	NT
Pitangus sulphuratus	O	I, F	I-F-A-S	DD	G	NR	C	NE	R	R	NT
Megarynchus pitangua	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Myiozetetes similis	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Myiodynastes maculatus	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Myiodynastes luteiventris	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Legatus leucophaius	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Tyrannus melancholicus	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Tyrannus vociferans	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	C	NT
Tyrannus verticales	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Tyrannus tyrannus	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Pachyramphus major	PC	I, F	I-F-A-S	M-C	I	NR	C	NE	R	U	NT
Pachyramphus aglaiae	PC	I, F	I-F-A-S	M-C	I	NR	C	NE	R	U	NT
Tityra semifasciata	O	I,F	I-F-A-S	C	G	NR	C	NE	R	C	NT
Vireonidae											
Vireo bellii	O	I, F	I-F-A-G	M	G	NR	C	NE	T-W	U	NT
Vireo solitarius	O	I, F	I-F-A-G	M	G	R	C	NE	T-W	C	NT
Vireo flavifrons	O	I,F	I-F-A-G	M	G	R	C	NE	T-W	U	NT
Vireo gilvus	O	I,F	I-F-A-G	M	G	NR	C	NE	T-W	U	NT
Vireo leucophrys	O	I, F	I-F-A-G	M	G	NR	C	NE	T-W	U	NT
Vireo philadelphicus	O	I, F	I-F-A-G	M	G	R	C	NE	T-W	C	NT
Vireo olivaceus	O	I,F	I-F-A-G	M	G	R	C	NE	T-W	U	NT
Vireo flavoviridis	O	I,F	I-F-A-G	M	G	NR	C	NE	T-W	U	NT
Hylophilus decurtatus	O	I, F	I-F-A-G	M	G	R	C	NE	T-W	C	NT
Vireolanius melitophrys	O	I,F	I-F-A-G	M	G	R	C	NE	T-W	U	NT
Vireolanius pulchellus	O	I,F	I-F-A-G	M	G	NR	C	NE	T-W	U	NT
Cyclarhis gujanensis	O	I, F	I-F-A-G	M-C	B	NR	C	NE	R	U	NT
Corvidae											
Cyanocorax yncas	O	I, F, S, V	O-A	M	G	NR	C	NE	R	F	NT
Cyanocorax pumilo	O	I, F, S, V	O-A	M	G	NR	C	NE	R	R	NT
Aphelocoma unicolor	O	I, F, S, V	O-A	M	G	NR	C	NE	R	R	NT
Troglodytidae											
Campylorhynchus zonatus	P	I, F, S, V	I-A-G	U-M	G	NR	C	NE	R	C	NT
Campylorhynchus chiapensis	P	I, F, S, V	I-A-G	U-M	G	NR	C	NE	R	C	NT
Campylorhynchus rufinucha	P	I, F, S, V	I-A-G	U-M	G	NR	C	NE	R	C	NT
Thryothorus maculipectus	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT
Thryothorus rufalbus	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT
Thryothorus pleurostictus	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT
Thryothorus modestus	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT
Troglodytes musculus	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT
Troglodytes rufociliatus	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT
Henicorhina leucosticta	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT

	Trophic guild	Dietary specialization	Trophic-behavioural guild	Use of forest strata	Restriction to forest interior	Restriction to CF and NSC	Distribution range	Endemicity	Resident/ Migratory status	Rarity	Conservatio
Henicorhina leucophrys	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT
Ramphocaenus melanurus	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT
Troglodytes aedon	P	I	I-A-G	U-M	B	NR	C	NE	R	R	NT
Sylviidae											
Polioptila caerulea	P	I	I-A-G	M-C	G	NR	C	NE	T-W	U	NT
Polioptila albiloris	P	I	I-A-G	M-C	G	NR	C	NE	T-W	U	NT
Sialia sialis	P	I	I-A-G	M-C	G	NR	C	NE	T-W	U	NT
Turdidae											
Myadestes obscurus	O	I, F	I-F-A-G	M-C	G	NR	C	NE	R	C	NT
Myadestes unicolor	O	I, F	I-F-U-G	U	G	NR	C	NE	R	U	NT
Catharus aurantiirostris	O	I, F	I-F-U-G	U	G	NR	C	NE	R	U	NT
Catharus frantzii	O	I, F	I-F-U-G	U	G	NR	C	NE	R	U	NT
Catharus dryas	O	I, F	I-F-U-G	U	G	NR	C	NE	R	U	NT
Catharus ustulatus	O	I, F	I-F-U-G	U	G	NR	C	NE	R	U	NT
Catharus guttatus	O	I, F	I-F-U-G	U	G	NR	C	NE	R	U	NT
Hylocichla mustelina	O	I, F	I-F-U-G	U-M	G	NR	C	NE	R	U	NT
Turdus infuscatus	O	I, F	I-F-A-G	M	B	NR	C	NE	R	U	NT
Turdus plebejus	O	I, F	I-F-A-G	M	B	NR	C	NE	R	U	NT
Turdus grayi	O	I, F	I-F-A-G	M	B	NR	C	NE	R	U	NT
Turdus assimilis	O	I, F	I-F-A-G	M	B	NR	C	NE	R	C	NT
Turdus rufitorques	O	I, F	I-F-A-G	M	B	NR	C	NE	R	U	NT
Mimidae											
Dumetella carolinensis	O	I, F	I-F-A-G	M	VM	NR	C	NE	T-W	R	NT
Mimus gilvus	O	I, F	I-F-U-G	U	VM	NR	C	NE	R	R	NT
Melanotis hypoleucus	O	I, F	I-F-U-G	U	B	NR	C	M	R	U	CC
Bombycillidae											
Bombycilla cedrorum	PC	F	F-A	M	I	NR	C	NE	T-W	R	NT
Ptilogonatidae											
Ptilogonys cinereus	O	F, I	F-I-A	C	G	NR	C	NE	R	C	NT
Parulidae											
Vermivora pinus	O	F, I	F-I-A	M	I	NR	C	NE	T-W	R	NT
Vermivora chrysoptera	O	F, I	F-I-A	M-C	I	NR	C	NE	T-W	U	NT
Vermivora peregrina	O	F, I	F-I-A	DD	I	NR	C	NE	T-W	R	NT
Vermivora celata	O	I, N	I-N-A-G	DD	I	NR	C	NE	T-W	R	NT
Vermivora ruficapilla	O	I, N	I-N-A-G	M-C	I	NR	C	NE	T-W	U	NT
Vermivora superciliosa	O	I, N	I-N-A-G	M-C	I	NR	C	NE	T-W	U	NT
Dendroica petechia	I	I-A-G	U-M	M-C	NR	C	NE	NE	T-W	U	NT
Dendroica magnolia	I	I-A-G	C	B	NR	C	NE	NE	T-W	R	NT
Dendroica tigrina	I	I	I-A-G	M-C	NR	C	NE	NE	T-W	R	NT
Dendroica coronata	P	I	I-A-G	M	B	NR	C	NE	T-W	F	NT
Dendroica nigrescens	P	I	I-A-G	M	G	NR	C	NE	T-W	F	NT
Dendroica townsendi	P	I	I-A-G	M	G	NR	C	NE	T-W	F	NT
Dendroica townsendi	P	I	I-A-G	M-C	G	NR	C	NE	T-W	F	NT
Dendroica occidentalis	P	I	I-A-G	M-C	G	NR	C	NE	T-W	F	NT
Dendroica virens	P	I	I-A-G	M-C	G	NR	C	NE	T-W	U	NT
Dendroica chrysoparia	P	I	I-A-G	M	I	NR	C	NE	T-W	R	NT
Dendroica fusca	P	I	I-A-G	M	I	NR	C	NE	T-W	R	NT
Dendroica graciae	P	I	I-A-G	M	I	NR	C	NE	T-W	R	NT
Mniotilta varia	P	I	I-A-G	M-C	I	NR	C	NE	T-W	U	NT
Setophaga ruticilla	P	I	I-T-G	U	I	NR	C	NE	T-W	R	NT
Protonotaria citrea	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Helmitheros vermivorus	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Seiurus aurocapillus	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Seiurus noveboracensis	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Seiurus motacilla	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Oporornis formosus	P	I	I-A-G	M	VM	NR	C	NE	T-W	R	NT
Oporornis philadelphia	P	I	I-A-G	M	VM	NR	C	NE	T-W	R	NT
Oporornis tolmiei	P	I	I-A-G	M	VM	NR	C	NE	T-W	R	NT
Geothlypis trichas	P	I	I-A-G	M	VM	NR	C	NE	T-W	R	NT
Geothlypis poliocephala	P	I	I-A-G	M	VM	NR	C	NE	R	R	NT
Wilsonia citrina	P	I	I-A-G	A	G	NR	C	NE	T-W	C	NT
Wilsonia pusilla	P	I	I-U-G	U	I	NR	C	NE	T	R	NT
Ergaticus versicolor	P	I	I-A-G	U	I	NR	C	NE	T	R	NT
Myioborus pictus	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Myioborus miniatus	P	I	I-A-G	M	I	NR	C	NE	R	R	NT
Euthlypis lachrymosa	P	I	I-A-G	U-M	VM	NR	C	NE	R	R	NT
Basileuterus culicivorus	P	I	I-A-G	U-M	G	NR	C	NE	R	U	NT
Basileuterus rufifrons	P	I	I-A-G	U-M	G	NR	C	NE	R	U	NT
Basileuterus delatrii	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Basileuterus belli	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Icteria virens	P	I	I-A-G	U-M	G	NR	C	NE	R	U	NT

	Trophic guild	Dietary specialization	Trophic-behavioural guild	Use of forest strata	Restriction to forest interior	Restriction to CF and NSC	Distribution range	Endemicity	Resident/ Migratory status	Rarity	Conservatio
Thraupidae											
Peucedramus taeniatus	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Cyanerpes cyaneus	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Chlorophonia occipitalis	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Euphonia affinis	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Euphonia hirundinacea	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Euphonia elegantissima	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Thraupis episcopus	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Thraupis abbas	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Habia rubica	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Piranga flava	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Piranga rubra	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Piranga ludoviciana	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Piranga bidentata	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Piranga leucoptera	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Chlorospingus ophthalmicus	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Chlorophonia occipitalis	PC	F, N	F-A	C	VM	NR	C	NE	R	C	NT
Saltator coerulescens	PC	F, N	F-N-A	M-C	VM	NR	C	NE	R	R	NT
Saltator atriceps	PC	F, N	F-N-A	M-C	VM	NR	C	NE	R	R	NT
Pheucticus chrysopeplus	PC	F, N	F-N-A	M-C	VM	NR	C	NE	R	R	NT
Pheucticus ludovicianus	PC	F, N	F-N-A	C	VM	NR	C	NE	R	R	NT
Emberizida											
Cyanocompsa parellina	PC	F, N	F-N-A	M-C	VM	NR	C	NE	R	R	NT
Guiraca caerulea	PC	S	G-A	U-M	I	R	M	MA, M	R	R	NT
Passerina cyanea	PC	S	F-N-A	M-C	VM	NR	C	NE	R	C	NT
Passerina versicolor	PC	S	F-N-A	M-C	VM	NR	C	NE	R	R	NT
Passerina ciris	PC	S	F-N-A	M-C	VM	NR	C	NE	R	R	NT
Spiza americana	PC	S	F-N-A	M-C	VM	NR	C	NE	R	R	NT
Atlapetes gutturalis	PC	S	G-A	M	VM	NR	C	NE	R	R	NT
Buarremon brunneinuchus	PC	S, F	G-F-U	U	I	NR	C	NE	R	R	NT
Melozone biarcuatum	PC	S, F	G-F-U	U	I	NR	C	NE	R	R	NT
Volatinia jacarina	PC	S, F	G-F-U	U	I	NR	C	NE	R	R	NT
Sporophila torqueola	PC	S, F	G-F-U	U	I	NR	C	NE	R	R	NT
Haplospiza rustica	PC	S, F	G-F-U	U	I	NR	C	NE	R	R	NT
Diglossa baritula	PC	S, F	G-F-U	U	I	NR	C	NE	R	R	NT
Aimophila rufescens	PC	S, F	G-F-A	M	B	NR	C	NE	T-W	R	NT
Melospiza lincolnii	PC	S, F	G-F-E	NA	VM	NR	C	NE	T-W	R	NT
Zonotrichia capensis	PC	S, F	G-F-U	U	I	NR	C	NE	R	R	NT
Junco phaenotus	PC	S, F	G-F-A	M	B	NR	C	NE	T-W	R	NT
Agelaius phoeniceus	PC	S, F	G-F-E	NA	VM	NR	C	NE	T-W	R	NT
Icteridae											
Dives dives	PC	F	F-G-A	A	G	NR	C	NE	R	R	NT
Quiscalus mexicanus	PC	F	F-G-A	A	G	NR	C	NE	R	C	NT
Molothrus aeneus	PC	F	F-G-A	A	G	NR	C	NE	R	C	NT
Icterus maculialatus	PC	F	F-G-A	A	G	NR	C	NE	R	C	NT
Icterus spurius	PC	F	F-G-A	A	G	NR	C	NE	R	C	NT
Icterus chrysater	PC	F	FA	M-C	G	NR	C	NE	R	C	NT
Icterus pustulatus	PC	F	FA	M-C	VM	NR	C	NE	R	R	NT
Icterus gularis	PC	F	F-A	C	VM	NR	C	NE	R	R	NT
Icterus galbula	PC	F	F-A	M-C	G	NR	C	NE	R	R	NT
Fringillidae											
Amblycercus holosericeus	PC	S	G-A	C	B	NR	C	NE	R	F	NT
Carduelis notata	PC	S	G-A	C	VM	NR	C	NE	R	R	NT
Coccothraustes abeillei	PC	S	G-A	C	B	NR	C	NE	R	F	NT
Paser domesticus	PC	S	G-A	C	B	NR	C	NE	R	F	NT

APPENDIX VIII

Number of species per family in all the sites at Barranca Grande.

Family	CF	NSC	Inga	SC
Tinamidae	1	1	0	0
Accipitridae	3	3	3	0
Falconidae	2	2	0	0
Cracidae	3	1	1	0
Columbiadae	8	7	5	0
Psittacidae	5	5	3	0
Cuculidae	3	3	2	2
Strigidae	1	1	1	0
Caprimulgidae	3	1	1	0
Trochilidae	13	12	8	1
Momotidae	1	1	1	0
Ramphastidae	3	3	3	0
Picidae	6	6	5	0
Dendrocolaptidae	3	3	3	0
Tyrannidae	22	22	17	7
Vireonidae	5	5	2	1
Corvidae	2	2	2	2
Troglodytidae	3	3	3	0
Sylviidae	1	1	1	1
Turdidae	5	5	4	1
Mimidae	3	3	2	1
Bombycillidae	1	1	0	0
Ptilogonatidae	1	0	0	0
Parulidae	36	31	23	5
Thraupidae	10	8	7	0
Emberizidae	7	5	5	0
Icteridae	8	7	7	2
Fringillidae	3	2	2	2

APPENDIX IX

Relative abundances of the bird species detected in the cloud forest (CF), natural shade coffee (NSC), Inga shade coffee (Inga), and sun coffee (SC) at Barranca Grande. Relative abundances are expressed as the mean number of individuals at 60 surveyed points in each habitat. Species without relative abundance were not detected in the point counts.

Species	**Common name**	**Relative abundance**			
		CMF	**NSC**	**Inga**	**SC**
Crypturellus cinnamomeus	Thicket Tinamou	0.040	0.071		
Accipiter striatus	Sharp-Shined Hawk	0.048	0.044	0.080	
Asturina nitida	Gray Hawk	0.064	0.062	0.171	
Buteo magnirostris	Road Hawk	0.120	0.044	0.137	
Micrastur ruficollis	Barred Forest-Falcon	0.024	0.036		
Micrastur semitorquatus	Collared Forest-Falcon	0.016	0.027		
Ortalis vetula	Plain Chachalaca	3.177	2.169	2.298	
Penelope purpuracens	Crested Guan	1.972			
Dendrortyx barbatus	Bearded Wood-Partridge	1.884			
Columba flavirostris	Red-Billed Pigeon	2.874	0.373	0.273	
Columba fasciata	Band-Tailed Pigeon	1.333	0.978		
Columbina inca	Inca Dove	2.283		0.273	
Columbina passerina	Common Ground-Dove	2.578	0.124	0.273	
Columbina talpacoti	Rudy Ground-Dove	0.990	0.355		
Leptotila verreauxi	White-Tipped Dove	2.411	0.151	0.262	
Leptotila jamaicensis	Dove			0.284	
Geotrygon albifacies	White-Faced Quail-Dove	3.488			
Geotrygon montana	Ruddy Quail-Dove	3.967			
Aratinga holochlora	Green Parakeet	0.758	2.186		
Aratinga nana	Olive-Throated Parakeet	0.607	1.538	0.239	
Bolborhynchus lineola	Barred Parakeet	1.780	0.933		
Pionus senilis	White-Crowned Parrot	1.940	0.693	0.307	
Amazona albifrons	White-Fronted Parrot	1.078	0.418	0.091	
Coccyzus americanus	Yellow-billed Cuckoo	0.655	1.253	0.046	0.80
Tapera naevia	Striped Cuckoo	0.591	0.364		
Crotophaga sulcirostris	Groove-Billed Ani	1.357	0.204	0.421	0.801
Glaucidium brasilianum	Ferruginous Pygmy-Owl	0.463	0.533	0.171	
Nyctidromus albicollis	Pauraque	0.311	1.475	0.284	
Nyctibius jamaicensis	Northern Potoo	0.694			
Phaethornis longuemareus	Little Hermit	0.415			
Campylopterus curvipennis	Wedge-tailed Sabrewing	0.734	0.133	0.262	
Campylopterus hemileucurus	Violet Sabrewing	0.575	0.160	0.228	
Chlorostilbon canivetii	Fork-Tailed Emerald	0.231			
Cynanthus latirostris	Broad-Billed Hummingbird	0.647	0.364		
Hylocharis leucotis	White-Eared Hummingbird	0.495	0.222	0.091	
Amazilia cyanocephala	Azure-Crowned Hummingbird	0.806	0.178	0.193	
Amazilia tzacatl	Rufous-Tailed Hummingbird	1.996	1.271	0.512	
Amazilia yucatanensis	Buff-Bellied Hummingbird	1.102	2.257	4.482	0.801
Lamprolaima rhami	Garnet-Throated Hummingbird	1.317	0.747		

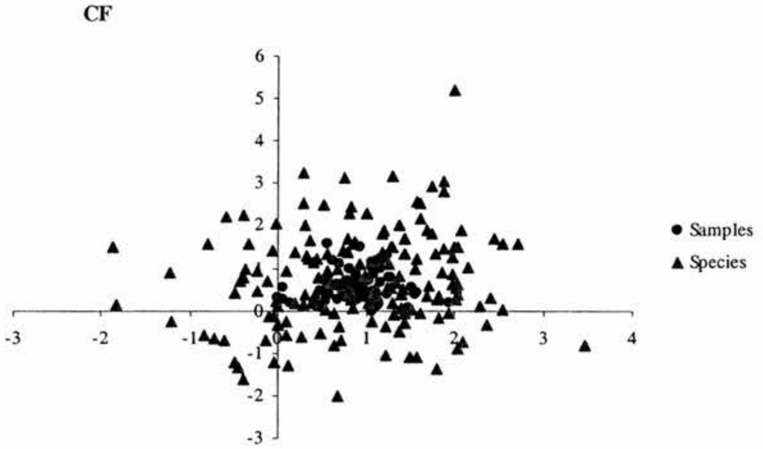
Species	Common name	Relative abundance			
		CMF	NSC	Inga	SC
Eugenes fulgens	Magnificent Hummingbird	0.471	1.075		
Heliomaster longirostris	Long-Billed Starthroat	0.431	0.907	0.557	
Archilochus colubris	Ruby-Throated Hummingbird	0.407	1.173	0.353	
Atthis heloisa	Bumblebee Hummingbird	1.078	0.995	0.159	
Momotus momota	Blue-Crowned Motmot	3.680	3.004	1.524	
Aulacorhynchus prasinus	Emerald Toucanet	0.567	0.738	0.159	
Pteroglossus torquatus	Collared Aracari	0.160	0.889	0.102	
Ramphastos sulfuratus	Keel-billed Toucan	0.319	0.240	0.102	
Melanerpes formicivorus	Acorn Woodpecker	0.686	1.004	1.217	1.122
Melanerpes aurifrons	Golden-Fronted Woodpecker	1.429	1.013	0.296	
Sphyrapicus varius	Yellow-Billed Sapsucker	0.878	1.164		
Picoides scalaris	Ladder-backed Woodpecker	0.575	0.889	0.171	
Piculus rubiginosus	Golden-Olive Woodpecker	0.998	1.875	0.216	
Campephilus guatemalensis	Pale-Billed Woodpecker	0.056	0.320	0.148	
Sittasomus griseicapillus	Olivaceus Woodpecker	0.200	0.009	0.239	
Xiphorhynchus flavigaster	Ivory-Billed Woodpecker	0.766	0.089	0.171	
Lepidocolaptes affinis	Spot-Crowned Woodpecker	0.407	0.053		
Mitrephanes phaeocercus	Tufted Flycatcher	0.655	0.151	0.137	
Contopus virens	Eastern Wood Pewee	0.231	0.240	0.046	
Empidonax flaviventris	Yellow-Billed Flycatcher	0.870	0.213	0.228	
Empidonax virescens	Acadian Flycatcher	0.176	0.293	0.125	1.683
Empidonax alnorum	Alder Flycatcher	0.104	0.524		
Empidonax traillii	Willow Flycatcher	0.208	0.027		
Empidonax albigularis	White-Throated Flycatcher	0.255			
Empidonax minimus	Least Flycatcher	0.311	0.018	0.239	
Empidonax hammondii	Hammond's Flycatcher	0.200	0.151	0.137	
Sayornis nigricans	Black Phoebe	0.631	0.355	0.193	5.609
Sayornis saya	Say's Phoebe	0.152	0.400	0.387	
Attila spadiceus	Bright-Rumped Attila	0.439	0.462	0.546	
Myiarchus tuberculifer	Dusky-Capped Flycatcher	1.884	0.755	2.878	9.054
Myiarchus cinerascens	Ash-Throated Flycatcher	0.918	0.276	0.671	
Myiarchus crinitus	Great-Crested Flycatcher	0.391	0.649		
Pitangus sulphuratus	Great Kiskadee	0.670	2.053	3.572	16.106
Megarynchus pitangua	Boat-Billed Flycatcher	0.926	0.542	1.740	14.824
Tyrannus melancholicus	Tropical Kingbird	0.479	0.355	0.364	
Tyrannus vociferans	Cassin's Kingbird	0.303	0.640	0.193	14.343
Tyrannus tyrannus	Eastern Kingbird	1.509	0.755	0.273	
Pachyramphus aglaiae	Rose-throated Becard	0.607	0.800	0.171	
Tityra semifasciata	Masked Tityra	0.471	0.658	0.216	
Vireo solitarius	Solitary Vireo	0.503	1.786	1.627	
Vireo leucophrys	Brown-Capped Vireo	0.255	0.604		
Vireo olivaceus	Red-Eyed Vireo	0.208	2.382	2.844	6.250
Vireo flavoviridis	Yellow-Green Vireo	0.287	0.640		
Cyclarhis gujanensis	Rufous-Browed Peppershrike	0.686	0.231		
Cyanocorax yncas	Green Jay	2.347	0.924	5.278	9.856
Cyanocorax morio	Brown Jay	6.362	0.702	5.267	24.760
Campylorhynchus zonatus	Band-Backed Wren	0.631	2.346	1.991	
Thryothorus maculipectus	Spot Breasted Wren	0.415	0.747	0.751	

Species	Common name	Relative abundance			
		CMF	NSC	Inga	SC
Troglodytes aedon	House Wren	1.189	1.529	0.148	
Polioptila caerulea	Blue-Gray Gnatcatcher	0.375	3.208	1.593	5.769
Myadestes obscurus	Omao	0.287	1.644	1.251	
Catharus aurantiirostris	Orange-Billed Night-Trush	0.088	0.462		
Hylocichla mustelina	Wood trush	0.088	0.969	0.648	
Turdus grayi	Clay-Colored Robin	0.846	1.591	0.319	5.288
Turdus assimilis	White-Throated Robin	0.375	1.564	0.887	
Dumetella carolinensis	Gray Catbird	1.253	1.742	2.514	6.250
Toxostoma longirostre	Long-billed Thrasher	0.527	0.071		
Melanotis caerulescens	Blue Mockingbird	0.311	1.280	0.250	
Bombycilla cedrorum	Cedar Waxwing	0.367	0.969		
Ptilogonys cinereus	Gray Silky-Flycatcher	0.231			
Vermivora pinus	Blue-winged Warbler	0.216	1.689	0.842	
Vermivora chrysoptera	Golden-Winged Warbler	0.072	1.280	0.933	
Vermivora peregrina	Tennessee Warbler	0.128	0.915		
Vermivora celata	Orange-Crowned Warbler	0.311	3.884	2.503	7.372
Vermivora ruficapilla	Nashville Warbler	0.327	1.386	0.216	
Parula pitiayumi	Tropical Parula	0.192	0.480		
Dendroica petechia	Yellow Warbler	0.088	0.595	0.057	
Dendroica pensylvanica	Chestnut-sided Warbler	0.080	1.866		
Dendroica magnolia	Magnolia Warbler	0.168	0.907	0.205	5.929
Dendroica caerulescens	Black-throated Blue Warbler	0.144	0.133		
Dendroica coronata	Yellow-rumped Warbler	0.064	0.187	0.091	
Dendroica chrysoparia	Golden-Cheeked Warbler	0.152	0.231	0.171	
Dendroica virens	Blackthroated-Green Warbler	0.168	0.018	0.205	
Dendroica townsendi	Twonsend's Warbler	0.120	0.036		
Dendroica fusca	Blackburnian Warbler	0.168	0.107		
Dendroica dominica	Yellow-throated Warbler	0.080	0.044		
Dendroica pinus	Pine Warbler	0.064	0.116	0.137	
Dendroica cerulea	Cerulean Warbler	0.080	1.697	0.125	
Mniotilta varia	Black and White Warbler	0.216	0.160	0.956	8.093
Setophaga ruticilla	American Redstart	0.184	0.160	0.296	
Seiurus aurocapillus	Ovenbird	0.120	0.151		
Seiurus noveboracensis	Northern Watertrush	0.208		0.125	
Seiurus motacilla	Louisiana Watertrush	0.080			
Oporornis formosus	Kentucky Warbler	0.152	0.151	0.273	
Oporornis philadelphia	Mourning Warbler	0.192	0.684	0.330	
Oporornis tolmiei	MacGillivray's Warbler	0.080	0.053		8.894
Geothlypis trichas	Common Yellowthroat	0.168	0.249	0.808	
Geothlypis nelsoni	Hooded Yellowthroat	0.056			
Geothlypis poliocephala	Gray-Crowned Yellowthroat	0.104	0.053	0.171	
Wilsonia pusilla	Wilson's Warbler	2.147	1.955	2.741	9.295
Wilsonia canadensis	Canada Warbler	0.088	0.062	0.102	
Myioborus miniatus	Slate-throated redstart	0.287			
Euthlypis lachrymosa	Fan-tailed Warbler	0.120			

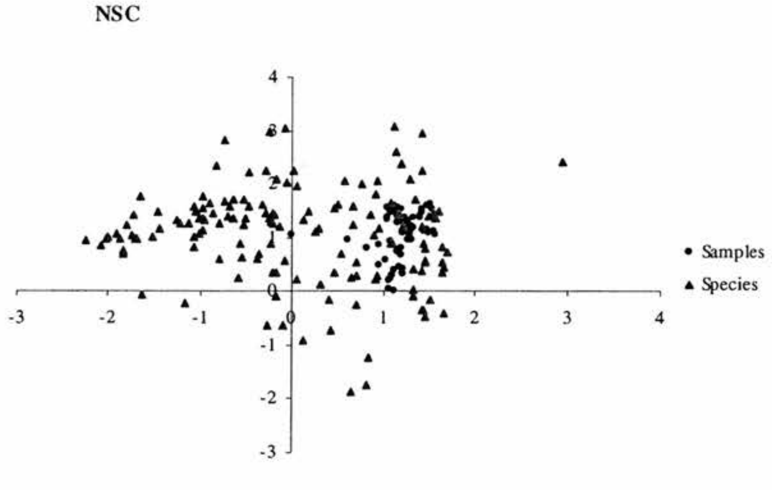
Species	Common name	Relative abundance			
		CMF	NSC	Inga	SC
Basileuterus culicivorus	Golden-Crowed Warbler	0.144	0.347	0.637	
Basileuterus rufifrons	Rufous-Capped Warbler	0.192	0.213		
Icteria virens	Yellow-Breasted Chat	0.239	0.569	0.762	
Chlorospingus ophthalmicus	Common-Bush Tanager	0.263	0.178	1.138	
Piranga rubra	Summer Tanager	0.208	0.284	0.432	
Piranga leucoptera	White-Winger Tanager	0.279	0.613		
Thraupis episcopus	Blue-Gray Tanager	0.407	0.240	0.842	
Thraupis abbas	Yellow-Winged Tanager	0.255	0.364	0.421	
Euphonia affinis	Scrub Euphonia	0.535	0.604	1.354	
Euphonia hirundinacea	Yellow-throated Euphonia	0.591	0.196	0.910	
Chlorophonia occipitalis	Blue-Crowned Chlorophonia	0.295			
Tangara larvata	Golden-hooded Tanager	0.279			
Cyanerpes cyaneus	Red-Legged Honeycreeper	1.141	0.355	1.490	
Atlapetes albinucha	White-naped Brush-Finch	0.551	0.231	0.819	
Atlapetes brunneinuchus	Chestnut-capped Brush-finch	0.487			
Aimophila rufescens	Rusty Sparrow	0.463	0.267	1.149	
Saltator atriceps	Black-Headed Saltator	0.870	0.453	2.104	
Pheucticus ludovicianus	Rose-Breasted Grosbeak	0.758	0.471	1.763	
Guiraca caerulea	Blue grosbeak	0.639			
Passerina cyanea	Indigo Bunting	0.303	0.329	0.341	
Dives dives	Melodius Blackbird	0.367	0.373	1.649	
Quiscalus mexicanus	Great-Tailed Grackle	0.319	0.080	6.154	11.298
Molothrus aeneus	Bronzed Cowbird	0.024			
Icterus spurius	Orchad Oriole	0.239	0.293	1.456	
Icterus cucullatus	Hooded Oriole	0.367	0.347	1.945	
Icterus gularis	Altamira Oriole	0.511	0.684	2.309	
Icterus graduacauda	Audubon's Oriole	0.591	0.480	1.422	
Icterus galbula	Northern Oriole	0.295	0.204	1.809	
Carpodacus mexicanus	House Finch	0.112	0.338	0.717	6.731
Carduelis notata	Great-Headed Sisking	0.208			6.410
Carduelis psaltria	Lesser Goldfinch	0.128	0.151	2.821	9.535

APPENDIX X

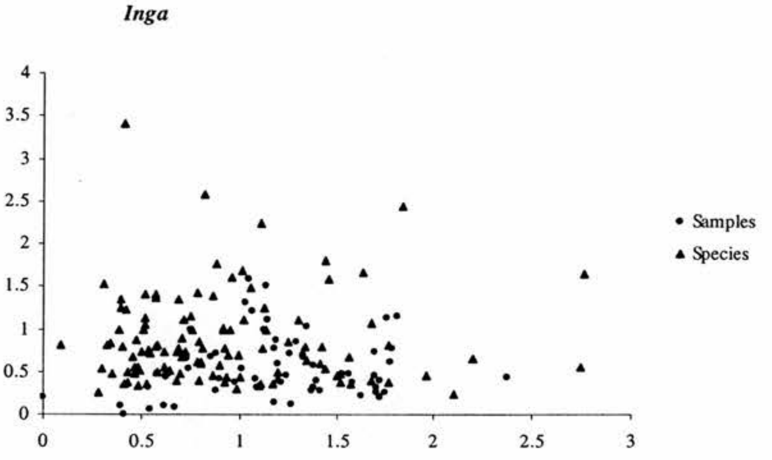
Detrended correspondence analysis (DCA) diagrams, based on the full bird data set and number of samples at Barranca Grande. A) In CF, the species were densely grouped, with few points apart which shows less variability, B) In NSC some species are grouped with the samples, C) In Inga, the pattern is spread out and shows high variability, and D) SC is grouped distinctively apart. This is a very large data set and therefore it is not surprising that the habitats are not distinct from another. This is reflected in the low eigenvalues.



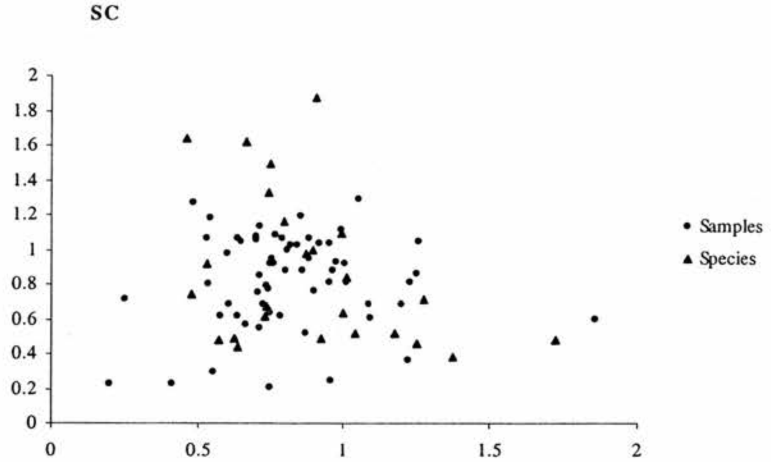
A) Detrended correspondence analysis (DCA) diagram for CF based on the full bird data set and number of samples. In this habitat the species were densely grouped



B) Detrended correspondence analysis (DCA) diagram for NSC based on the full bird data set and number of samples. The samples were grouped and the species presented a wide spread out distribution.



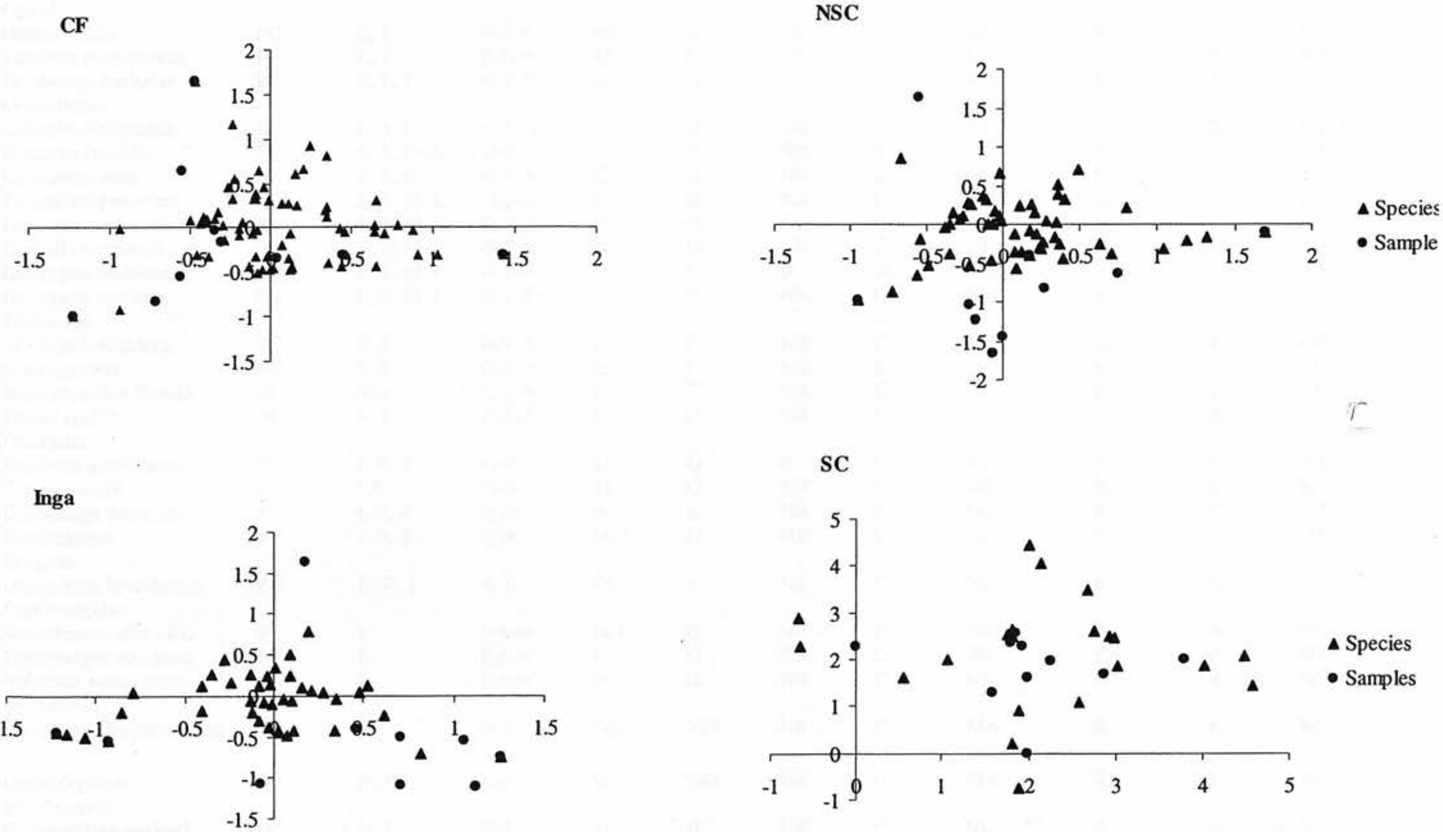
C) Detrended correspondence analysis (DCA) diagram for Inga based on the full bird data set and number of samples. This habitat shows a closer relationship between species and samples than in CF and NSC.



D) Detrended correspondence analysis (DCA) diagram for SC based on the full bird data set and number of samples. In this habitat species were distinctively apart from the samples.

APPENDIX XI

Detrended correspondence analysis (DCA) diagrams, based on the full bird data set (species in black) and number of samples (red), showing the spatial relationship between nets and species at Barranca Grande. The species in CF and NSC shows bird species cluster together in the centre of diagram suggesting that the species were more related with three nets (samples) and have similar species. In Inga, the species are clustered in the centre and have association with nets in the centre of the habitat. In general the bird species had very similar pattern throughout the area. SC is the most different habitat in the study area because the differences between the nets the bird species show a spread out pattern.



APPENDIX XII

Characteristics of the 162 bird species detected in 4 habitats surveyed at Barranca Grande, Veracruz, Mexico. Bird were arranged in groups based on the following criterias: trophic guild, dietary specialisation, trophic behavioural use of forest strata, restriction to a particular area, distribution range, conservation status, endemicity rarity and resident or migratory status.

	Trophic guild	Dietary specialization	Trophic-behavioural guild	Use of forest strata	Restriction to forest interior	Restriction to cloud forest	Distribution range	Endemicity	Resident/ Migratory status	Rarity	Conservation status
Tinamidae											
Crypturellus cinnamomeus	O	In, P	O-T	U	I	NR	C	NE	R	U	NT
Accipitridae											
Accipiter striatus	P	B, M, R,	R-D	M-C	G	NR	C	NE	R	U	NT
Asturina nitida	P	B, M, R,I	R-D	M-C	G	NR	C	NE	R	U	NT
Buteo magnirostris	P	B, M, R, I	R-D	M-C	G	NR	C	NE	R	C	NT
Falconidae											
Micrastur ruficollis	P	B, M, R, I	R-D	M-C	G	NR	C	NE	R	U	NT
Micrastur semitorquatus	P	B, M, R, I	R-D	M-C	G	NR	C	NE	R	U	NT
Cracidae											
Ortalis vetula	PC	L, F	F-F-A	M	B	NR	C	NE	R	R	NT
Penelope purpuracens	PC	L, F	F-F-A	M	I	NR	C	NE	R	R	NT
Dendrortyx barbatus	PC	S, L, F	G-F-T	U	G	R	M	MA, M,RR	R	R	CC
Columbidae											
Columba flavirostris	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	R	NT
Columba fasciata	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	C	NT
Columbina inca	PC	F, S, FI	G-F-A	C	G	NR	C	NE	R	C	NT
Columbina passerina	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	R	NT
Columbina talpacoti	PC	F, S, FI, L	G-F-A	C	G	NR	C	NE	R	C	NT
Leptotila verreauxi	PC	F, S, FI, L	G-F-T	U	G	NR	C	NE	R	U	NT
Geotrygon albifacies	PC	F, S, FI, L	G-F-T	U	I	R	M	MA	R	F	NT
Geotrygon montana	PC	F, S, FI, L	G-F-T	U	G	NR	C	NE	R	R	NT
Psittacidae											
Aratinga holochlora	PC	S, F	G-F-A	C	I	NR	C	M	R	F	CC
Aratinga nana	PC	S, F	G-F-A	C	I	NR	C	C	R	C	CC
Bolborhynchus lineola	PC	S, F	G-F-A	C	I	NR	C	C	R	C	CC
Pionus senilis	PC	S, F	G-F-A	C	G	NR	C	NE	R	R	CC
Cuculidae											
Coccyzus americanus	P	I, R, F	O-A	M	G	R	C	NE	R	R	NT
Tapera naevia	P	I,R	O-A	M	G	NR	C	NE	R	C	NT
Crotophaga sulcirostris	P	I, R, F	O-A	A	G	NR	C	NE	R	C	NT
Piaya cayana	P	I, R, F	O-A	M	G	NR	C	NE	R	U	NT
Strigidae											
Glaucidium brasilianum	P	B, R, I	R-D	DD	I	NR	C	NE	R	R	CC
Caprimulgidae											
Nyctidromus albicollis	P	I	I-A-N	DD	G	NR	C	NE	R	R	NT
Caprimulgus vociferus	P	I	I-A-N	U	G	NR	C	NE	R	R	NT
Nyctibius jamaicensis	p	I	I-A-N	U	G	NR	C	NE	R	R	NT
Trochilidae											
Phaethornis longuemareus	O	N,I	N-I	DD	VM	NR	C	MA	R	R	NT
Campylopterus hemileucurus	O	N, I	N-I	M	VM	NR	C	MA	R	R	NT
Chlorostilbon canivetii	O	N, I	N-I	M	B	NR	C	NE	R	R	NT
Cynanthus latirostris	O	N, I	N-I	M	G	NR	C	NE	R	R	NT
Hylocharis leucotis	O	N, I	N-I	U-M	B	NR	C	NE	R	R	NT
Amazilia cyanocephala	O	N, I	N-I	U-M	B	NR	C	MA	R	R	NT
Amazilia tzacatl	O	N, I	N-I	M	B	NR	C	NE	R	C	NT
Amazilia yucatanensis	O	N, I	N-I	M	B	NR	C	NE	R	C	NT
Lamprolaima rhami	O	N, I	N-I	M	B	NR	C	NE	R	R	NT
Eugenes fulgens	O	N, I	N-I	M	B	NR	C	NE	R	U	NT
Heliomaster longirostris	O	N, I	N-I	U-M	B	NR	C	NE	R	R	NT
Archilochus colubris	O	N, I	N-I	U-M	I	NR	C	NE	T	R	NT
Atthis heloisa	O	N, I	N-I	U-M	I	NR	C	M	R	U	CC
Momotidae											
Momotus momota	O	In, V, F	I-F-A-S	M	G	NR	C	NE	R	R	NT
Ramphastidae											
Aulacorhynchus prasinus	O	F, In, V	O-A	M	I	NR	M	NE	R	R	NT

	Trophic guild	Dietary specialization	Trophic-behavioural guild	Use of forest strata	Restriction to forest interior	Restriction to cloud forest	Distribution range	Endemicity	Resident/ Migratory status	Rarity	Conservation status
Pteroglossus torquatus	O	F, In, V	O-A	M	I	NR	M	NE	R	R	NT
Ramphastos sulfuratus	O	F, V	O-A	A	G	NR	C	NE	R	C	NT
Picidae											
Melanerpes formicivorus	O	I, F	I-F-B-I	M-C	B	NR	C	NE	R	C	NT
Melanerpes aurifrons	O	I, F	I-F-B-I	M	B	NR	C	NE	R	C	NT
Sphyrapicus varius	PC	Sa	S	M	B	NR	C	NE	T-W	U	NT
Picoides scalaris	O	I, F	I-F-B-I	M	I	NR	C	NE	R	R	NT
Piculus rubiginosus	O	I, F	I-F-B-I	M-C	G	NR	C	NE	R	U	NT
Campephilus guatemalensis	O	I, F	I-F-B-I	M	I	NR	C	NE	R	R	NT
Dendrocolaptidae											
Sittasomus griseicapillus	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Xiphorhynchus flavigaster	P	In	I-B-S	U-M	G	NR	C	NE	R	U	NT
Lepidocolaptes affinis	P	In	I-B-S	M	G	NR	C	NE	R	C	NT
Tyrannidae											
Mitrephanes phaeocercus	P	I	I-A-S	M	G	NR	C	NE	R	C	NT
Contopus virens	P	I	I-A-S	C	I	NR	C	NE	T	R	NT
Empidonax flaviventris	P	I	I-A-S	U-M	G	NR	C	NE	T-W	U	NT
Empidonax virescens	P	I	I-A-S	M	G	NR	C	NE	T	C	NT
Empidonax alnorum	P	I	I-A-S	DD	I	NR	C	NE	T-W	R	NT
Empidonax traillii	P	I	I-A-S	DD	I	NR	C	NE	T-W	R	NT
Empidonax albigularis	P	I	I-A-S	DD	I	NR	C	NE	T-W	R	NT
Empidonax minimus	P	I	I-A-S	DD	I	NR	C	NE	T-W	R	NT
Empidonax hammondii	P	I	I-A-S	DD	G	NR	C	NE	R	C	NT
Sayornis nigricans	P	I	I-A-S	U-M	G	NR	C	NE	R	C	NT
Sayornis saya	P	I	I-A-S	U-M	G	NR	C	NE	R	C	NT
Attila spadiceus	O	I, F	I-F-A-S	DD	I	NR	M	NE	R	R	NT
Myiarchus tuberculifer	O	I, F	I-F-A-S	M	G	NR	C	NE	R	C	NT
Myiarchus cinerascens	O	I, F	I-F-A-S	M	G	NR	C	NE	R	C	NT
Myiarchus crinitus	O	I, F	I-F-A-S	DD	G	NR	C	NE	R	C	NT
Pitangus sulphuratus	O	I, F	I-F-A-S	DD	G	NR	C	NE	R	R	NT
Megarynchus pitangua	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Tyrannus melancholicus	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Tyrannus vociferans	O	I, F	I-F-A-S	C	M	NR	C	NE	R	C	NT
Tyrannus tyrannus	O	I, F	I-F-A-S	C	VM	NR	C	NE	R	R	NT
Pachyramphus aglaiae	PC	I, F	I-F-A-S	M-C	I	NR	C	NE	R	U	NT
Tityra semifasciata	O	I,F	I-F-A-S	C	G	NR	C	NE	R	C	NT
Vireonidae											
Vireo solitarius	O	I, F	I-F-A-G	M	G	NR	C	NE	T-W	U	NT
Vireo leucophrys	O	I, F	I-F-A-G	M	G	R	C	NE	T-W	C	NT
Vireo olivaceus	O	I,F	I-F-A-G	M	G	R	C	NE	T-W	U	NT
Vireo flavoviridis	O	I,F	I-F-A-G	M	G	NR	C	NE	T-W	U	NT
Cyclarhis gujanensis	O	I, F	I-F-A-G	M-C	B	NR	C	NE	R	U	NT
Corvidae											
Cyanocorax yncas	O	I, F, S, V	O-A	M	G	NR	C	NE	R	F	NT
Cyanocorax morio	O	I, F, S, V	O-A	M	G	NR	C	NE	R	R	NT
Troglodytidae											
Campylorhynchus zonatus	P	I, F, S, V	I-A-G	U-M	G	NR	C	NE	R	C	NT
Thryothorus maculipectus	P	I	I-A-G	U-M	I	NR	M	NE	R	U	NT
Troglodytes aedon	P	I	I-A-G	U-M	B	NR	C	NE	R	R	NT
Sylviidae											
Polioptila caerulea	P	I	I-A-G	M-C	G	NR	C	NE	T-W	U	NT
Turdidae											
Myadestes obscurus	O	I, F	I-F-A-G	M-C	G	NR	C	NE	R	C	NT
Catharus aurantiirostris	O	I, F	I-F-U-G	U	G	NR	C	NE	R	U	NT
Hylocichla mustelina	O	I, F	I-F-U-G	U-M	G	NR	C	NE	R	U	NT
Turdus grayi	O	I, F	I-F-A-G	M	B	NR	C	NE	R	U	NT
Turdus assimilis	O	I, F	I-F-A-G	M	B	NR	C	NE	R	C	NT
Mimidae											
Dumetella carolinensis	O	I, F	I-F-A-G	M	VM	NR	C	NE	T-W	R	NT
Toxostoma longirostre	O	I, F	I-F-U-G	U	VM	NR	C	NE	R	R	NT
Melanotis caerulescens	O	I, F	I-F-U-G	U	B	NR	C	M	R	U	CC
Bombycillidae											
Bombycilla cedrorum	PC	F	F-A	M	I	NR	C	NE	T-W	R	NT
Ptilogonatidae											
Ptilogonys cinereus	O	F, I	F-I-A	C	G	NR	C	NE	R	C	NT
Parulidae											
Vermivora pinus	O	F, I	F-I-A	M	I	NR	C	NE	T-W	R	NT
Vermivora chrysoptera	O	F, I	F-I-A	M-C	I	NR	C	NE	T-W	U	NT
Vermivora peregrina	O	F, I	F-I-A	DD	I	NR	C	NE	T-W	R	NT
Vermivora celata	O	I, N	I-N-A-G	DD	I	NR	C	NE	T-W	R	NT

	Trophic guild	Dietary specialization	Trophic-behavioural guild	Use of forest strata	Restriction to forest interior	Restriction to cloud forest	Distribution range	Endemicity	Resident/ Migratory status	Rarity	Conservation status
Vermivora ruficapilla	O	I, N	I-N-A-G	M-C	I	NR	C	NE	T-W	U	NT
Parula pitiayumi	O	I, N	I-N-A-G	DD	I	NR	C	NE	R	R	NT
Dendroica petechia	I	I, N	I-N-A-G	M	I	NR	C	NE	R	R	NT
Dendroica pensylvanica	I	I-A-G	U-M	M-C	NR	C	NE	NE	T-W	U	NT
Dendroica magnolia	I	I-A-G	C	B	NR	C	NE	NE	T-W	R	NT
Dendroica caerulescens	I	I	I-A-G	M-C	NR	C	NE	NE	T-W	R	NT
Dendroica coronata	P	I	I-A-G	M	B	NR	C	NE	T-W	F	NT
Dendroica chrysoparia	P	I	I-A-G	M	G	NR	C	NE	T-W	F	NT
Dendroica virens	P	I	I-A-G	M	G	NR	C	NE	T-W	F	NT
Dendroica townsendi	P	I	I-A-G	M-C	G	NR	C	NE	T-W	F	NT
Dendroica fusca	P	I	I-A-G	M-C	G	NR	C	NE	T-W	U	NT
Dendroica dominica	P	I	I-A-G	M	I	NR	C	NE	T-W	R	NT
Dendroica pinus	P	I	I-A-G	M	I	NR	C	NE	T-W	R	NT
Dendroica cerulea	P	I	I-A-G	M	I	NR	C	NE	T-W	R	NT
Mniotilta varia	P	I	I-A-G	M-C	I	NR	C	NE	T-W	U	NT
Setophaga ruticilla	P	I	I-T-G	U	I	NR	C	NE	T-W	R	NT
Seiurus aurocapillus	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Seiurus noveboracensis	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Seiurus motacilla	P	I	I-T-G	U	I	NR	C	NE	T	R	NT
Oporornis formosus	P	I	I-A-G	M	VM	NR	C	NE	T-W	R	NT
Oporornis philadelphia	P	I	I-A-G	M	VM	NR	C	NE	T-W	R	NT
Oporornis tolmiei	P	I	I-A-G	M	VM	NR	C	NE	T-W	R	NT
Geothlypis trichas	P	I	I-A-G	M	VM	NR	C	NE	T-W	R	NT
Geothlypis nelsoni	P	I	I-A-G	DD	VM	NR	C	M	R	R	NT
Geothlypis poliocephala	P	I	I-A-G	M	VM	NR	C	NE	R	R	NT
Wilsonia pusilla	P	I	I-A-G	A	G	NR	C	NE	T-W	C	NT
Wilsonia canadensis	P	I	I-U-G	U	I	NR	C	NE	T	R	NT
Myioborus miniatus	P	I	I-A-G	M	I	NR	C	NE	R	R	NT
Euthlypis lachrymosa	P	I	I-A-G	U-M	VM	NR	C	NE	R	R	NT
Basileuterus culicivorus	P	I	I-A-G	U-M	G	NR	C	NE	R	U	NT
Basileuterus rufifrons	P	I	I-A-G	U-M	G	NR	C	NE	R	U	NT
Icteria virens	P	I	I-A-G	U-M	G	NR	C	NE	R	U	NT
Thraupidae											
Chlorospingus ophthalmicus	O	F, I	F-I-A	M-C	G	R	M	NE	R	C	NT
Piranga rubra	O	F, I	F-I-A	M-C	I	NR	C	NE	T-W	R	NT
Piranga leucoptera	O	F, I	F-I-A	M-C	I	NR	C	NE	R	R	NT
Thraupis episcopus	PC	F	F-A	C	B	NR	C	MA	T-W	R	NT
Thraupis abbas	PC	F	F-A	C	B	NR	C	MA	R	R	NT
Euphonia affinis	PC	F	F-A	C	B	NR	C	NE	R	C	NT
Euphonia hirundinacea	PC	F	F-A	C	B	NR	C	NE	R	C	NT
Chlorophonia occipitalis	PC	F, N	F-A	C	VM	NR	C	NE	R	C	NT
Tangara larvata	PC	F, N	F-N-A	M-C	VM	NR	C	NE	R	R	NT
Cyanerpes cyaneus	PC	F, N	F-N-A	C	VM	NR	C	NE	R	R	NT
Emberizidae											
Atlapetes albinucha	PC	S	G-A	U-M	I	R	M	MA, M	R	R	NT
Buarremon brunneinuchus	PC	S	G-T	U	G	NR	M	NE	R	C	NT
Aimophila rufescens	PC	S	G-A	M	VM	NR	C	NE	R	R	NT
Saltator atriceps	PC	S, F	G-F-U	U	I	NR	C	NE	R	R	NT
Pheucticus ludovicianus	PC	S, F	G-F-A	M	B	NR	C	NE	T-W	R	NT
Guiraca caerulea	PC	S, F	G-F-E	NA	VM	NR	C	NE	T-W	R	NT
Passerina cyanea	PC	F	F-A	U	VM	NR	C	NE	T-W	R	NT
Icteridae											
Dives dives	PC	F	F-G-A	A	G	NR	C	NE	R	C	NT
Quiscalus mexicanus	PC	F	F-G-A	A	G	NR	C	NE	R	C	NT
Molothrus aeneus	PC	F	F-G-A	A	G	NR	C	NE	R	C	NT
Icterus spurius	PC	F	FA	M-C	G	NR	C	NE	R	C	NT
Icterus cucullatus	PC	F	FA	M-C	VM	NR	C	NE	R	R	NT
Icterus gularis	PC	F	F-A	C	VM	NR	C	NE	R	R	NT
Icterus graduacauda	PC	F	F-A	M-C	G	NR	C	NE	R	U	CC
Icterus galbula	PC	F	F-A	M-C	G	NR	C	NE	R	R	NT
Fringillidae											
Carpodacus mexicanus	PC	S	G-A	C	VM	NR	C	NE	R	R	NT
Carduelis notata	PC	S	G-A	C	B	NR	C	NE	R	F	NT
Carduelis psaltria	PC	S	G-A	C	VM	NR	C	NE	R	R	NT