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## Avian use of Gmelina arborea plantations in southwestern Costa Rica

Allison Mains

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To the Graduate Council:

I am submitting herewith a thesis written by Allison Mains entitled "Avian use of Gmelina arborea plantations in southwestern Costa Rica." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Ecology and Evolutionary Biology.

David A. Buehler, Thomas G. Hallam, Major Professor

We have read this thesis and recommend its acceptance:

Arnold M Saxton, A. C. Echternacht

Accepted for the Council:


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Vice Provost and Dean of the Graduate School

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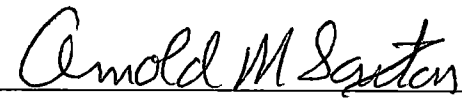
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Thomas G. Hallam, Department Head

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Accepted for the Council:

  
\_\_\_\_\_  
Associate Vice Chancellor and  
Dean of The Graduate School

**Avian Use of *Gmelina arborea*  
Plantations in Southwestern Costa Rica**

A Thesis

Presented for the

Master of Science

Degree

University of Tennessee, Knoxville

Allison R. Mains

August 2000

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## ABSTRACT

Tropical forests are disappearing at an accelerated rate due to increasing human development. In Costa Rica, reforestation of agricultural areas is occurring with plantations of an exotic, fast-growing hardwood tree, *Gmelina arborea*. Research on tropical plantations and their effect on local avifauna is severely lacking. Information is critically needed concerning whether or not these plantations can play a role in sustaining tropical avian communities. To help fill this need, we conducted 50-m point counts in May-July, 1998 and 1999 within stands of *Gmelina*, as well as within pastures and native forests. Avian community patterns were assessed according to different age classes and landscape contexts of *Gmelina* stands. In addition, community patterns of the plantations were compared with avian communities in stands of native forest and pastures. Habitat analyses within the plantations were conducted to identify stand features related to avian use.

Mean abundance (A) per point differed across community types (*Gmelina*, pastures and native forest) but not amongst *Gmelina* age classes. In 1998, A was greater in pastures and native stands (13.4, 9.6 individuals per point, respectively) than in young (1 year; 5.6), intermediate (2-5 years; 3.6), or old (6-9 years; 4.1) *Gmelina* stands. In 1999, pastures (23.9) contained the greatest A above that found in any of the other forested areas, followed most closely by native stands (11.9). Both richness (R, number of species), and diversity (D, Shannon-Weaver) per point differed among the age classes of *Gmelina* and among the community types. Young stands contained a greater R (3.9) and

D (1.0) than did the intermediate age class (1.06, 0.4) or the old age class (1.9, 0.5). R and D in all *Gmelina* stands were less than R and D in pastures (7.2, 1.6). R and D in intermediate and old stands were less than R and D in native stands (4.7, 1.3).

In 1998, community similarity was strongest between young stands and pastures (42%) and *Gmelina* stands compared amongst themselves (37%-56%). Similarity of old *Gmelina* stands compared with native stands was weak (23%). Again in 1999, young stands and pastures showed the strongest similarity (50%). Similarity amongst *Gmelina* stand age classes was weaker than that in 1998 (26% - 48%). Similarity between old stands and native stands was slightly stronger (29%).

In 1998 and 1999, abundance (A) in *Gmelina* stands adjacent to native forests (ADJ; 7.3, 9.3) did not differ from native stands (9.6, 11.9) in either year. In both years, pastures contained a greater A (13.4, 24.0) than any *Gmelina* stands (4.0 - 9.3). R was greatest in pastures (7.3) and lowest in *Gmelina* stands surrounded by other *Gmelina* (GMEL; 1.8) and *Gmelina* stands isolated from other forested areas (ISOL; 1.7). R in ADJ stands (3.4) did not differ from native stands (4.8). Mean D was greatest in pastures (1.6) and native stands (1.4) and lower in ADJ stands (1.0). GMEL (0.5) and ISOL (0.5) stands contained the lowest D.

In 1998, community similarity was greatest between ADJ and native stands (55%) and amongst *Gmelina* stands (39% - 44%). In 1999, similarity was greatest between ADJ and native stands (42%), ISOL and native stands (41%) and amongst *Gmelina* stands (40% - 50%).



Insectivorous birds predominated in all community types. Frugivorous species and individuals were more prevalent in forested sites and especially so in native forest stands. Granivorous and omnivorous species were more prevalent in the pastures than they were in the wooded sites.

Habitat features were measured and correlated with the avian distribution patterns observed. Differences in vegetative structure amongst *Gmelina* stands and community types were variable within and across years. Stands where understory structure was greater tended to be more diverse.

Implications for the role of plantations in avian conservation, such as stand vegetative features and landscape context, are discussed. Maintaining heterogeneity and vegetative structure within and around stands may help increase bird diversity. Establishing plantations in cleared areas with close proximity to native forests will provide additional forest cover, which may in turn enhance local bird diversity. The use of plantations in ecological restoration and regeneration of native forests is also presented.

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## CHAPTER 1

### INTRODUCTION

Tropical regions are characterized as being globally valuable because of the high degree of biodiversity, including the great number of endemic species contained within them. Of the terrestrial habitats in the tropics, biodiversity is greatest in rain forests (Wilson 1992, Kramer and van Schaik 1997). Although tropical rain forests cover less than seven percent of the earth's land surface, they harbor more than half of all known species (Wilson 1992, MacKinnon 1997). Human population growth and the subsequent increase in urbanization, agricultural practices, and the demand for wood products have resulted in the removal of large tracts of primary rain forest. Over the last century, the amount of global tropical rain forest habitat has diminished to about half its original area; approximately 170,000 km<sup>2</sup> have been lost every year (MacKinnon 1997). Because of this deforestation and in light of the high degree of endemism, tropical rain forests contain a great proportion of threatened species of mammals and birds. Thus, conservation biologists have focused on these habitats as areas of high priority for protection.

Recent focus has centered on the impacts of deforestation in tropical regions of Latin America. Costa Rica, which currently gives priority to forest preservation through the establishment of the National Park System, wildlife refuges, and forest reserves, is an example of a country that is working to reverse its deforestation trends. Forests may have covered over 96% of Costa Rica prior to European settlement (Keogh 1984). Accelerated

clearing of forests began with the arrival of Spanish settlers in the 19<sup>th</sup> century. Population growth and the subsequent need for subsistence farming resulted in the removal of primary forests. Construction of the Pan-American Highway during WWII led to additional deforestation and facilitated increased commercial timber harvest (Parsons 1976, Veldkamp et al. 1992) By 1943, forest cover had decreased to 76.5% of the total area, suggesting an average deforestation rate of 12,000 ha/yr (Keogh 1984) (Figure 1; all figures are located in Appendix A). However, the greatest rate of deforestation occurred from 1943 to 1977. During this time, exportation of agricultural products provided strong contributions to the Costa Rican economy, causing a shift in economic policies (Parsons 1976, Lehmann 1992, Wendland and Bawa 1996). These policies provided incentives for landowners to “improve” their land by clearing the forest for cattle and annual crops. Forest cover decreased to 41.7% by 1977, an average rate of loss of 52,000 ha/yr (Keogh 1984). By the mid 1970’s, more than one third of the country had been cleared for cattle grazing. Based on satellite image interpretation, primary forest decreased to 17% by 1983 (Sader and Joyce 1988, Sader et al. 1991). Keogh (1984) predicted that this deforestation would render Costa Rica to be without primary forest cover by the end of the first quarter of the twenty-first century.

In the early 1980’s, deforestation rates in Costa Rica were the highest in Central America (Hartshorn 1992, Nygren 1995). In light of this, a number of programs were initiated to promote natural forest protection, management, and regeneration (Lehmann 1992, Wendland and Bawa 1996). Of the primary forest remaining in 1991, nearly 70% was under protection of some type. As of 1996, a total of 109 areas had been designated



as conservation areas. These protected areas encompassed 29% to 36% of total land area, but were not necessarily completely composed of primary forest (Wendland and Bawa 1996). As of 1992, secondary forests comprised approximately 3.8% of the total land area (400,000 ha). Unprotected primary forests remain vulnerable (as of 1992, 3.8% of land area). These areas continue to be unsustainably harvested because of inadequate incentives and insufficient enforcement of forestry laws (Wendland and Bawa 1996). Thus, primary forest cover may ultimately be limited to that which is currently designated as protected.

With the aid of fiscal incentives, reforestation projects have become more prevalent in recent decades (Lehmann 1992, Wendland and Bawa 1996). In light of continued loss of native forests, it has become imperative to examine the impact that reforestation has on the biota so that effective conservation measures can be enacted. Included in these reforestation projects are commercial plantations designed for the timber and pulp industries. Few studies have explored the role that industrial tree plantations may play in sustaining the biota of the tropics. Many questions remain as to how the regional fauna responds to these managed forests.

Examination of avian community response to plantation forestry may be an effective method for learning how other faunal communities respond. Concern for avian conservation is rising, which has contributed to the establishment of well-developed census techniques. Because approximately 60% of terrestrial birds in Costa Rica depend on forests, their abundance has undoubtedly been affected by deforestation (Stiles and Skutch 1989). Concern remains for the adequacy of the protected areas to provide

sufficient habitat for forest-dwelling birds. Of specific consideration are the lowland areas located below the Atlantic and Pacific slopes (Stiles and Skutch 1989). These areas are largely unprotected and have been the target of deforestation for conversion to agricultural production. For example, the area from Golfo Dulce east to the Panamanian border is almost completely devoid of primary forest because forests were cleared and converted to pasture, rice fields, and banana and oil palm plantations. Wooded corridors from the parks of the lowlands to the protected montane areas are nonexistent, which jeopardizes those species dependent on elevational migration (Stiles and Clark 1989). The establishment of tree plantations is likely to have an effect on the regional community structure of the avifauna. The question remains as to what value the addition of forest cover through tree plantations has in supporting avifaunal communities.

In recent years, forest products companies have utilized deforested areas in tropical countries for tree plantations. One such company, Ston Forestal, has established plantations of a fast-growing, tropical hardwood tree, *Gmelina arborea*, in areas (2-350 ha) that had previously been cleared for agriculture. Virtually no efforts have been made to quantify and qualify the role that these plantation forests play in sustaining the southwestern Costa Rica avifauna. Questions arise such as what species utilize these plantations and in what way? Do forest-dwelling birds utilize these plantations? How might the context in which the plantations are planted influence the species that use them? What habitat features contribute to increased usage of the forests by resident birds?

The objectives of this project were to

- (1) describe avian community patterns (species diversity, species richness, abundance, community similarity and trophic guilds) in *Gmelina arborea* plantations located in southwestern Costa Rica based on:
  - (A) a comparison of differing age classes of the *Gmelina* stands amongst themselves and with pastures and stands of native forest,
  - (B) an assessment of the effects of the landscape context in which the *Gmelina* was planted,
- (2) evaluate habitat characteristics as they relate to the observed community patterns;
- (3) evaluate the feasibility of developing conservation strategies that incorporate plantations to enhance avian conservation.

**LITERATURE REVIEW**  
**AVIAN USE OF TROPICAL PLANTATIONS**  
**CHAPTER 2**

The available literature describing resident avian community patterns in tropical plantations confirms weak but increasing attention to this area. Studies involve plantations in both the Old and New World tropics and include a variety of tree species either exotic or native to the study region. Most projects were performed in areas where native forests were removed expressly for the purpose of establishing tree plantations. Thus, the primary objectives of most research involve an evaluation of how similar the bird communities were between the plantations and the native forests that they replaced.

**Avian Distribution Patterns in Tropical Plantations**

Pine (*Pinus caribaea*, *P. radiata*), eucalyptus (*Eucalyptus grandis*, *Eucalyptus spp.*), and teak (*Tectona grandis*) are several species that have been used widely in plantations in tropical nations. Bird species abundance (Carlson 1986, Pomeroy and Dranzoa 1998, Petit et al. 1999), richness (Hayes and Samad 1998), and diversity (Petit et al. 1999) were typically lower in pine plantations than that recorded in native forests of the same region. However, some abundance measures in pine stands were comparable to those found in native forests (Hayes and Samad 1998). Results were similar in eucalyptus plantations that typically supported less diversity than local native forests (Daniels et al. 1990, Pomeroy and Dranzoa 1998). In one study, eucalyptus stands were more diverse

than pine plantations surveyed (Pomeroy and Dranzoa 1998) The five-year rotation cycles of many eucalyptus stands left little time for a complex vegetative structure to become established and, thus, the bird communities supported were relatively limited (Daniels et al. 1990). Likewise, teak stands were also found to be less species rich and diverse (Beehler et al. 1987)

However, not all studies have revealed such depauperate avian community structure. Betelnut (*Areca catechu*) (Daniels et al. 1990) and *Albizia falcataria* (Mitra and Sheldon 1993), other commonly used trees in tropical plantations, and one study with teak (Daniels et al. 1990), have documented avian communities that approach avian diversity supported by native forests The betelnut and teak plantations of these studies had rotation lengths of 50 years or more, and thus, were allowed to mature in such a way that they attained bird diversities comparable to neighboring natural forests (Daniels et al. 1990). Although the *Albizia* plantations were harvested on a much shorter rotation, the older stands were found to harbor similar diversity and richness as compared to the native forests nearby (Mitra and Sheldon 1993).

### **Community Composition**

Measurements of species richness and diversity are important for determining distribution patterns, but such indices do not describe the community composition. Although plantations may share a similar richness with native forests, the communities within the two may be dissimilar (Daniels et al. 1990). Therefore, it is important to evaluate and compare species composition among the habitats. Forest generalists were

typically found to predominate within most plantation types while forest specialists were rare (Carlson 1986, Beehler et al. 1987, Daniels et al. 1990, Hayes and Samad 1998, Pomeroy and Dranzoa 1998). Support of forest generalists in plantations may be of more limited conservation value because these species are not as dependent on specific habitat features.

Examining the trophic guild structure of bird communities in tropical plantations provides additional information regarding how birds use plantations. Insectivorous birds were most commonly found to be the predominant feeding guild in tropical plantations (Beehler et al. 1987, Daniels et al. 1990, Petit et al. 1999). In one case, nectarivorous birds composed a great portion of the avian community in pine stands (Hayes and Samad 1998). However, the authors believed this result to be misleading because of the lack of data concerning actual avian resource use. Because monocultures offered little heterogeneity in the availability of fruits, there tended to be less frugivorous birds (Beehler et al 1987, Daniels et al. 1990, Mitra and Sheldon 1993). In addition, granivorous birds did not show strong representation in plantations with the exception of young stands of *Albizia falcataria* (Mitra and Sheldon 1993).

### **Habitat Characteristics**

Simple understory structure and limited heterogeneity are commonly cited as reasons for reduced avian species diversity in tropical plantations (Carlson 1986, Daniels et al. 1992, Hayes and Samad 1998, Petit et al. 1999). Typically, plantations contained a less developed understory than native forests of the same study (Carlson 1986, Beehler et

al. 1987, Mitra and Sheldon 1993, Hayes and Samad 1998, Petit et al 1999) Because plantations possessed vegetative structure less complex than native stands, fewer niches were available to attract birds. Additionally, plantations that were intensively managed contained lower species richness than those that were not managed (Pomeroy and Dranzoa 1998) Because areas with simple vegetative structure lack food resources or appropriate foraging substrates and nesting sites, native birds utilize them to a lesser degree (Carlson 1986, Cruz 1988).

In eucalyptus and pine plantations of East Africa, stands were found to possess understory structure comparable to native forests (Pomeroy and Dranzoa 1998). Thus, understory structure did not explain the lower avian diversity of the plantations. In addition, the quantity of insects was comparable in plantations and native forests. The authors concluded that arthropod species composition was different in such a way that the birds had not adapted to using them as a food resource. Therefore, the birds were less likely to survive there (Pomeroy and Dranzoa 1998).

Proximity to native forests is also an important consideration in evaluating avian diversity in tropical plantations. The closer a plantation was to intact native forest, the greater the number of birds and bird species that were observed (Daniels et al. 1990, Mitra and Sheldon 1993, Pomeroy and Dranzoa 1998). The resources of the nearby native forests apparently supported bird populations in these plantations. In light of this, it is important to understand what effect these plantations have on bird populations. Little, if any, research has been done to qualify the role that plantations near native forests have on the source/sink dynamics of breeding birds in tropical regions

## **CHAPTER 3**

### **STUDY AREA**

The development of Ston Forestal (SF), a subsidiary of Stone Container Corporation (SCC), began in 1989 with the initial purchase and conversion of a 1000-ha cattle farm and banana plantation, Finca Salamá. Since then, SF has leased over 200 sites located on privately owned farms and has converted them into tree plantations. SF has maintained all existing naturally forested areas including individual trees. These sites range from 2 to over 350 ha and occur in a variety of settings from coastal plain to montane landscapes. The total area incorporated into SF's forestry project includes over 24,000 ha, managed on a six to nine year rotation.

The study area, characterized as tropical wet forest, is located in the Golfo Dulce region on the Pacific side of southern Costa Rica. During the months of May through July, average temperature is 27° C and average rainfall is 40 cm. Corcovado National Park (41,788 ha), located on the Osa Peninsula, remains the only area in this region with extensive protected native forest. The landscape of the southwestern region has been largely deforested and is dominated by agricultural uses including rice, bananas, oil palm, and cattle grazing.



### ***Gmelina arborea* description**

A member of the family Verbenaceae, *Gmelina arborea* is a tropical hardwood tree (for botanical description see Bolstad and Bawa 1981, Greaves 1981). Its native range extends from eastern Pakistan to the southern provinces of China and includes India, Bangladesh, Myanmar (formerly Burma), Sri Lanka, Thailand, Laos, Kampuchea, and Vietnam. Characteristically, *Gmelina* is not a common tree and is found sparsely distributed throughout deciduous forests. As a short-lived tree, it generally grows in gaps where the ground has been disturbed (Greaves 1981). Its distribution is most commonly found between 90 and 900 m in elevation, but is found as high as 1500 m. Diameter under natural forest conditions averages 70 cm (but can reach 150 cm) with a height of 30 m in moist mixed forests (Greaves 1981). Tree dimension decreases with decreasing moisture regimes. *Gmelina* is most productive in moist valleys with fertile, well-drained soils (Greaves 1981). Mean annual rainfall in its distribution ranges from 76 cm to 450 cm and the temperature ranges from  $-1^{\circ}$  C to  $16^{\circ}$  C. *Gmelina* sheds its leaves from January to March and flowers at the end of this time. The abundant drupe fruits ripen between April and July and germinate during the rainy season (May-November). Pollination occurs through various species of bees and other insects (Greaves 1981)

Because of its success in tropical climates, *Gmelina* has been used in commercial plantations in the countries bordering its native distribution, as well as in Africa, and Central and South America. In Costa Rica, the ecology of the tree mimics that in its native range. It favors gaps and disturbed areas with minimal regeneration under its own canopy. It is a poor competitor with grasses and other early successional species (D.

Zeasar, pers. comm ). However, it has been found growing in pastures due to ingestion and dispersal of fruits by cattle and deer (*Odocoileus virginianus*). The popularity of *Gmelina* as a plantation tree lies in its rapid growth. It reaches a height of approximately 30 m and a diameter of 30 cm in less than 9 years. *Gmelina* is mostly used for pulp and low quality wood products, such as pallets.

### **Site description**

The *Gmelina* plantations used in this study were scattered across the southwestern region (Figure 2). Twelve plantations were located on Finca Salamá (all stands used in age analysis and oldest stands used in context analysis), elevation of 10 m, located approximately 10 km northwest of the town of Chacarita and 80 km northwest of Golfito. The ranch was a 1000-ha land purchase with a history of banana plantations and cattle grazing. At one time, a railroad system transected the property for service to the banana industry. An abandoned airstrip was located north of the ranch alongside a remnant active banana plantation. The *Gmelina* plantations laid in a contiguous block of differing age classes. The ages of the plantations ranged from less than one year old to nine years of age. Plantation sizes ranged from 1 ha to 115 ha. Because of previous agricultural practices, numerous ditches were present throughout the plantations, most of which held water in the rainy season (July to November). A number of roads transected the ranch as service to the plantations for logging and general maintenance. Interspersed throughout the plantations were remnant native trees such as *Cecropia* (*Cecropia* spp) and large patches of bamboo established during the banana plantation operations. Several

tributaries of the Río Sierpe ran through the ranch creating riparian zones with native vegetation buffers ranging from 20-50 m in width. Understory in older plantations (6-9 years) was dense and 1-3 m in height. Young plantations (1 year) consisted of an understory of dense grasses reaching up to 2 m in height in some sites.

The Río Sierpe ran along the southern and western edges of the ranch, creating a marshy habitat along these borders. Interspersed throughout this area were active rice fields, abandoned fields, and grazed pastures. Beyond the marshy area to the south, were thousands of hectares of forest reaching elevations of nearly 300 m. The northern edge of the area was bordered by the Pan-American Highway. Above the highway was a large block of native forest, reaching elevations in excess of 400 m. To the east of the ranch, the area became increasingly more populated approaching Chacarita. Most of the land holdings included modest houses with small-scale farming. Beyond the marshy area to the northwest and approaching Palmar Norte, approximately 20 km northwest of Salamá, the situation was similar to that of Chacarita.

One stand (BA; used as ADJ = stand adjacent to native forest) was located in the area north of the Pan-American Highway directly adjacent to Salamá. The tributary, Río Salamá Viejo, ran through the stand creating a buffer of native vegetation. In addition, a powerline transected the plantation. To the north and east was a large contiguous block of native forest. The understory of this plantation was tall and dense and many remnant native trees were interspersed throughout.

Two stands (EB and EC; used as ISOL = stand isolated from other forested areas) were located in Palmar Sur (elevation 10 m). This area was highly agricultural in nature

with large blocks of oil palm and banana plantations as well as pasture and rice fields. An active airstrip was located in this area for use of rice crop dusting. To the north of the plantations was a small community and interspersed between the plantations were houses with small-scale farming. The areas were bordered to the east by wetlands and to the south by Río Sierpe. Separating the two stands was a river tributary and oil palm plantations. The western edge of the area was dominated by a complex system of rivers and associated wetlands. Within the plantations, the understory was sparse with low height in some areas whereas in other areas it was relatively dense and approximately 2 m in height. Indicative of an agricultural history, many remnant ditches ran through both areas.

Two stands located in Rincón (AC and AI; used as ADJ stands) were planted in pastures amidst remnant native forest with elevations of nearly 300 m. These areas were located to the south of Salamá and bordered on the south by a highway. Both sites were directly adjacent to native forest to the west that was being selectively logged in both survey years. The understory was dominated by a thick growth of ferns in many areas and with grasses and small shrubs in others. Both sites were situated on slopes. The Golfo Dulce was located to the south.

Two stands were located on the Osa peninsula (IB and IC; used as ISOL stands) near the town of Puerto Jiménez, located at sea level. Both sites were situated in a landscape heavily dominated by agriculture and used mostly for grazing. Several small creeks ran through one site (IC), which were buffered by native vegetation of variable height. The understory in both stands was relatively sparse and reached an average of 1 m

in height in most places. A number of large native trees were dispersed throughout both sites.

Two stands (MD and MA; used as ADJ stands) were located near the city of Río Claro approximately 35 km southeast of Salamá. The elevation ranged from approximately 100 to 200 m depending on the site. Both plantations were located northeast of and adjacent to the Pan-American Highway. Several small houses existed nearby. To the north of these sites were small remnant blocks of native forest. One site was dominated by thick patches of ferns in most places while the other consisted of a thick, shrubby understory, 2-3 m in height. Both sites contained large native trees interspersed throughout and were located on significant slopes.

Two young stands (SV and SW) were located to the east of Río Claro at elevations of about 100 m. One stand (SV; used as young stand in 1998 and intermediate in 1999) was located directly adjacent to the Pan-American Highway and surrounded by a system of small-scale agricultural plots such as oil palms. This site was also located near an older *Gmelina* plantation. The understory was very sparse and consisted mostly of grass. The other stand (SW; used as young stand in 1998) was located in a remote area where cattle grazed and oil palm dominated the landscape. This site contained a denser understory, but was still dominated by grasses.

Two stands (BP and BS; used as ADJ stands) were located approximately 7 km west of Salamá at elevations of 200-300 m. To the north and east of these sites were small blocks of remnant native forest as well as small houses and cattle ranches. One site (BS) was also adjacent to oil palm plantations. Both sites contained a dense understory in most

places with an average height of about 2 m. Both sites contained small rivers bordered by native trees. Both sites were situated on slopes

One stand (ID; used as ADJ stand) was located north of the Golfo Dulce at an elevation of 400 m. The stand was directly adjacent to extensive native forest. To the north, the site was bordered by Laguna Chocuaco. The site consisted of a number of native trees interspersed throughout the stand. There were several marshy areas as well as small creeks within the plantation. The understory was diverse in that some areas were characterized by dense patches of fern while others contained sparse shrubs of about 1 m in height. In addition, the site was situated on a slope.

A total of three agricultural areas (approximately 30 to > 100 ha) were surveyed each year. Two sites were surveyed both years while the third site surveyed differed between years. The two areas surveyed both years were located to the south and west of Salamá. One site was a wet, fallow pasture, overgrown with grasses and directly adjacent to a *Gmelina* plantation and a rice field. The other site was an active pasture with numerous native trees interspersed throughout the fields and to the east it was adjacent to an extensive rice field. In addition, a tributary to the Río Sierpe bisected the pasture. The third pasture used in 1998 was an active pasture, small in size with a hedgerow bisecting the middle and was adjacent to stands of *Gmelina* and oil palm. This site was not surveyed in 1999 due to logistics. The third site used in 1999 was located in Palmar Norte. It was an active pasture surrounded by houses and various buildings with a rice field directly adjacent.

Two primary forest sites (approximately 100 ha to >200 ha) were surveyed in 1998 and 1999. One site was adjacent to the site BA (see description above) and was located north of Salamá. This area reached an elevation in excess of 250 m at some points of the surveyed area. The second site surveyed in both years was adjacent to the site AI (see description above) at an elevation of 100 m. An additional stand was surveyed in 1999 (approximately 100–200 ha). This stand was adjacent to the plantation ID (see description above) reaching an elevation in excess of 350 m. The vegetation in all three areas was characterized by a thick understory with an average height of 3 m but sometimes continuous to the canopy. All three sites were situated on steep slopes and small streams were located throughout.

## CHAPTER 4

### METHODS

#### **Stand selection**

We selected stands based on three criteria: stand area, age, and landscape context (Table 1; all tables are found in Appendix A). All selected stands were at least 23.9 ha containing a minimum of 3 avian point-count stations. We placed a maximum of 10 point-count stations in stands over 100 ha. Stand shape was variable, with some stands containing narrow strips of *Gmelina* unsuitable for surveying.

Stand ages ranged from 1-9 years and were grouped into three age classes: young (1 year), intermediate (2-5 years), and old (6-9 years). The age classes were structurally distinct based on diameter of the *Gmelina* trees. All stands used in the test of age effects, with the exception of two, were located at Finca Salamá. Due to limited availability of young stands, 2 stands in 1998 and 1 in 1999 were surveyed off of Finca Salamá in the region of Río Claro. In 1998, 3 young stands, 3 intermediate stands and 6 old stands were surveyed. Stand development resulted in a shift in age class and several stands were harvested between the sampling years. Thus, in 1999, 3 young stands, 4 intermediate stands, and 5 old stands were surveyed.

We also selected mature stands based on three different landscape contexts: stands in a context of other *Gmelina* (GMEL), stands adjacent to native forests (ADJ), and stands that were isolated from other forested areas (ISOL). GMEL stands were



located on Finca Salamá which was comprised of a 1000-ha block of *Gmelina* stands. ADJ stands were contiguous on at least one side with primary forest of varying sizes (approximately 30 to >1000 ha). ISOL stands were located in a landscape dominated by agriculture, such as cattle grazing, oil palm, rice, or bananas. All *Gmelina* stands for this comparison were 5-9 years old. We surveyed 7 GMEL stands at Finca Salamá, 7 ADJ stands, and 4 ISOL stands in 1998. In 1999, we surveyed 6 GMEL stands, 5 ADJ stands, and 4 ISOL stands. Three sites classified as pasture were sampled both years. The location of one pasture differed between years. Two primary forest stands were sampled in 1998; one additional native stand was included in 1999 to increase the sample size to 3 sites.

### **Vegetation sampling**

Habitat parameters (Table 2) were evaluated at each point-count station within each stand with the exception of points located in pasture. Basal area was measured using a 2.5 factor metric prism. All trees, native and *Gmelina*, identified as "in" with the prism were measured for diameter at breast height (DBH) and used to calculate an average DBH. Canopy cover (percent) at each point was measured using a spherical densiometer at 5.6 m from plot center in each cardinal direction. The four values were averaged for each point. For canopy height, one tree that was representative of stand height was measured using a clinometer. Vertical understory cover was characterized with the use of a cover density board (2.0 x 0.8 m) placed at 5 m from the census plot center in each of the four cardinal directions. The average height of the vegetation within that 5 m distance

was also visually estimated. Each point was characterized as being an edge point if it was 50 m from a road, riparian zone, powerline, agricultural field, an area of secondary growth, or native vegetation. Interior points were those located greater than 50 m from an edge. Presence of riparian zones, primary edges, secondary edges (stands of *Gmelina* with similar height), and non-*Gmelina* trees that contributed to the canopy were noted if they were within 150 m of the point count station. Percent slope and slope aspect were measured using a clinometer and a compass at each point.

### **Bird point count sampling**

We sampled each stand using 50-m-radius point counts (Reynolds et al. 1980, Hutto et al. 1986, Whitman et al. 1997). Points were established along trails under closed canopies or in the interior of the forest. In addition, all points were at least 50 m from any edges (riparian zones, roads, powerlines, native vegetation, agricultural fields) and at least 150 m from each other.

Surveys were completed during the height of breeding from 26 May to 29 June, 1998 and from 27 May to 3 July, 1999. In both years, each stand was sampled twice with all stands being surveyed once before any stands were resurveyed. Thus, approximately three weeks passed between samples.

Point count surveys began at 5:15 a.m. CST and were completed before 10:00 a.m. (Verner and Ritter 1986, Blake 1992). Within years, each point was surveyed by different observers to decrease bias. If two stands were sampled in one morning, the survey order of the stands was reversed on the second visit. In addition, during the second

visit, points were censused in reverse order to reduce any temporal bias associated with bird activity (Verner and Ritter 1986, Blake 1992). Each point was censused for a total of ten minutes. All birds detected by sight and/or sound were recorded. The distance from the observer to the location of each bird was recorded in one of four categories: within 50 m, more than 50 m but within the stand, outside of the stand, or flyovers. Each bird was identified to species or to the next highest taxonomic level possible (e.g., hummingbird). All other individuals were recorded as unknowns. Environmental variables such as temperature, wind speed, rain, and cloud cover were recorded at each point.

Biases of the point count method include greater detection of non-cryptic and vocal individuals (Wiens 1989). Most of the unidentified individuals occurred in the native forests (19.2%), followed by the *Gmelina* stands (9.5%) across all age classes and landscape contexts. The fewest unknowns occurred in the pastures (5.6%) where visual detection was obstructed by a dense groundcover of grass. As compared to the pastures, visual detection was much more difficult in wooded sites, especially the native stands, and therefore, a greater proportion of the avifauna went undetected or unidentified to species.

## **Data analysis**

### **Habitat Vegetation Characteristics**

Analysis of variance (ANOVA) was performed to establish which of the thirteen habitat parameters differed by *Gmelina* age class, landscape context, and community type (only native and *Gmelina* stands were used) (SAS Institute, Inc 1997, 1999). Least square

means were calculated to evaluate the trends in habitat characteristics so that possible correlation with avian distribution patterns could be identified.

### Avian Community Patterns

#### *Abundance, Richness, Diversity*

We calculated three indices of bird presence for comparisons across stands using the data within 50 m only. Bird abundance (A) was the total number of individuals heard or seen within the 50-m-radius plot at each point. Species richness (R) was the total number of known species observed in each 50-m-radius plot. Species diversity (D), which accounts for the proportion of identified individuals of each species, was calculated using the Shannon-Weaver index (Peet 1975):

$$H' = -[\sum p_i \text{Log}(p_i)], \text{ where } p_i \text{ is the proportion of individuals of the } i\text{th species.}$$

We calculated A, R, and D for each point of each stand for each date surveyed.

We performed an ANOVA using a repeated measures general linear model to test for differences ( $\alpha = 0.05$ ) in least square means of A, R, and D among stands of different age, landscape context, and cover type (SAS Institute, Inc 1997, 1999). We used point type (edge or interior) as a covariate to explain some of the variability observed across points. We tested for a year effect for each index and pooled the data across years if there were no significant effects ( $p > 0.05$ ). The ANOVA tested the following null hypotheses:

- (1) mean A, R, and D did not differ among *Gmelina* stands according to age class or in comparison with pastures and native stands;

(2) mean A, R, and D did not differ among *Gmelina* stands according to landscape contexts or in comparison with pastures or native forests.

Evaluation at the stand level is valuable because estimates of avian use at individual point counts may underestimate species richness and diversity. However, the sampling effort across sites was unbalanced (ranging from 3 to 10 points) making a comparison at the stand level difficult. Therefore, we generated rarefaction curves to estimate the number of species expected based on the smallest number of individuals sampled in any one site (Simberloff 1972, James and Rathbun 1981, James and Warner 1982) with the assumption that, spatially, birds were distributed randomly. The expected number of species is calculated as:

$$E(S_n) = \sum_{i=1}^s \left[ 1 - \frac{\left[ \frac{N-N_i}{n} \right]}{\left[ \frac{N}{n} \right]} \right]$$

where  $E(S_n)$  = expected number of species,  
 $S$  = total number of species in survey,  
 $N$  = number of individuals in original sample,  
 $N_i$  = number of individuals in species  $i$ , and  
 $n$  = random sample of  $N$  individuals.

The right-hand term is the probability that the random sample of  $n$  individuals will not include species  $i$ . In turn, the expected number of species equals the sum of the probabilities that each species will be included in the random sample.

We used an ANOVA to test for significant differences ( $\alpha = 0.05$ ) of richness across stands using the expected number of species generated from the rarefaction calculations (SAS Institute, Inc 1997, 1999). The null hypotheses tested for the rarified richness index were the same as previously stated for the point level analyses

### *Percent Similarity*

We calculated percent similarity for each survey year to examine overlap of bird species among community types (Krebs 1999):  $P = \sum \text{minimum}(p_{1i}, p_{2i})$

where  $P$  = percentage similarity between samples 1 and 2,

$p_{1i}$  = percentage of species  $i$  in community sample 1, and

$p_{2i}$  = percentage of species  $i$  in community sample 2.

These comparisons consisted of the following for 1998 and 1999, respectively:

- (1) Young, intermediate, and old *Gmelina* stands with each other and with pastures and native stands; and
- (2) *Gmelina* stands within a landscape context of other *Gmelina* stands (GMEL), adjacent to native forest (ADJ), and isolated from other wooded areas (ISOL); these stands were also compared with pastures and native stands.

### *Trophic Guild Representation*

We assigned bird species to trophic guilds based on feeding habits (Karr et al. 1990) (scientific names and trophic assignment of all bird species observed are given in Appendix B). Where trophic designation was not reported in the literature, assignment

was made based on field observations and familiarity with the species in question. For each community type, we calculated the percentage of individuals and the percentage of species in each of the feeding guilds. Carnivores, piscivores and carrion eaters were combined into a miscellaneous category. Birds recorded as unknown were not included in either evaluation with the exception of unknown hummingbirds. Because all the hummingbirds were classified as nectarivorous/insectivorous, they were included in the analysis at the level of individuals but not species. We performed chi-square analysis to test the null hypothesis that percent composition across feeding guilds was independent of community type (SAS Institute, Inc 1997, 1999). These comparisons consisted of the following:

- (1) young, intermediate, and old *Gmelina* stands with each other;
- (2) *Gmelina* stands, according to their landscape context with each other; and
- (3) *Gmelina* stands with pastures and native stands.

## CHAPTER 5

### STAND AGE CLASS RESULTS

#### **Habitat characteristics**

Basal area (BA) differed among age classes and between *Gmelina* and native stands in 1998 (Table 3a). The greatest BA occurred in the oldest *Gmelina* stands (36.0 m<sup>2</sup>/ha) and native stands (35.0 m<sup>2</sup>/ha). BA in intermediate stands was less than that in old stands (28.2 m<sup>2</sup>/ha), and young stands had very limited BA (8.8 m<sup>2</sup>/ha) (Table C.1a).

BA differed among age classes and between *Gmelina* and native stands in 1999 (Table 3b). The greatest BA occurred in the oldest *Gmelina* stands (35.6 m<sup>2</sup>/ha), followed by lower BA in native stands (28.9 m<sup>2</sup>/ha) and intermediate stands (25.3 m<sup>2</sup>/ha), and minimal BA in young stands (0.3 m<sup>2</sup>/ha) (Table C.1a).

Average DBH of *Gmelina* trees (GDBH) differed among age classes in 1998 (Table 3a). The greatest GDBH occurred in the oldest *Gmelina* stands (27.5 cm), followed by intermediate stands (21.8 cm), and young stands (10.7 cm) (Table C.1b).

GDBH differed among age classes in 1999 (Table 3b). The greatest GDBH occurred in the oldest *Gmelina* stands (27.9 cm), followed by intermediate stands (19.1 cm). Young stands contained no measurable trees (<10 cm DBH) (Table C.1b).

Only old and native stands contained points with non-*Gmelina* trees in 1998 (5% of points in old stands). Of the stands with non-*Gmelina* trees present, average DBH of those trees (NDBH) did not differ between *Gmelina* and native stands (Table 3a). In



1999, NDBH (5% of points = young; 6% = int; 21% in old) did not differ (Table 3b, Table C 1c).

Average DBH of all trees (TDBH) differed among age classes and between *Gmelina* and native stands in 1998 (Table 3a) The greatest TDBH occurred in the native stands (46.0 cm) followed by old *Gmelina* stands (27.5 cm). Lower TDBH occurred in intermediate stands (21.8 cm), and minimal TDBH in young stands (8.9 cm) (Table C.1d).

TDBH differed among age classes and between *Gmelina* and native stands in 1999 (Table 3b). The greatest TDBH occurred in native stands (54.2 cm), followed by old (27.8 cm) and intermediate *Gmelina* stands (19.1 cm). Lowest TDBH occurred in young stands (5.3 cm) (Table C.1d).

Understory density (UD) differed among age classes and between *Gmelina* and native stands in 1998 (Table 3a). The greatest UD occurred in native stands (55.8%) followed by young *Gmelina* stands (40.7%) Lowest UD occurred in old stands (24.7%) and intermediate stands (16.0%) (Table C.1e). UD did not differ among age classes and between *Gmelina* and native stands in 1999 (Table 3b).

Understory height (UH) differed between *Gmelina* and native stands in 1998 (Table 3a). The greatest UH occurred in native stands (14.8 m). Lowest UH occurred in young (3.5 m), old (2.0 m), and intermediate stands (1.0 m) (Table C 1f). UH did not differ between *Gmelina* and native stands in 1999 (Table 3b).

Canopy cover density (CC) differed among age classes and between *Gmelina* and native stands in 1998 (Table 3a). The greatest CC occurred in the intermediate *Gmelina*

stands (95.8%), native stands (95.7%), and old stands (94.7%). CC was lower in young stands (44.3%) (Table C 1g).

CC differed among age classes and between *Gmelina* and native stands in 1999 (Table 3b). The greatest CC occurred in native (88.1%) and intermediate stands (86.0%). CC was lower in old stands (81.1%). Young stands contained no measurable canopy (Table C.1g).

Canopy height (CH) significantly differed among age classes and between *Gmelina* and native stands in 1998 (Table 3a). The greatest CH occurred in the native stands (33.5 m). CH was lower in old (21.3 m) and intermediate stands (20.3 m) and minimal in young stands (8.1 m) (Table C.1h).

CH differed among age classes and between *Gmelina* and native stands in 1999 (Table 3b). The greatest CH occurred in the native (30.7 m) and old stands (27.6 m). CH was lower in intermediate stands (17.7 m), and limited in young stands (3.0 m) (Table C.1h).

The presence of water within 150 m of point count stations did not differ across stands in 1998 ( $F = 2.3$ ,  $p = 0.0839$ ,  $df = 3$ ) but did differ in 1999 ( $F = 3.6$ ,  $p = 0.0172$ ,  $df = 3$ ) (Table C.1i). The proportion of points with the presence of water in 1998 was as follows: young = 58%; intermediate = 45%; old = 71%; and native = 30%. In 1999, it was as follows: young = 40%; intermediate = 53%; old = 65%; and native = 19%.

The presence of non-*Gmelina* trees near point count stations did not differ across *Gmelina* stands in 1998 ( $F = 0.4$ ,  $p = 0.7031$ ,  $df = 2$ ) or in 1999 ( $F = 1.2$ ,  $p = 0.3199$ ,  $df = 2$ ) (Table C.1j). The proportion of points with the presence of non-*Gmelina* trees in 1998

was as follows: young = 92%; intermediate = 82%; and old = 90%. In 1999, it was as follows: young = 85%, intermediate = 80%; and old = 94%

The presence of a primary edge near point count stations did not differ across stands in 1998 ( $F = 2.0$ ,  $p = 0.1268$ ,  $df = 3$ ) (Table C.1k) or in 1999 ( $F = 0.7$ ,  $p = 0.5367$ ,  $df = 3$ ). The proportion of points with the presence of a primary edge in 1998 was as follows: young = 100%; intermediate = 73%; old = 68%; and native = 60%. In 1999, it was as follows: young = 95%; intermediate = 93%; old = 91%; and native = 81%.

The presence of secondary edges near point count stations differed across *Gmelina* stands in 1998 ( $F = 6.6$ ,  $p = 0.0025$ ,  $df = 2$ ) but not so in 1999 ( $F = 0.5$ ,  $p = 0.6237$ ,  $df = 2$ ) (Table C.1l). The proportion of points with the presence of secondary edges in 1998 was as follows: young = 50%; intermediate = 82%; and old = 27%. In 1999, it was as follows: young = 50%; intermediate = 67%; and old = 56%.

## **Avian Community Patterns**

### Overall Patterns

The 539 point counts yielded a total of 114 species identified, and 3,527 individuals counted in *Gmelina* plantations across all age classes and all landscape contexts for 1998 and 1999 combined (Table 4). The 52 point counts in the native forests yielded 69 species and 593 individuals, and the 72 point counts in pastures yielded 74 species with 1,387 individuals.

### Abundance, richness and diversity patterns

Abundance differed between years, thus, the results are presented separately. Mean abundance per point differed between *Gmelina* stand age classes and community types in 1998 ( $F = 10.03$ ,  $p = 0.0008$ ,  $df = 12$ ) (Table 5a). Pastures (13.4) and native stands (9.6) contained the greatest number of individuals per point. Abundance was lower in young stands (5.6) than in pastures. Also, abundance was lower in old (4.1) and intermediate stands (3.6) than abundance in either pastures or native stands.

Mean abundance per point differed between *Gmelina* stand age classes and community types in 1999 ( $F = 24.98$ ,  $p < 0.0001$ ,  $df = 14$ ) (Table 5b). Pastures (23.9) contained the greatest number of individuals per point. Abundance was lower in native (11.9) and young stands (8.3) than it was in pastures. In addition, abundance was lower in old (6.2) and intermediate (4.9) stands than it was in either pastures or native stands.

There was no year effect on mean richness (number of species recorded per point). Therefore, results presented are pooled across years. Mean richness per point differed across *Gmelina* stand age classes and across community types ( $F = 16.05$ ,  $p < 0.0001$ ,  $df = 26$ ) (Table 6). Pastures contained the greatest number of species per point (7.2), followed by native (4.7) and young (3.9) stands. The lowest richness occurred in old (1.9) and intermediate (1.6) stands.

There was no year effect on mean diversity per point, thus, results presented are pooled across years. Mean diversity per point, calculated by the Shannon-Weaver index, differed across *Gmelina* stand age classes and across community types ( $F = 16.58$ ,  $p < 0.0001$ ,  $df = 26$ ) (Table 7). Pastures (1.6) and native stands (1.3) contained the greatest

diversity of species per point. Diversity in young *Gmelina* (1.0) was lower than diversity in pastures. The lowest diversity occurred in old (0.5) and intermediate (0.4) stands.

### Rarefaction

The expected number of species did not differ among age categories and community types in 1998 ( $F = 2.53$ ,  $p = 0.0955$ ,  $df = 4$ ) (Table 8). However, the expected number of species did differ among age categories and community types in 1999 ( $F = 4.94$ ,  $p = 0.0121$ ,  $df = 4$ ) (Table 8). Trends observed in mean richness per point count were less apparent by rarefaction. Expected number of species was greatest in young stands (12.2), native stands (11.6), and pastures (11.0). Expected number of species was lower in old stands (8.9) than it was in young or native stands. Intermediate stands (7.6) yielded a lower richness than richness in young stands, native stands, and pastures.

### Community Similarity

Among age classes in 1998, similarity was greatest between young and old *Gmelina* stands (56% overlap), followed closely by old and intermediate stands (53% overlap) (Table 9a). Percent similarity was lowest between young and intermediate *Gmelina* stands (37% overlap). Among the community types, young *Gmelina* stands were most similar to pastures (42% overlap). All other comparisons of *Gmelina* stands with pastures and native stands showed less than 30% overlap. Pastures and native stands also showed very little similarity (8% overlap).

Among age classes in 1999, similarity was greatest between intermediate and old *Gmelina* stands (48% overlap), followed by intermediate and young stands (32% overlap) (Table 9b). Similarity was lowest between young and old *Gmelina* stands (26% overlap). Among the community types, young *Gmelina* stands were most similar to pastures (50% overlap). All other comparisons of *Gmelina* stands with pastures and native stands showed less than 30% overlap. Pastures and native stands also showed very little similarity (5% overlap).

### Trophic Guilds

Insectivores (I, FI, NI, abbreviations of guilds are located in Figure 3) showed the strongest representation in all the community types. In addition, fruit eaters and seed eaters showed strong representation in some cases. In general, native stands harbored more frugivores than did other community types. Frugivorous and nectivorous insectivores were represented most highly in the forested sites. Pastures harbored more granivores and omnivores than did other community types.

In 1998, pastures contained species of all 9 guilds followed by young stands with 8 guilds (Figures 3a-e). Only 5 guilds were represented in the native stands. The proportion of species within each guild did not differ across stand type ( $X^2 = 43.9$ ,  $p = 0.079$ ,  $df = 32$ ). However, the proportion of individual birds in each guild did differ by stand type ( $X^2 = 845.4$ ,  $p = 0.001$ ,  $df = 32$ ). Old stands contained more FI individuals than expected while both intermediate stands and pastures were underrepresented. Pastures showed a strong representation for granivores and insectivores while old stands showed

an underrepresentation in these same guilds. Representation of NI individuals was greater than expected in both old and intermediate stands while the contrary was true for the pastures.

In 1999, representation was more variable (Figures 4a-e) Pastures again contained species in all 9 guilds, followed closely by young stands that contained 8 guilds. Intermediate stands carried the lowest with species in only 4 guilds. The proportion of species in each guild differed across stand type ( $X^2 = 46.9$ ,  $p = 0.044$ ,  $df = 32$ ). Likewise, the proportion of individuals in each guild differed across stand type ( $X^2 = 11311.3$ ,  $p = 0.001$ ,  $df = 32$ ). Native and old stands carried more frugivores than expected while pastures carried fewer than expected. Old and young stands were highly represented in the FI guild while pastures were underrepresented. Granivores were more strongly represented in the pastures while native and old stands were weakly represented. Intermediate and native stands carried more NI individuals than expected while for pastures the contrary was true. Pastures carried more omnivores than expected while old stands carried fewer.

### **Habitat use of individual species**

The following is a descriptive analysis of the habitat preferences of common species found in the *Gmelina*. Vulnerable species recorded within the *Gmelina* are mentioned as well. Of the 114 bird species found at point count stations within *Gmelina* plantations, 37 were shared with the native stands, 34 were shared with the agricultural sites, 26 were shared by all three, and 17 were found only in the *Gmelina*.

Within the young plantations the five most abundant species were the Black-striped Sparrow, the Blue-black Grassquit, the Variable Seedeater, the Smooth-billed Ani, and the Ruddy Ground-dove. Within the older stands, the most abundant species were Rufous-tailed Hummingbird, Red-crowned Woodpecker, Black-striped Sparrow, Scarlet-rumped Tanager, and Orange-billed Sparrow. Additionally, Black-hooded Antshrike, Chestnut-mandibled Toucan, Fiery-billed Aracari, Red-lored Parrot, and Tawny-winged Woodcreeper were also recorded as utilizing these stands. Although fairly common, their conservation status is considered as vulnerable at current deforestation rates (Stotz et al. 1996).

The most abundant birds in the pastures were Blue-black Grassquit, Great-tailed Grackle, Smooth-billed Ani, Black-bellied Whistling Duck, and Black-striped sparrow. The most abundant birds in the native forest were Chestnut-backed Antbird, Long-tailed Hermit, Mealy Parrot, Rufous Piha, and Short-billed Pigeon. Black-hooded Antshrike, Chestnut-mandibled Toucan, Red-lored Parrot, and Tawny-winged Woodcreeper, which are considered as vulnerable species, were also found within native stands (Stotz et al. 1996).



## CHAPTER 6

### STAND LANDSCAPE CONTEXT RESULTS

#### **Habitat characteristics**

BA differed among landscape contexts and between *Gmelina* and native stands in 1998 (Table 10a). The greatest BA occurred in the *Gmelina* stands surrounded by other *Gmelina* (GMEL) (35.1 m<sup>2</sup>/ha), native stands (35.0 m<sup>2</sup>/ha), and *Gmelina* stands isolated from other forested areas (ISOL) (33.3 m<sup>2</sup>/ha). BA was lower in *Gmelina* stands adjacent to native forest (ADJ) (29.3 m<sup>2</sup>/ha) than it was in GMEL stands (Table C.2a). BA did not differ between *Gmelina* and native stands in 1999 (Table 10b, Table C.2a).

GDBH differed among landscape contexts in 1998 (Table 10a). The greatest GDBH occurred in GMEL (27.0 cm) and ADJ stands (26.3 cm). GDBH was lowest in ISOL stands (22.2 cm) (Table C.2b).

GDBH differed among landscape contexts in 1999 (Table 10b). The greatest GDBH occurred in the GMEL stands (27.3 cm). Lower GDBH occurred in ISOL (22.6 cm) and ADJ stands (22.5 cm) (Table C.2b).

Of those stands with non-*Gmelina* trees in 1998 (GMEL = 4% of points; ADJ 21%; ISOL 26%), NDBH did not differ among landscape contexts and between *Gmelina* and native stands (Table 10a; Table C.2c). NDBH (11% of points in GMEL, ADJ, and ISOL) did differ in 1999 ( $F = 6.6$ ,  $p = 0.0017$ ,  $df = 3$ ) (Table 10b) The greatest NDBH

occurred in ISOL stands (166.7 cm). Lower DBH occurred in ADJ (56.3 cm), native (54.2 cm) and GMEL stands (31.5 cm) (Table C.2c).

TDBH differed among landscape contexts and between *Gmelina* and native stands in 1998 (Table 10a). The greatest TDBH occurred in native stands (46.0 cm), followed by ADJ (29.2 cm) and GMEL stands (27.1 cm). TDBH in ISOL stands (23.2 cm) was lower than that found in ADJ stands (Table C.2d).

TDBH differed between *Gmelina* and native stands in 1999 (Table 10b). The greatest TDBH occurred in native stands (54.2 cm). Lower TDBH occurred in GMEL (27.1 cm), ISOL (23.7 cm), and ADJ stands (22.7 cm) (Table C.2d).

UD differed among landscape contexts and between *Gmelina* and native stands in 1998 (Table 10a). The greatest UD occurred in native (55.8%) and ADJ stands (46.4%). UD was lower in GMEL (23.3%) than it was in native stands. UD was lowest in ISOL stands (21.5%) (Table C.2e).

UD differed among landscape contexts and between *Gmelina* and native stands in 1999 (Table 10b). Greatest UD occurred in native stands (35.1%). UD was lower in ADJ (27.1%) and GMEL stands (24.8%), and lowest in ISOL stands (14.2%) (Table C.2e).

UH differed among landscape contexts and between *Gmelina* and native stands in 1998 (Table 10a). Greatest UH occurred in native stands (14.8 m), followed by ADJ (3.6 m) and GMEL stands (1.9 m). Lowest UH occurred in ISOL stands (1.2 m) (Table C.2f).

UH differed between *Gmelina* and native stands in 1999 (Table 10b). Greatest UH occurred in native stands (8.2 m). UH was lower in GMEL (1.7 m), ADJ (1.7 m), and ISOL stands (1.2 m) (Table C.2f)

CC differed among landscape contexts and between *Gmelina* and native stands in 1998 (Table 10a). The greatest CC occurred in native (95.7%), ISOL (95.5%), and GMEL stands (95.5%). CC was lowest in ADJ stands (91.5%) (Table C.2g).

CC differed among landscape contexts and between *Gmelina* and native stands in 1999 (Table 10b). The greatest CC occurred in native stands (88.1%), followed by ISOL stands (82.8%). CC was lowest in GMEL (81.9%) and ADJ stands (69.7%) (Table C.2g).

CH differed between *Gmelina* and native stands in 1998 (Table 10a). The greatest CH occurred in native stands (33.5 m). CH was lower in ADJ (23.0 m), GMEL (20.9 m), and ISOL stands (20.3 m) (Table C.2h).

CH differed among landscape contexts and between *Gmelina* and native stands in 1999 (Table 10b). Greatest CH occurred in native (30.7 m) and GMEL stands (26.8 m). CH was lower in ISOL (22.9 m) and ADJ stands (22.4 m) than that in native stands. (Table C.2h).

Percent slope differed across stands in 1998 ( $F = 62.9$ ,  $p = 0.0001$ ,  $df = 3$ ). Slope was greatest in native stands (44.6%) ADJ stands were the only stands of the *Gmelina* that were situated on a slope (20.0%) (Table C.2i). Slope aspect also differed across stands in 1998 ( $F = 34.3$ ,  $p = 0.0001$ ,  $df = 3$ ) (Table C.2j). ADJ stands had a mean slope aspect of  $83^\circ$  while native stands had a slope aspect of  $91^\circ$ .

Percent slope differed across stands in 1999 ( $F = 105.4$ ,  $p = 0.0001$ ,  $df = 3$ ). Slope was greatest in native stands (41.4%) ADJ stands were the only stands of the *Gmelina* that were situated on a slope (24.0%) (Table C.2i). Slope aspect also differed across

stands in 1999 ( $F = 68.0$ ,  $p = 0.0001$ ,  $df = 3$ ) (Table C.2j). ADJ stands had a mean slope aspect of  $88^\circ$  while native stands had a slope aspect of  $85^\circ$ .

The presence of water within 150 m of point count stations differed across stands in 1998 ( $F = 3.8$ ,  $p = 0.0125$ ,  $df = 3$ ) and in 1999 ( $F = 3.9$ ,  $p = 0.0106$ ,  $df = 3$ ) (Table C.2k). The proportion of points with the presence of water in 1998 was as follows: GMEL = 89%; ADJ = 39%, ISOL = 42%; and native = 30%. In 1999 it was as follows: GMEL = 63%; ADJ = 33%; ISOL = 44%, and native = 19%.

The presence of non-*Gmelina* trees near point count stations did not differ across *Gmelina* stands in 1998 ( $F = 0.6$ ,  $p = 0.5425$ ,  $df = 2$ ) or in 1999 ( $F = 2.1$ ,  $p = 0.1313$ ,  $df = 2$ ) (Table C.2l). The proportion of points with the presence of non-*Gmelina* trees in 1998 was as follows: GMEL = 91%; ADJ = 89%, and ISOL = 83%. In 1999 it was as follows: GMEL = 89%; ADJ = 70%, and ISOL = 75%.

The presence of a primary edge near point count stations did not differ across stands in 1998 ( $F = 0.8$ ,  $p = 0.5058$ ,  $df = 3$ ) or in 1999 ( $F = 2.1$ ,  $p = 0.1052$ ,  $df = 3$ ) (Table C.2m). The proportion of points with the presence of a primary edge in 1998 was as follows: GMEL = 71%; ADJ = 82%, ISOL = 72%; and native = 60%. In 1999 it was as follows: GMEL = 90%; ADJ = 78%; ISOL = 69%; and native = 81%.

The presence of secondary edges near point count stations differed across *Gmelina* stands in 1998 ( $F = 11.3$ ,  $p = 0.0001$ ,  $df = 2$ ) and in 1999 ( $F = 35.0$ ,  $p = 0.0001$ ,  $df = 2$ ) (Table C.2n). The proportion of points with the presence of a secondary edge in 1998 was as follows: GMEL = 31%; ADJ = 0%, and ISOL = 0%. In 1999 it was as follows: GMEL = 61%; ADJ = 0%; and ISOL = 0%.

## Avian Community Patterns

### Abundance, richness and diversity patterns

Abundance (A) differed between years, thus, the results are presented separately. Mean A per point differed across *Gmelina* stands according to landscape contexts and across community types in 1998 ( $F = 11.16$ ,  $p < 0.0001$ ,  $df = 18$ ) (Table 11a). Pastures (13.3) and native stands (9.7) contained the greatest A per point. Abundance was lower in ADJ stands (7.3) than A in pastures. Abundance was lower in ISOL (4.7) than A in pastures or native stands. GMEL stands (4.0) contained fewer individuals than all sites except ISOL stands.

Mean A per point differed across *Gmelina* stands according to landscape contexts and across community types in 1999 ( $F = 33.27$ ,  $p < 0.0001$ ,  $df = 17$ ) (Table 11b). Pastures (24.0) contained the greatest number of individuals per point. Abundance was lower in native (11.9) and ADJ stands (9.3). ISOL stands (6.3) contained fewer individuals than pastures and native stands. GMEL stands (6.2) contained fewer individuals than all sites except ISOL.

Mean richness (R) per point differed across *Gmelina* stands according to landscape contexts and across community types ( $F = 24.65$ ,  $p < 0.0001$ ,  $df = 35$ ) (Table 12). Pastures contained the greatest R (7.3). R was lower in native (4.8) and ADJ stands (3.4). R was lowest in GMEL (1.9) and ISOL stands (1.7).

Mean diversity (D) per point differed across *Gmelina* stands according to landscape contexts and across community types ( $F = 20.45$ ,  $p < 0.0001$ ,  $df = 35$ ) (Table

13) Pastures contained the greatest D (1.6), followed by native stands (1.4). D was lower in ADJ stands (1.0), and lowest in GMEL (0.52) and ISOL stands (0.46)

### Rarefaction

The expected number of species differed among *Gmelina* stand landscape contexts and community types in 1998 ( $F = 5.83$ ,  $p = 0.0034$ ,  $df = 4$ ) (Table 14). However, trends observed in mean richness per point count were less apparent by rarefaction. Expected number of species was greatest in native stands (14.7), pastures (13.1), and ADJ stands (13.1). Expected number of species was lowest in GMEL (10.3) and ISOL stands (9.4).

The expected number of species did not differ among *Gmelina* stand landscape contexts and community types in 1999 ( $F = 2.69$ ,  $p = 0.0688$ ,  $df = 4$ ) (Table 14). Expected number of species was greatest in native stands (14.3) and lower in pastures (13.1), ADJ (11.0), GMEL (10.6), and ISOL stands (10.0).

### Community Similarity

Among landscape contexts in 1998, percent similarity was greatest between ISOL and GMEL stands (44% overlap), followed closely by ISOL and ADJ stands (42% overlap) (Table 15a). Percent similarity was lowest between GMEL and ADJ stands (39% overlap). Among the community types, ADJ stands were most similar to native stands (55% overlap). All other comparisons of *Gmelina* stands with pastures and native stands

showed less than 30% overlap. Pastures and native stands also shared a low percent similarity (8% overlap).

Among landscape contexts in 1999, percent similarity was greatest between GMEL and ADJ stands (50% overlap), followed closely by GMEL and ISOL stands (45% overlap) (Table 15b). Percent similarity was lowest, although still relatively high, between ADJ and ISOL stands (40% overlap). Among the community types, ADJ stands were most similar to native stands (42% overlap), although ISOL stands shared nearly the same similarity with native stands (41% overlap). GMEL stands were the least similar to native stands (30% overlap). All comparisons of *Gmelina* stands with pastures showed less than 20% overlap. Pastures and native stands showed little similarity (5% overlap).

### Trophic Guilds

Insectivores (I, FI, NI) showed the strongest representation in all the community types. In addition, fruit eaters and seed eaters showed strong representation in some cases. In general, native stands harbored more frugivores than did other community types. Frugivorous and nectivorous insectivores were represented most highly in the forested sites. Pastures harbored more granivores and omnivores than did other community types.

In 1998, pastures contained species of all 9 guilds followed by ADJ and GMEL stands with 7 each (Figures 5a-e). Only 5 guilds were represented in the native stands. The proportion of species within each guild differed across stand type ( $X^2 = 49.2$ ,  $p = 0.026$ ,  $df = 32$ ). In addition, the proportion of individual birds in each guild differed across stand type ( $X^2 = 922.6$ ,  $p = 0.001$ ,  $df = 32$ ). GMEL stands contained more FI

individuals than expected while both ISOL stands and pastures were underrepresented. Pastures showed a strong representation for granivores and insectivores while ISOL and GMEL stands showed an underrepresentation in these same guilds. The proportion of NI individuals was greater than expected in all three *Gmelina* types while the contrary was true for the pastures.

In 1999, representation was more variable (Figures 6a-e). Pastures again contained species in all 9 guilds followed closely by the *Gmelina* stands with 7. Native stands carried representation in 5 guilds. The proportion of species in each guild differed across stand type ( $X^2 = 47.2$ ,  $p = 0.041$ ,  $df = 32$ ). Likewise, the proportion of individuals in each guild differed across stand type ( $X^2 = 1477.4$ ,  $p = 0.001$ ,  $df = 32$ ). Native stands carried more frugivores than expected while pastures carried fewer than expected. Pastures were underrepresented in the FI guilds. Granivores were more strongly represented in the pastures while native, GMEL, and ISOL stands were more weakly represented than expected. All three *Gmelina* stands types and native stands carried more NI individuals than expected while for pastures the contrary was true. Lastly, pastures carried more omnivores than expected.

### **Habitat use of individual species**

In the stands located near native stands, the most abundant birds recorded were Rufous-tailed Hummingbird, Orange-billed Sparrow, Chestnut-backed Antbird, Beryl-crowned Hummingbird, and Band-tailed Barbthroat. Additionally, the Black-cheeked Ant-Tanager (endemic to Costa Rica), Black-hooded Antshrike, Chestnut-mandibled



Toucan, Fiery-billed Aracari, Red-lored Parrot and Tawny-winged Woodcreeper were found in two stands of *Gmelina* adjacent to native forest. Although locally they are fairly common, their conservation status is considered to be vulnerable (Stotz et al 1996).

The most abundant birds in the isolated stands consisted of the Chestnut-backed Antbird, Rufous-tailed Hummingbird, White-tipped Dove, Roadside Hawk, Long-tailed Hermit, and Tropical Kingbird. Also found in the isolated stands were Black-hooded Antshrike, Chestnut-mandibled Toucan, Fiery-billed Aracari, Red-lored Parrot, Scarlet Macaw, and Tawny-winged Woodcreeper. The macaws were observed foraging on the *Gmelina* fruit on two occasions. Although they are documented as being fairly common within this region, their conservation status has been determined to be vulnerable (Stotz et al. 1996).

The most abundant birds in the pastures were Blue-black Grassquit, Great-tailed Grackle, Smooth-billed Ani, Black-bellied Whistling Duck, and Black-striped sparrow. The most abundant birds in the native forest were Chestnut-backed Antbird, Long-tailed Hermit, Mealy Parrot, Rufous Piha, and Short-billed Pigeon. Black-hooded Antshrike, Chestnut-mandibled Toucan, Red-lored Parrot, and Tawny-winged Woodcreeper, which are considered as vulnerable species, were also found within native stands (Stotz et al. 1996).

## CHAPTER 7

### DISCUSSION

#### Stand Age Patterns

##### Habitat features

Forest structure and composition are important determinants of tropical bird community composition (Cruz 1988). In addition to providing cover and nesting sites, habitat structure also determines resources of arthropods, fruit, nectar and foliage upon which the birds feed (Cruz 1988). Not only is the interaction of various habitat features and habitat quality important, such as the interplay between canopy density and understory growth, but also stand history and management intensity are important considerations. For instance, young *Gmelina* stands were treated with herbicides to reduce competition with grasses and other early successional plants. After two years of growth, stands were thinned to decrease intraspecific competition. Application of treatments was somewhat variable across stands, and thus, vegetative structure may have been affected.

Most studies of bird communities in tropical plantations include little more than a descriptive analysis of vegetation characteristics. Thus, conclusions regarding correlation between avian communities and the associated habitat are based on speculation. Important considerations include the composition and structure of the understory and overstory. In *Gmelina* stands, understory structure ranged from dense and tall to barren

due to either a thick canopy, inundation, or a history of rice farming where herbicides were applied. Older *Gmelina* stands typically were comprised of closed canopies with little heterogeneity, although some old stands contained native trees sparsely dispersed within and around the plantation. Because habitat features were variable across *Gmelina* stand types and across community types, it is reasonable to assume that these differences played a part in the differences observed in the avifauna. Evaluation of these habitat differences can provide direction in developing useful conservation strategies.

Stand structure of young *Gmelina* differed markedly from the intermediate and old *Gmelina* stands in both years (Tables 3a, 3b, C.1a-h). On average, young stands contained trees that were less than 9 m in height and DBH's of less than 10 cm. Therefore, virtually no canopy was present. The grassy understory was generally thicker and taller when compared to understory composition of older stands in 1998. In 1999, although no canopy was present, understory height and density were not different from the older stands. This was due, in part, to one young stand that was treated so that no ground cover remained and the *Gmelina* saplings were pruned to one stem that supported few leaves. As a whole, the young stands resembled pastures more so than forests in that they were dominated by grasses in the ground cover and no canopy was present. There were no differences in the occurrence of water, primary and secondary edges, or non-*Gmelina* trees in either year (Tables C.11-1) as compared to both older age classes. Thus, these parameters were probably unrelated to observed changes in the bird community.

Less disparity existed between the stands of the two older age classes. Old stands possessed a greater BA and GDBH in both years, a greater CH in 1999, and less CC in

1999 (Tables 3a and 3b). However, UH and UD were not different between the two age classes in either year (Tables C.1e-1) In addition, with the exception of presence of secondary edges in 1998, there were no differences in the presence of water, primary edges, non-*Gmelina* trees and secondary edges between intermediate and old age stands (Tables C.11-1).

With advanced tree growth and canopy development, old *Gmelina* stands more closely resembled native forests than they did pastures (Tables 3a and 3b). There were no differences in BA and CC in 1998 or CH and UD in 1999 between old stands and native forests (Tables C.1a-h) However, other differences did exist. In 1998, native stands possessed greater TDBH, UD, UH and CH than old *Gmelina* stands. In 1999, TDBH, UH, and CC were also greater in native stands Interestingly, BA was greater in old *Gmelina* stands in 1999, probably because of the dense stocking of 30 cm diameter trees. Canopy cover was dense even with a lower basal area. In both years, there was a greater occurrence of water and in 1999 there was a greater occurrence of primary edges in old *Gmelina* stands than in native forest sites.

### Avifaunal Patterns

Results supported the research hypothesis that resident bird communities differed among *Gmelina* stand age classes (young, intermediate, and old) surveyed in southwestern Costa Rica. There were no differences in mean abundance per point among the three age classes (Table 5a-b) However, mean richness and diversity were significantly higher in young stands (3.9, 1.0) as compared to the intermediate (1.6, 0.4)

and old age classes (1.9, 0.5) (Tables 6 and 7) Likewise, the expected number of species generated from rarefaction analysis was significantly higher in young stands over that found in old stands in both years as well as over that found in intermediate stands in 1999 (Table 8). The dense understory structure found in the young stands, perhaps, provided a broader resource base for more birds and bird species to exploit. Alternatively, sampling techniques may have biased our results in that obscured visibility in the older stands may have caused an underestimation of canopy birds (Waide and Narins 1988). These distribution patterns were contrary to the findings of Mitra and Sheldon (1993) where richness and diversity were greatest in the oldest stands (seven years) of *Albizia falcataria* plantations surveyed in Borneo. Young stands in their study were also dominated by grassy ground cover under shrub-like trees.

With regard to community type, pastures supported a significantly greater mean abundance (12.7), richness (7.2), and diversity (1.6) per point above that found in all three age classes of *Gmelina*. Compared to native stands, pastures also harbored a greater bird abundance in 1999 and a greater species richness in both years (Tables 7-9). Native stands possessed a significantly greater species richness and diversity (4.7, 1.3) than only old (1.9, 0.5) and intermediate (1.6, 0.4) *Gmelina* stands. The native stands had a greater vegetative structure in the understory than the *Gmelina*, which may contribute to the higher bird diversity recorded (MacArthur and MacArthur 1961, MacArthur 1964, Karr and Roth 1971). In Borneo, bird communities in *Albizia* plantations with greater understory approached numbers observed in natural forests (Mitra and Sheldon 1993). Similarly, in tropical Africa, eucalyptus plantations that had greater understory structure

supported a greater number of bird species (Pomeroy and Dranzoa 1998). However, the authors attribute the lower richness of the plantations as compared to native forests as a result of a different prey base. Since the plantations supported exotic vegetation, the arthropods foraging there may have been different. Thus, fewer bird species were adapted to feeding there.

Rarefaction analyses of richness resulted in no significant differences between community types in 1998 (Table 8). However, in 1999 native stands were significantly richer than old and intermediate stands and pastures were significantly richer than only intermediate stands. Young stands were not different than either pastures or native stands. It is possible that few differences were significant in the rarefaction estimates because analyses were made based on less than 20 individuals in both years. Significant differences in stand richness among these sites may have been measurable in a larger pool of sampled individuals.

The greater number of birds and bird species found in the pastures may reflect the variability of the agricultural fields themselves. Site characteristics ranged from grazed pasture with little structural diversity to grazed pasture with numerous standing trees and hedgerows, to fallow fields. Petit et al. (1999) separated grazed pastures from fallow pastures in their analyses and found that the naturally forested sites carried far more species than either of the two agricultural site types. In addition, sampling bias may account for greater numbers in the agricultural sites above that which is found in the forested sites simply because visibility is greater in the agricultural sites.

Examining diversity patterns, although valuable, does not indicate the differences in species composition among the communities. Daniels et al. (1990) discovered in southern India that diversity patterns between native forests and tree plantations were similar but community composition was not. Because young *Gmelina* stands resembled agricultural sites in habitat structure, community composition might also be similar. Community similarity was much greater between young stands and pastures in both years (42%, 50%) than it was between young and native stands (12%, 9%) (Tables 9a and 9b). In both years, neither the intermediate (19%, 22%) nor the old (27%, 17%) age classes shared great similarity with the pastures. Likewise, intermediate and old did not share a great similarity with native stands (8%, 20% intermediate, 23%, 29% old), although the old stands showed a slightly higher similarity with the native stands in 1999 than they did with pastures. Old and intermediate stands showed great similarity in both years (53%, 48%). Interestingly, young *Gmelina* was most similar to old stands (56%) in 1998, but dropped in 1999. The young stands used in 1998 possessed considerably more structure in that the trees were taller (8.1 m) thereby providing some canopy cover (44%) for birds that prefer advanced second-growth. Young stands in 1999 contained trees in their shrub stage (3 m) and provided no canopy. In light of this, it seems that as *Gmelina* plantations age, they provide a unique habitat for resident birds apart from that found in either native forest or pastures.

The most prominent guilds in the *Gmelina* were those characterized as insectivorous to some degree (FI, I, NI) (Figures 3-4). Karr (1980) also found this to be true in several native tropical forests of Central America, Africa and Malaysia. *Gmelina*

stands had limited overstory and understory plant diversity, thus, available fruit and nectar producing plants were probably limited in both the canopy and understory as well. As a result of the apparent lack of these food resources, insectivorous birds predominated. This pattern was strong throughout all the land cover types. Those birds characterized as frugivore-insectivores were probably relying mostly on insects in the *Gmelina* rather than fruits

Young stands and pastures contained a strong species and individual bird representation in the G, FG and IG guilds. More granivores were present since grasses were prominent in these areas. Few of these species existed in the intermediate, old, and native stands. Granivorous birds also predominated in young *Albizia falcataria* plantations in Borneo and were less abundant in older stands (Mitra and Sheldon 1993). Likewise, Petit et al. (1999) found more granivorous species in pastures as opposed to the more abundant frugivorous birds in forested sites.

Frugivorous individuals and species were more abundant in the intermediate, old, and native stands since overstory and understory structure provided more fruiting and flowering resources. Fruit heterogeneity in *Gmelina* stands was limited although *Cecropia* and other native tree species were dispersed throughout a number of stands.

It is important to note that many bird species exhibit seasonal movements in conjunction with ephemeral resources (Martin and Karr 1986, Levey 1988, Loiselle 1988, Blake and Loiselle 1991, Loiselle and Blake 1991, 1994). The patterns reported here reflect a rather restricted period of time during the height of the breeding, and thus, only limited, although informative, conclusions. Also important is that although unidentified



hummingbirds were included in the individual bird analyses, they were not included in the species analyses. Therefore, nectarivorous species were underestimated. Frugivores were also most likely underestimated because of the difficulty detecting birds in the canopy where fruit eaters are more likely to feed (Levey and Stiles 1992) This bias may be most significant in native stands where tree heights were greater and vegetative structure beneath the canopy greatly obstructed visual and aural detectability (Waide and Narins 1988).

## **Landscape context**

### Habitat features

Habitat parameters differed by landscape context. Trends differed across years such that consistent patterns were difficult to discern for some parameters (Tables 10a and 10b, C.2a-h). In 1998, BA and CC were lowest in ADJ stands (stands adjacent to native forest) while UD and UH were greatest there. GDBH was greatest in ISOL stands (stands isolated from other forested areas). In 1999, there were no differences in BA, CH and UH across stands GDBH was greatest in GMEL stands (stands surrounded by other *Gmelina* plantations), UD was lowest in ISOL stands and CC was lowest in ADJ stands. The occurrence of water and secondary edges near point count stations was greatest in GMEL stands in 1998. Sites situated on a slope only occurred in the ADJ stands in both years. Factors that influence these patterns within the stands include site characteristics, historical management or land use practices, and surrounding habitat.

The interaction of site characteristics is an important consideration in the observed vegetative measurements. For example, understory growth in the ADJ stands may have been influenced by the lower density of CC. Also ADJ stands were the only stands of this study that were situated on a slope, which may have affected vegetative growth. Soil types probably differed since these stands were usually at an elevation greater than 200 m above that of the GMEL and ISOL stands

Stands closer to native forests may have been exposed to a greater seed source and greater numbers of seed dispersers. Thus, ADJ stands, where UD was no different from native stands in both years, may have been influenced by the native forests in the surrounding landscape.

Lastly, historical management or land use practices may have been an important factor. Banana plantations and cattle grazing were practiced in the area where the GMEL stands were located. Two of the ISOL stands were planted on what were previously rice fields. Both of these areas had a history of intensive agriculture, such that regrowth of native vegetation was limited. Likewise, some *Gmelina* stands were thinned after two years of growth while others were not. For instance, two ISOL stands, where GDBH was least in 1998, were not thinned after two years of growth. Thus, understory growth may have been impeded by lack of light penetrating through a dense canopy.

#### Avifaunal Patterns

Results supported the research hypothesis that avian communities in southwestern Costa Rica differed among *Gmelina* stands according to landscape context Mean

abundance, richness and diversity per point was greatest in ADJ stands (8.4, 3.4, 1.0) over that found in GMEL (5.1, 1.9, 0.5) and ISOL stands (6.8, 1.7, 0.5) (Tables 11-13). Likewise, the expected number of species generated from rarefaction analysis was significantly higher in ADJ stands (13.1) as compared to GMEL stands (10.3), and ISOL stands (9.4) (Table 14). Furthermore, regarding community type, abundance and richness in ADJ stands did not differ from native stands. No differences between pastures and native and ADJ stands occurred in the expected number of species.

Understory structure was greatest in the ADJ stands, which may have accounted for the numbers of birds and bird species present (MacArthur and MacArthur 1961, MacArthur 1964, Karr and Roth 1971). Other studies of bird communities in tropical plantations proposed similar conclusions in that plantations with greater structure in the understory usually contained more species of birds (Carlson 1986, Beehler et al. 1987, Mitra and Sheldon 1993, Hayes and Samad 1998, Pomeroy and Dranzoa 1998, Petit et al. 1999). Daniels et al. (1992) found this to be true in a variety of tropical plantations in southern India. In contrast, this pattern did not hold in their study for the native forests in the same area. Species richness was inversely related to increasing foliage structure and woody plant species diversity. The authors attribute these results to the impoverished species pool in an area regarded as a habitat island.

An alternative conclusion is that the greater number of birds observed in the ADJ stands was correlated with their proximity to native forests. Primary forest may have been a source for greater colonization in *Gmelina*. Other studies in tropical plantations found similar results in that avian diversity and richness increased as the proximity of the

plantation to native forests decreased (Daniels et al. 1990, Mitra and Sheldon 1993, Pomeroy and Dranzoa 1998).

Evaluation of community similarity between land cover types supports the claim that nearby native forests influence the birds using the *Gmelina*. Community similarity among the *Gmelina* stands ranged from 39% to 50% (Tables 15a and 15b). In 1998, however, ADJ stands were more similar to native stands (55%) than they were to ISOL (42%) or GMEL stands (42%). Furthermore, community overlap between native and ISOL (28%) stands and native and GMEL (22%) stands was low. In 1999, this trend was not as strong, for the ADJ stands were most similar to GMEL stands (50%) and comparisons of all three *Gmelina* types with native forests were similar (30%-41%). All wooded sites shared less than 30% similarity with pastures. This suggests that *Gmelina* stands alone may not be sufficient to support native forest bird communities, but they may offer a better alternative than the agricultural fields that they replaced, especially in areas where remnant forests remain.

The most prominent guilds in the *Gmelina* were those characterized as insectivorous to some degree (FI, I, NI) (Figures 5-6). Trends were similar among *Gmelina* stands. Granivorous species constituted a greater percentage of the bird communities found in pastures compared to the forested sites. Frugivores comprised a greater percentage of the recorded species in the forested sites as compared to the pastures. Furthermore, frugivores were more prominent in the native stands than they were in the *Gmelina*. Fruit eaters were also less abundant in eucalyptus and betelnut plantations in the Western Ghats and teak in the Eastern Ghats of India (Beehler et al.

1987, Daniels et al. 1992). Fruit heterogeneity in *Gmelina* stands was limited although *Cecropia* and various other native tree species dispersed throughout a number of stands did offer some variety. The abundant *Gmelina* fruits were not seen being eaten by any birds at the time of the survey with the exception of the Scarlet Macaw.

### **Habitat use of individual species**

As suggested in other studies (Pramod et al. 1997), an investigation of the bird communities can help establish management plans that promote biodiversity. The species using *Gmelina* represent a broad cross-section of types, ranging from those that prefer open habitats to those that prefer primary forest. Several of the species found in the *Gmelina* plantations are forest obligates. Some can be considered to prefer primary forested habitat, e.g., Rufous Piha, Bi-colored Antbird, Sulfur-rumped Flycatcher and Tawny-crowned Greenlet. Also found in the *Gmelina* are bird species which prefer older second-growth, such as the Blue-crowned Manakin, the Red-capped Manakin, and the Buff-throated Foliage Gleaner. All of these species were generally found to occur in low numbers in the *Gmelina* and usually found in those plantations near native forests.

Those birds found in the young stands typically prefer shrubby second-growth, woodland edges, gardens, grassy or weedy fields, and roadsides. The Black-striped Sparrow and Smooth-billed Ani have been known to utilize plantations (Stiles and Skutch 1989).

The most abundant birds of the old stands prefer second-growth of varying degrees of thickness. All can be found in edges, but the Red-crowned Woodpecker and

Scarlet-rumped Tanager prefer woodland edges. The woodpecker, being dependent on wooded areas for forage and nesting, prefers the open parts of a forest. The Orange-billed Sparrow prefers the dark understory of humid and older second-growth woods (Stiles and Skutch 1989). Rufous-tailed Hummingbirds, although known users of coffee plantations (Stiles and Skutch 1989), are not typically noted to occur in wooded areas. However, they were observed in the old plantations with regularity in this study. Perhaps they predominantly used the stands for travel corridors. The five species found in these stands that are listed as vulnerable prefer forest interior or old second-growth (Stiles and Skutch 1989). These species are determined to be vulnerable if current deforestation rates are maintained (Stotz et al. 1996). In this regard, *Gmelina* may serve to impede their decline.

In stands located near native forests, two species (Orange-billed Sparrow and Chestnut-backed Antbird) prefer the dark understory of humid forests and old second-growth woods. Here again, Rufous-tailed Hummingbirds were observed in forested areas that they are not known to prefer. The other abundant species, also hummingbirds, prefer open woodland, older second-growth and interior forest edges along streams and clearings. Six species, classified as vulnerable (Stotz et al. 1996), were found in these stands and are at risk at current rates of deforestation and, thus, may benefit from areas reforested with *Gmelina*. One of these species, Black-cheeked Ant-Tanager is endemic to Costa Rica.

The most common birds within the isolated stands prefer second-growth areas. Some like the developed understory of a wooded area while others utilize open woodlands and edges. Six species classified as vulnerable also occurred in these stands

(Stotz et al. 1996). One of these species, the Scarlet Macaw, was observed foraging on the *Gmelina* fruit. Not only will the added forest cover benefit this species, but the *Gmelina* will also provide additional foraging resources for these birds at risk.

As in other studies of bird communities of tropical plantations (Carlson 1986, Daniels et al. 1990, Hayes and Samad 1998, Pomeroy and Dranzoa 1998), this coarse examination of the most abundant birds in *Gmelina* stands shows that these plantations mostly attract forest generalists. However, *Gmelina* plantations, although not sufficient to support the large, rich communities found in the native forests, may provide an environment for at least some birds dependent on forested habitat, such as the seven species classified as vulnerable. Diversity within a habitat, while important, may not contribute to the diversity measured at the landscape level. In this light, plantations are preferable to the pastures that existed directly before the *Gmelina* was planted.

## CHAPTER 8

### CONSERVATION VALUE OF TROPICAL PLANTATIONS

Perceptions concerning tropical forests have changed over the last two decades. No longer are they perceived as limitless resources that can be removed in vast quantities so that land is "improved" for other practices. These regions are now valued for their high degree of biodiversity and endemism and because they harbor more than half of all known species (Wilson 1992, MacKinnon 1997). As an example of their richness, these areas, totaling only 0.2% of the Earth's land surface, contain 15% of all known plant species (Myers 1990). Tropical forests are valued for their supply of timber, food, botanical and pharmaceutical products, as well as their recreational potential (Myers 1988).

#### **Tropical deforestation**

At the end of 1990, tropical forests covered 1,761 million ha of the earth's land surface. The corresponding rate of deforestation between 1980 and 1990 was 15.4 million ha/yr or 0.8% annually (FAO 1993). Latin America and the Caribbean regions possessed the largest coverage of remaining tropical forest (52% of total tropical forest area) as opposed to Africa (30%), and Asia and the Pacific (18%). Annual loss of forest cover between 1980 and 1990 was greatest in Asia and the Pacific (1.2%), followed by Latin America and the Caribbean (0.8%), and Africa (0.7%) (FAO 1993). The greatest loss of



forest cover within ecological zones occurred in upland areas (1.1%; 2.5 million ha), and moist deciduous forests (1.0%, 6.1 million ha), followed by dry forests (0.9%; 2.2 million ha), and tropical rainforests (0.6%; 4.6 million ha) (FAO 1993). As a result of this deforestation, the greatest impact on species richness as of 1990 was thought to occur in the tropical forests of Asia. Even though forest loss there was half that of Latin America and the Caribbean, species loss was estimated to be twice as much (FAO 1993). In light of this, massive extinctions are projected to occur if these rates are not reduced (Wilson 1992).

Awareness has brought great efforts to preserve, restore and manage naturally forested areas. Changes in perspectives concerning forest management have developed as a result of several reasons. Included is the awareness of (1) economically nonviable tropical forest management practices, (2) the alarming rate of deforestation, (3) tropical forest ecology, (4) developing timber markets that include a wider array of tropical tree species, and (5) the need to involve local people in tropical forestry practices (Hartshorn 1992). As a consequence, various global organizations, such as the International Tropical Timber Organization (ITTO), and a myriad of regional efforts, such as PORTICO and COFYAL (Yanesha Forestry Cooperative) of Peru, have been established to promote natural forest management (Hartshorn 1992). A total of 706.7 million ha (14.8% of tropical land area) were designated as conservation areas in 1990 with the greatest proportion occurring in Latin America and the Caribbean (21.5%) (FAO 1993). However, progress in natural forest management is slow and unreliable (FAO 1993).

## **Plantations as an alternative**

Despite the increased desire to rectify deforestation problems, human populations continue to increase and high demands for wood products and agricultural production remain. In light of the economic status of many tropical nations and the demand for wood products, the goal of restoring biodiversity based solely on native forest regeneration may be unrealistic. There are other options that should be considered. A reasonable alternative is to supplement the pulp and timber industry through the establishment and management of plantations. Such a strategy could effectively reduce the pressure on harvest of native forests and may provide additional benefits in providing habitat for wildlife use. At the end of 1990, there were approximately 43.8 million ha of industrial and non-industrial forest plantations in the tropical regions (FAO 1993). The largest amount occurred in Asia and the Pacific (73%) followed by Latin America (20%) and Africa (7%). At this time, 85% of tropical plantations were found in only five countries: India, Indonesia, Brazil, Vietnam, and Thailand.

It is unnecessary to establish plantations by removing natural forest as once proposed (Dyson 1965). Reforestation efforts should be focused in areas that have already been cleared of native forest. Because it is common for cleared regions under heavy agricultural practices to become degraded (Keller et al. 1993), these areas are usually left to grow fallow. Planting trees not only reestablishes economic productivity, but it may also provide forest cover attractive to wildlife unable to survive in a pasture-type setting.

### Plantation designs

Most monocultures are thought to provide limited wildlife habitat and reduced biodiversity when compared to natural plant communities. Efforts to study the effectiveness of tropical plantations have been minimal (FAO 1993). In light of the trend towards increased reliance on plantation forestry, the key question becomes whether in tropical countries there are practices that can promote higher levels of diversity. Increased heterogeneity provides for greater resources of forage, nesting sites and refugia. Planting schemes that incorporate a variety of tree species such as using buffer strips, mosaics and polycultures enhance heterogeneity, thereby, attracting more species (Lamb 1998, Petit et al 1999). For example, shade-grown coffee, which incorporates polycultural management, carries more bird species than coffee grown as a monoculture (Vannini 1994, Greenberg et al. 1996, Perfecto et al. 1996, Greenberg et al. 1997, Wunderle and Latta 1998, Moguel and Toledo 1999, Petit et al. 1999, Wunderle 1999). Another important management tool may be increasing rotation length to allow for understory development. Plantations with greater vegetative structure in the understory have been shown to contain greater bird diversity (Carlson 1986, Beehler et al. 1987, Mitra and Sheldon 1993, Hayes and Samad 1998, Pomeroy and Dranzoa 1998, Petit et al. 1999). In addition, maintaining or enhancing native vegetation growth within or surrounding plantations or along riparian zones may also improve biodiversity.

Plantations near native forests have also been shown to carry more avian species by providing additional forest cover that at least some of the birds of the native forest

utilized (Daniels et al. 1990, Mitra and Sheldon 1993, Pomeroy and Dranzoa 1998) The *Gmelina* stands in this study that were situated near primary forest carried the greatest bird diversity, abundance and richness and shared the greatest community similarity to native forests. Thus, promoting reforestation near native forests would increase total forest cover, which may in turn provide additional resources and travel corridors for wildlife.

#### Exotic trees versus native trees

The use of exotics, such as *Gmelina*, may not be appropriate in all circumstances (Hughes and Styles 1987, Gonzalez and Fisher 1994, Stuhmann et al. 1994, Butterfield 1996, Richardson 1998) but there can be advantages (Shepherd 1993, Lugo 1997, Lamb 1998). Growth rates tend to be higher since interspecific competition and predation are not well developed. Greater success in site productivity and tree growth may occur due to increased knowledge of the ecology and silvicultural practices already well established for these species (Shepherd 1993). Often, the available seeds are of improved genetic stock. Furthermore, many of these species already have an established commercial market. As in any forest management schemes, the planting of exotics must be carefully considered to reduce risks of invasive populations becoming established elsewhere in the area (Hughes and Styles 1987, Richardson 1998).

### Native forest restoration

In areas where timber harvest is not the goal, plantations may be valuable tools for native forest restoration (Shepherd 1993, Lugo 1997, Lamb 1998). In large denuded areas designated to be restored, allowing forests to regenerate naturally may be too labor intensive. Additionally, seed sources are often too distant and too limited for a timely restoration to occur. In these cases, using tree plantations may provide a more successful alternative. Plantations can help to restore favorable conditions for native vegetative growth in degraded areas where restoration has proven to be difficult (Fisher 1995, Kuusipalo et al. 1995, Lugo 1997, Parrotta et al. 1997, Lamb 1998). Shade is provided which encourages the growth of native trees that are shade tolerant (Kuusipalo et al 1995, Keenan et al. 1997, Lamb 1998). In addition, seed dispersers may be attracted to these areas, which brings in an input of new seed sources. Furthermore, in some cases, soil conditions are improved (Egunjobi 1991). Included in these conditions are the increase in nitrogen and organic matter levels and an improved soil ph (Fisher 1995). Also, appropriate temperature and atmospheric conditions may be established. Protection from disturbances like fire and grazing may also be increased (Lamb 1998). However, some disturbances may be enhanced, such as wind damage and pest outbreaks.

*Gmelina arborea* has been widely used in tree plantations outside of its native range. Research concerning their usefulness in a restorative manner is on-going. In several instances, *Gmelina* has been shown to improve soil conditions of K, N and organic matter and has been shown to be superior in phenological characteristics as a planted tree (Halenda 1989, Egunjobi 1991, Ruhigwa et al. 1993, Fisher 1995, Amara et

al. 1996, Otsamo et al. 1997). In fact, Egunjobi (1991) suggested that *Gmelina* planted in tropical Africa displayed a greater nutrient cycling efficiency, in at least its first rotation cycle, than that of the regional natural forests.

## **Conclusions**

In summary, tree plantations may be useful in place of and within the context of an area where large tracts of native forest have been removed for other agricultural practices. Although these managed forests may not possess a biodiversity equal to that found in the neighboring native forests, with proper management, they still may prove to be more valuable than a landscape dominated by agriculture. Regardless, thorough surveys that are sensitive to species survival, reproductive success, and species of conservation status are needed. In this sense, it becomes of dire importance that the forest managers pay heed to the information indicating those conservation practices that will promote local biodiversity.

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## **Appendices**

**Appendix A.**  
**Tables and Figures**



## Tables

Table 1 *Gmelina arborea* stand descriptions (area, age class, landscape context, number of points censused each year, and year(s) censused), May-July 1998 and 1999, southwestern Costa Rica

Area	Plot	Size (ha)	Age Class 1998/1999 <sup>b,d</sup>	Landscape Context <sup>b,e</sup>	# Pts. 98/99	Yrs. Censused
Salamá	AAB	63.0	Young	-	-/6	- 1999
Salamá	AAB1	23.9	Int	-	3/3	1998, 1999
Salamá	AAC	45.0	Old	GMEL	4/4	1998, 1999
Salamá	AAE	109.0 <sup>a</sup>	Old	GMEL	8/8	1998, 1999
Salamá	AAF	65.0	Old/Young	GMEL <sup>c</sup>	7/7	1998, 1999
Salamá	AAG	77.9	Old	GMEL	7/9	1998, 1999
Salamá	AAH	45.3	Old/-	GMEL	5/-	1998 -
Salamá	AAI	115.2	Old	GMEL	10/10	1998, 1999
Salamá	AAP	46.8	Int/Old	GMEL <sup>c</sup>	4/3	1998, 1999
Salamá	AAR	34.1	Int	GMEL <sup>c</sup>	4/4	1998, 1999
Rincón	AC	80.0	Old	ADJ	6/6	1998, 1999
Rincón	AI	34.9	Old	ADJ	7/7	1998, 1999
Salamá	AJ	85.3	Young	-	6/5	1998, 1999
Salamá	BA	96.3 <sup>a</sup>	Old/Young	ADJ <sup>c</sup>	10/7	1998, 1999
Santa Rosa	BP	30.1	Old	ADJ	3/3	1998 -
Santa Rosa	BS	50.9	Old	ADJ	5/-	1998, 1999
Palmar Sur	EB	170.0	Old	ISOL	10/10	1998, 1999
Palmar Sur	EC	185.0	Old	ISOL	10/10	1998, 1999
Puerto Jiménez	IB	44.5	Old	ISOL	6/6	1998, 1999
Puerto Jiménez	IC	151.0	Old	ISOL	10/10	1998, 1999
Rancho Quemado	ID	102.6	Old	ADJ	-/8	- 1999

Table 1. (Continued) *Gmelina arborea* stand descriptions (area, age class, landscape context, number of points censused each year, and year(s) censused), May-July 1998 and 1999, southwestern Costa Rica

Area	Plot	Size (ha)	Age Class 1998/1999 <sup>b</sup>	Landscape Context <sup>b</sup>	# Pts. 98/99	Yrs. Censused
Río Claro	MA	25.6	Old	ADJ	3/3	1998, 1999
Río Claro	MD	31.8	Old	ADJ	4/-	1998 -
Río Claro	SV	17.2	Young	-	3/3	1998, 1999
Río Claro	SW	24.7	Young/-	-	3/-	1998 -

<sup>a</sup> Stand was partially harvested so area was not known in 1999

<sup>b</sup> Stands with no designated age class or context were not used in those respective analyses

<sup>c</sup> Stands were not used in landscape analysis for both years because age class changed

<sup>d</sup> Age classes are categorized as the following Young = 1 year, Int = 2-5 years, and Old = 6-9 years

<sup>e</sup> Landscape contexts are categorized as the following GMEL = *Gmelina* stands in a context of other *Gmelina* stands, ADJ = *Gmelina* stands adjacent to native forests; and ISOL = *Gmelina* stands isolated from other wooded areas.

Table 2 Habitat variables measured to characterize stand features of *Gmelina arborea* and native forest stands, May-July 1998 and 1999, southwestern Costa Rica

Acronym	Habitat variable	How Measured
ASP	Slope Aspect	Compass
BA	Basal area	2.5 factor metric prism, m <sup>2</sup> /ha
CC	Average canopy cover	Average (%) of four densiometer readings at 5.6 m from plot center in each cardinal direction
CH	Average canopy height	Clinometer measuring one tree representative of canopy height, m
GDBH	Average diameter at breast height for <i>Gmelina</i> trees	DBH tape measuring <i>Gmelina</i> trees determined "in" by prism, cm
NDBH	Average diameter at breast height for non- <i>Gmelina</i> trees	DBH tape measuring non- <i>Gmelina</i> trees determined "in" by prism, cm
PPE	Proximity to primary edge road, river, powerline, change on cover type	Visual estimation, m
PRIP	Presence of riparian zones	Visual estimation, m
PSE	Proximity to secondary edge <i>Gmelina</i> stand of similar height	Visual estimation, m
SL	Percent Slope	Clinometer (%)
TDBH	Average diameter at breast height for all trees	DBH tape measuring all trees determined "in" by prism, cm
UD	Average understory cover density	Average (%) of four 2.0 x 0.8 m cover density board readings at 5.6 m from plot center in each cardinal direction
UH	Average understory height	Average of four visual estimations at 5.6 m from plot center in each cardinal direction, m

Table 3a. Least square means, standard errors, F values, p values, and degrees of freedom of habitat measurements in *Gmelina* stands (according to age class) and native stands, May-July 1998, southwestern Costa Rica.

Stand Type <sup>a</sup>	# pts	Basal Area (m <sup>2</sup> /ha)		DBH <i>Gmelina</i> (cm)		DBH Non- <i>Gmelina</i> (cm)		DBH Total (cm)		Understory Density (%)		Understory Height (m)		Canopy Cover Density (%)		Canopy Height (m)	
		LS Mean/ SE	SE	LS Mean/ SE	SE	LS Mean/ SE	SE	LS Mean/ SE	SE	LS Mean/ SE	SE	LS Mean/ SE	SE	LS Mean/ SE	SE	LS Mean/ SE	SE
Young	12	8.8	2.48	10.7	1.76	-	-	8.9	2.38	40.7	5.60	3.5	0.77	44.3	5.4	8.1	2.09
Int	11	28.2	2.59	21.8	1.68	-	-	21.8	2.48	16.0	5.85	1.0	0.80	95.8	5.7	20.3	2.18
Old	41	36.0	1.34	27.5	0.87	52.5	16.25	27.5	1.29	24.7	3.03	2.0	0.42	94.7	2.9	21.3	1.13
Native	10	35.0	2.72	-	-	46.0	7.27	46.0	2.60	55.8	6.13	14.8	0.84	95.7	5.9	33.5	2.41
F value		32.3		37.2		0.1		38.4		10.0		66.9		24.5		21.6	
p value		0.0001		0.0001		0.7232		0.0001		0.0001		0.0001		0.0001		0.0001	
df		3		2		1		3		3		3		3		3	



Table 4 Total richness and abundance (for all points surveyed) of resident birds recorded in *Gmelina* stands, native forest stands, and pastures, May-July 1998 and 1999, southwestern Costa Rica

Community type <sup>a,b</sup>	#Pts	Richness	Abundance
Young	64	60	507
Intermediate	52	31	247
Old	150	60	830
GMEL	166	63	909
ADJ	129	78	1,116
ISOL	144	61	827
All <i>Gmelina</i> stands	539	114	3,527
Native stands	52	69	593
Pastures	72	74	1,387

<sup>a</sup> Age classes are categorized as the following Young = 1 year; Int = 2-5 years, and Old = 6-9 years

<sup>b</sup> Landscape contexts are categorized as the following GMEL = *Gmelina* stands in a context of other *Gmelina* stands, ADJ = *Gmelina* stands adjacent to native forests, and ISOL = *Gmelina* stands isolated from other wooded areas

Table 5 Abundance (individuals per point count) least square means, standard errors, and pairwise comparisons among *Gmelina* stands (according to age), native stands, and pastures for resident birds, May-July (a) 1998, and (b) 1999, southwestern Costa Rica

(a)

Community	Abundance LS Mean	Standard Error	Pairwise Comparison <sup>a</sup>
Young	5.6	1.55	BC
Intermediate	3.6	1.41	C
Old	4.1	0.91	C
Pasture	13.4	1.44	A
Native	9.6	1.64	AB

<sup>a</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )

(b)

Community	Abundance LS Mean	Standard Error	Pairwise Comparison <sup>a</sup>
Young	8.3	1.72	BC
Intermediate	4.9	1.87	C
Old	6.2	1.33	C
Pasture	23.9	1.89	A
Native	11.9	1.84	B

<sup>a</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )



Table 6 Richness (number species per point) least square means, standard errors, and pairwise comparisons among *Gmelina* stands (according to age), native stands, and pastures for resident birds, May-July 1998 and 1999 pooled, southwestern Costa Rica

Community	Richness LS Mean	Standard Error	Pairwise Comparison <sup>a</sup>
Young	3.9	0.65	B
Intermediate	1.6	0.61	C
Old	1.9	0.44	C
Native	4.7	0.64	B
Pasture	7.2	0.70	A

<sup>a</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )

Table 7 Diversity (Shannon-Weaver Index) least square means, standard errors, and pairwise comparisons among *Gmelina* stands (according to age), native stands, and pastures for resident birds, May-July 1998 and 1999 pooled, southwestern Costa Rica

Community	Diversity LS Mean	Standard Error	Pairwise Comparison <sup>a</sup>
Young	1.0	0.14	B
Intermediate	0.4	0.13	C
Old	0.5	0.10	C
Native	1.3	0.14	AB
Pasture	1.6	0.15	A

<sup>a</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )

Table 8 Least square mean of expected number of species (through rarefaction), standard error, and pairwise comparison of resident birds in *Gmelina* stands (according to age class) and pastures and native stands, May-July 1998 and 1999, southwestern Costa Rica

Community	Least Square Mean	1998 Standard Error	Pairwise Comparison <sup>a</sup>	Least Square Mean	1999 Standard Error	Pairwise Comparison <sup>a</sup>
Young	10.2	0.8792	A	12.2	0.9642	A
Intermediate	7.7	0.8792	AB	7.6	0.8350	B
Old	7.7	0.6217	B	8.9	0.7468	BC
Pastures	9.5	1.8792	A	11.0	0.9642	AC
Native stands	10.3	1.0768	A	11.6	0.9642	A

<sup>a</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )

Table 9 Similarity (%) of resident birds among *Gmelina* stands (according to age), native stands, and pasture, May-July (a) 1998, and (b) 1999, southwestern Costa Rica

(a)

	Young	Intermediate	Old	Native	Pasture
Young	-	0.37	0.56	0.12	0.42
Intermediate	-	-	0.53	0.08	0.19
Old	-	-	-	0.23	0.27
Native	-	-	-	-	0.08

(b)

	Young	Intermediate	Old	Native	Pasture
Young	-	0.32	0.26	0.09	0.50
Intermediate	-	-	0.48	0.20	0.22
Old	-	-	-	0.29	0.17
Native	-	-	-	-	0.05



Table 10b. Least square means, standard errors, F values, p values, and degrees of freedom of habitat measurements in *Gmelina* stands (according to landscape context) and native stands, May-July 1999, southwestern Costa Rica.

Stand Type <sup>a</sup>	# pts	Basal Area (m <sup>2</sup> /ha)		DBH <i>Gmelina</i> (cm)		DBH Non- <i>Gmelina</i> (cm)		DBH Total (cm)		Understory Density (%)		Understory Height (m) <sup>a</sup>		Canopy Cover Density (%)		Canopy Height (m)	
		LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE	LS Mean/ SE
GMEL	38	35.7	1.59	27.3	0.77	31.5	18.16	27.1	1.32	24.8	2.53	1.7	1.28	81.9	1.04	26.8	1.69
ADJ	27	33.2	1.88	22.5	0.91	56.3	29.66	22.7	2.05	27.1	3.01	1.7	1.52	69.7	1.23	22.4	2.01
ISOL	36	34.8	1.63	22.6	0.79	166.7	25.68	23.7	1.77	14.2	2.61	1.2	1.32	82.8	1.07	22.9	1.74
Native	16	28.9	2.44	-	-	54.2	12.84	54.2	2.66	35.1	3.91	8.2	1.97	88.1	1.60	30.7	2.69
F value		2.0		12.0		6.6		36.5		7.9		3.4		34.3		2.9	
p value		0.1157		0.0001		0.0017		0.0001		0.0001		0.0205		0.0001		0.0386	
df		3		2		3		3		3		3		3		3	

<sup>a</sup> Landscape contexts are categorized as the following: GMEL = *Gmelina* stands in a context of other *Gmelina* stands; ADJ = *Gmelina* stands adjacent to native forests; and ISOL = *Gmelina* stands isolated from other wooded areas.

Table 11 Abundance (individuals per point) least square means, standard errors, and pairwise comparisons among *Gmelina* stands (according to context), native stands, and pastures for resident birds, May-July (a) 1998, and (b) 1999, southwestern Costa Rica

(a)

Community <sup>b</sup>	Abundance LS Mean	Standard Error	Pairwise Comparison <sup>b</sup>
GMEL	4 0133	0 49	D
ADJ	7 3043	0 52	BC
ISOL	4 6854	0 64	CD
Pasture	13.3889	0 77	A
Native	9 6612	0 92	AB

<sup>a</sup> Landscape contexts are categorized as the following GMEL = *Gmelina* stands in a context of other *Gmelina* stands, ADJ = *Gmelina* stands adjacent to native forests, and ISOL = *Gmelina* stands isolated from other wooded areas

<sup>b</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )

(b)

Community <sup>a</sup>	Abundance LS Mean	Standard Error	Pairwise Comparison <sup>b</sup>
GMEL	6 1544	0 52	D
ADJ	9 3270	0.60	BC
ISOL	6 3006	0 64	CD
Pasture	24 0297	0.76	A
Native	11 9322	0 76	B

<sup>a</sup> Landscape contexts are categorized as the following GMEL = *Gmelina* stands in a context of other *Gmelina* stands, ADJ = *Gmelina* stands adjacent to native forests, and ISOL = *Gmelina* stands isolated from other wooded areas

<sup>b</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )

Table 12 Richness (number of species per point) least square means, standard errors and pairwise comparisons among *Gmelina* stands (according to context), native stands, and pastures for resident birds, May-July 1998 and 1999 pooled, southwestern Costa Rica

Community <sup>a</sup>	Richness LS Mean	Standard Error	Pairwise Comparison <sup>b</sup>
GMEL	1 8639	0 35	C
ADJ	3 3896	0 39	B
ISOL	1 6837	0 45	C
Pasture	7 3288	0 54	A
Native	4 7644	0 59	B

<sup>a</sup> Landscape contexts are categorized as the following GMEL = *Gmelina* stands in a context of other *Gmelina* stands, ADJ = *Gmelina* stands adjacent to native forests, and ISOL = *Gmelina* stands isolated from other wooded areas

<sup>b</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )

Table 13 Diversity (Shannon-Weaver index) least square means, standard errors, and pairwise comparisons among *Gmelina* stands (according to context), pastures, and native stands for resident birds, May-July 1998 and 1999 pooled, southwestern Costa Rica

Community <sup>a</sup>	Diversity LS Mean	Standard Error	Pairwise Comparison <sup>b</sup>
GMEL	0.5173	0.09	C
ADJ	1.0077	0.10	B
ISOL	0.4617	0.11	C
Pasture	1.6246	0.13	A
Native	1.3550	0.15	A

<sup>a</sup> Landscape contexts are categorized as the following GMEL = *Gmelina* stands in a context of other *Gmelina* stands; ADJ = *Gmelina* stands adjacent to native forests, and ISOL = *Gmelina* stands isolated from other wooded areas

<sup>b</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )

Table 14 Least square mean of expected number of species (through rarefaction) of resident birds in *Gmelina* stands (according to landscape context), pastures, and native stands, May-July 1998 and 1999, southwestern Costa Rica

Community <sup>a</sup>	1998			1999		
	LS Mean	Standard Error	Pairwise Comparison <sup>b</sup>	LS Mean	Standard Error	Pairwise Comparison <sup>b</sup>
GMEL	10.3	0.6682	A	10.6	0.8671	A
ADJ	13.1	0.6682	B	11.0	0.9499	A
ISOL	9.4	0.8839	A	10.0	1.0621	A
Pastures	13.1	1.0206	B	13.3	1.2264	AB
Native	14.7	1.2501	B	14.3	1.2264	B

<sup>a</sup> Landscape contexts are categorized as the following GMEL = *Gmelina* stands in a context of other *Gmelina* stands, ADJ = *Gmelina* stands adjacent to native forests, and ISOL = *Gmelina* stands isolated from other wooded areas

<sup>b</sup> Means of community types that share a common letter do not differ ( $p > 0.05$ )



Table 15 Similarity (%) of resident birds among *Gmelina* stands (according to context), pasture, and native stands, May-July (a) 1998 and (b) 1999, southwestern Costa Rica

(a)

	GMEL	ADJ	ISOL	Native	Pasture
GMEL	-	0.39	0.44	0.22	0.27
ADJ	-	-	0.42	0.55	0.13
ISOL	-	-	-	0.28	0.19
Native	-	-	-	-	0.08

<sup>a</sup> Landscape contexts are categorized as the following GMEL = *Gmelina* stands in a context of other *Gmelina* stands, ADJ = *Gmelina* stands adjacent to native forests, and ISOL = *Gmelina* stands isolated from other wooded areas.

(b)

	GMEL	ADJ	ISOL	Native	Pasture
GMEL	-	0.50	0.45	0.30	0.18
ADJ	-	-	0.40	0.42	0.11
ISOL	-	-	-	0.41	0.11
Native	-	-	-	-	0.05

<sup>a</sup> Landscape contexts are categorized as the following GMEL = *Gmelina* stands in a context of other *Gmelina* stands; ADJ = *Gmelina* stands adjacent to native forests, and ISOL = *Gmelina* stands isolated from other wooded areas

## **Figures**

Figure 1 Deforestation patterns in Costa Rica, 1940-1987 (Lehmann 1992)

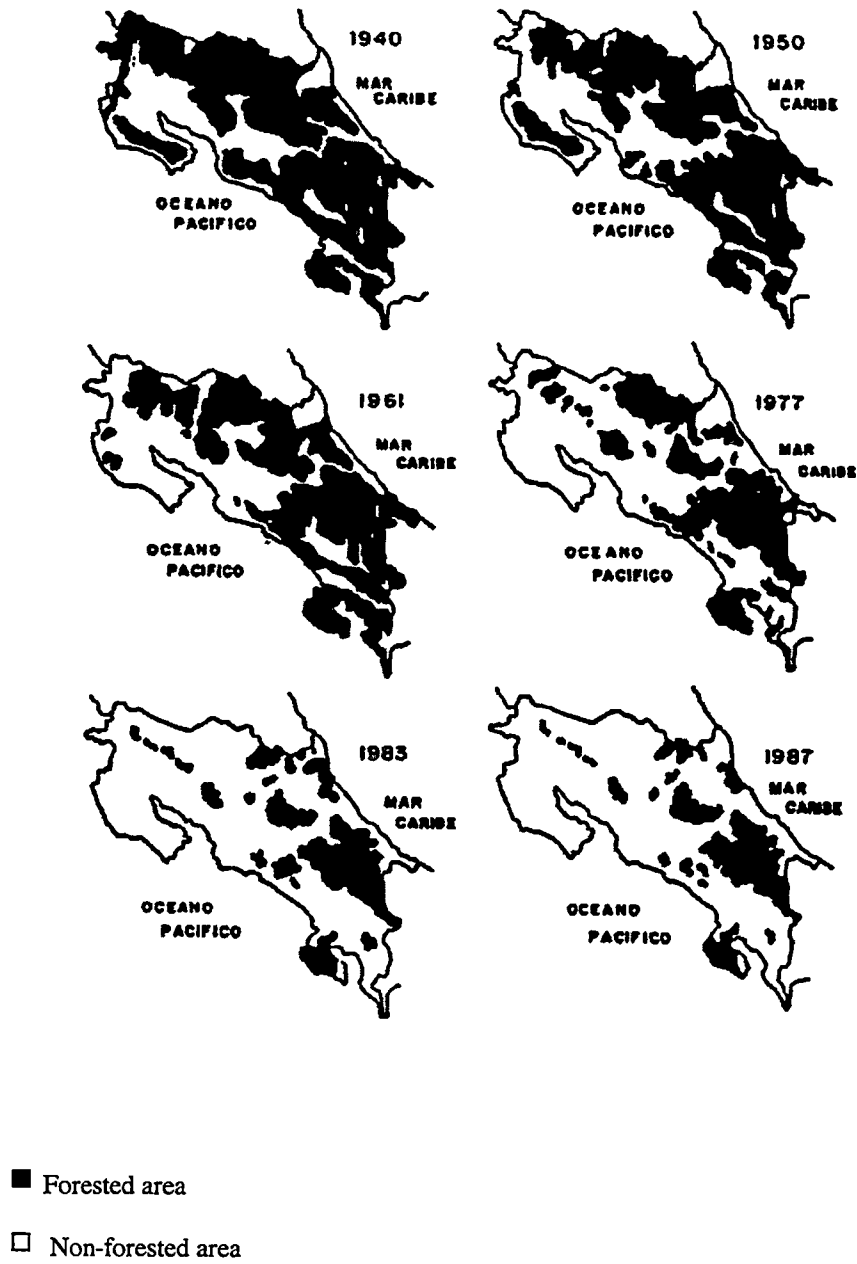


Figure 2. Study site locations, May-July 1998 and 1999, southwestern Costa Rica.

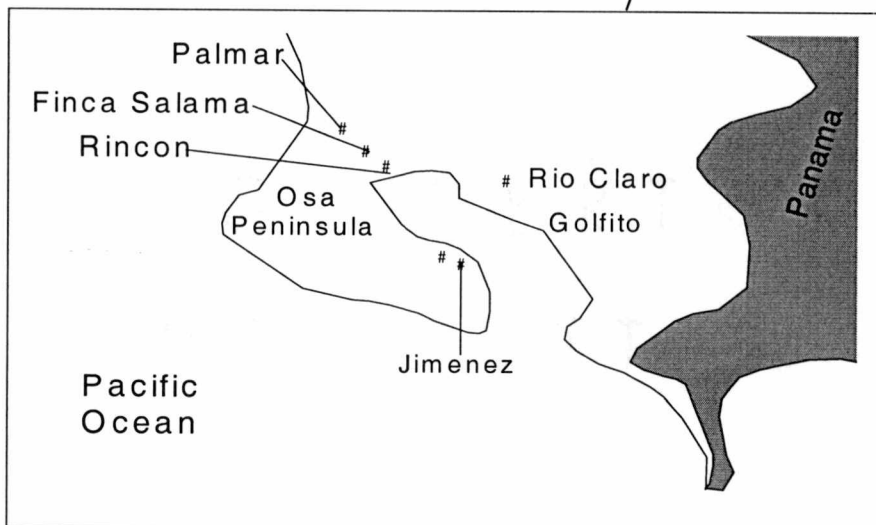
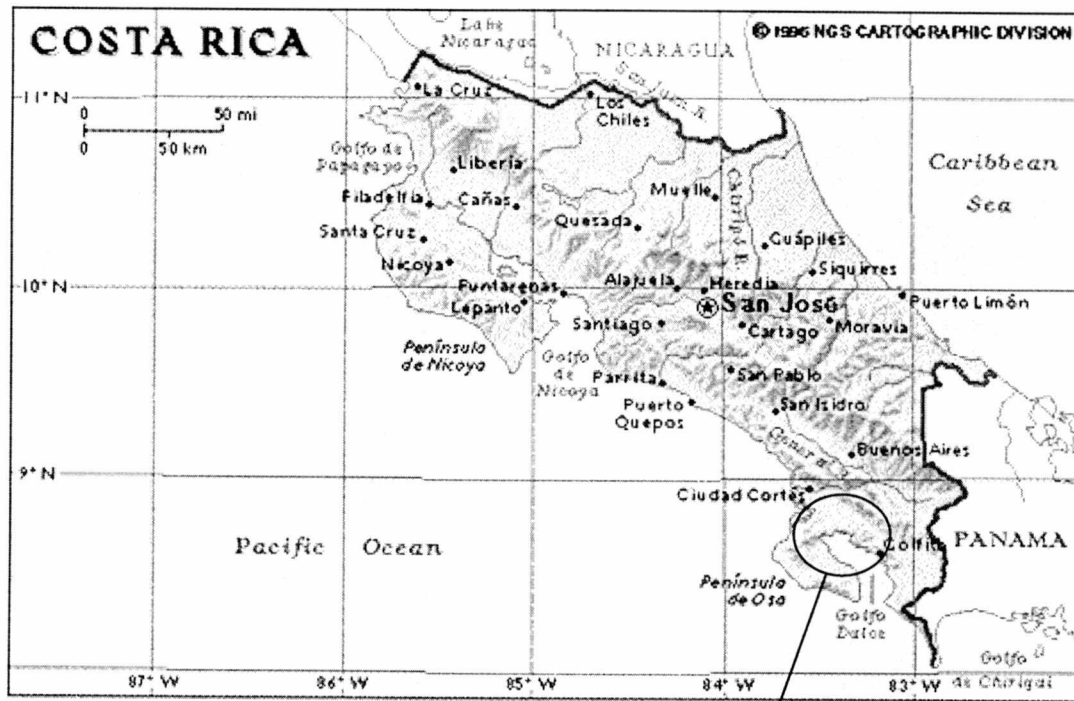
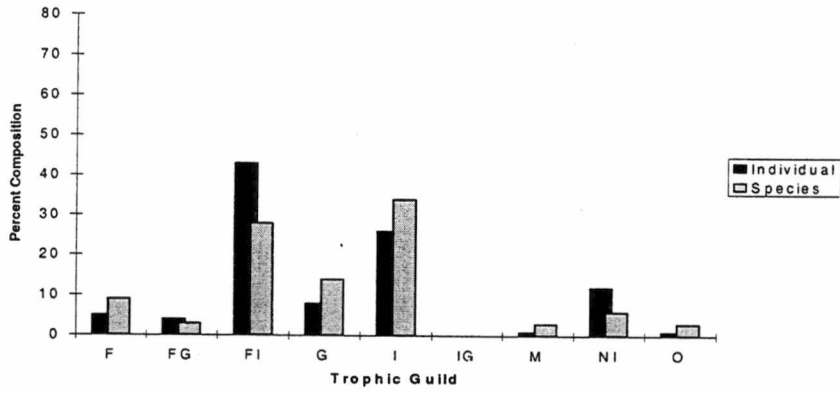
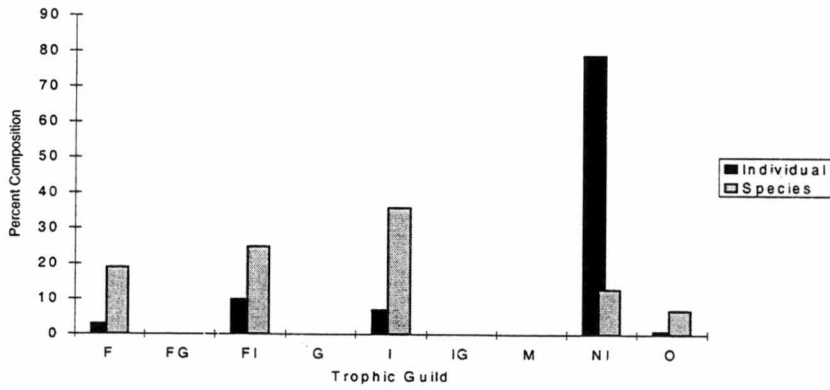


Figure 3. Guild composition (%) of individual birds and species in (a) young, (b) intermediate, (c) old *Gmelina* stands, (d) pastures, and (e) natives stands, May-July 1998, southwestern Costa Rica.

(a)



(b)



(c)

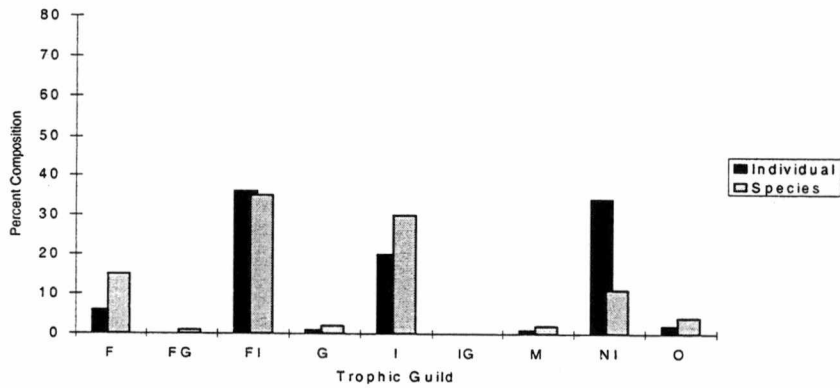
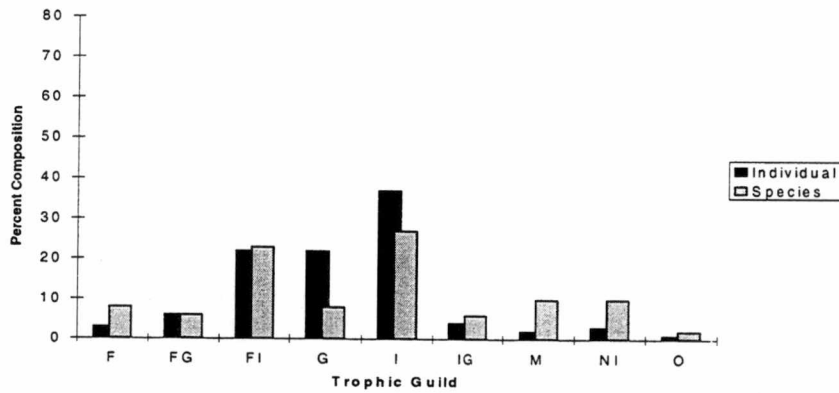
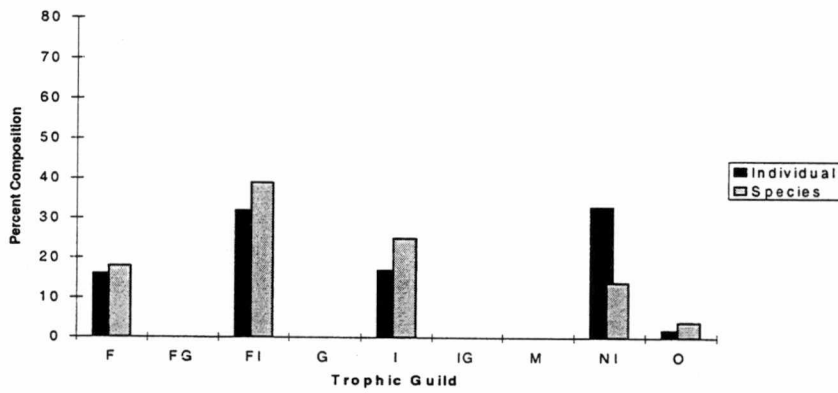


Figure 3. (continued)

(d)



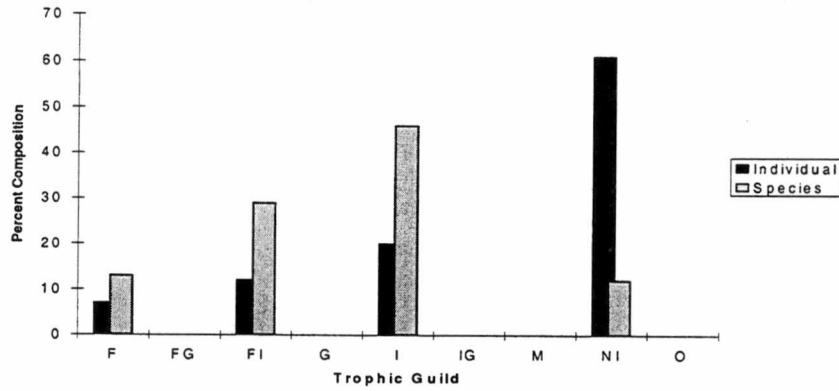
(e)



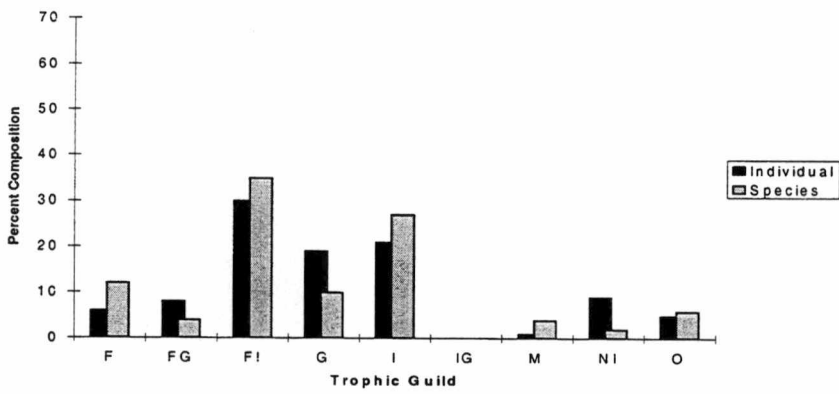
- F = Frugivorous
- FG = Frugivorous/Granivorous
- FI = Frugivorous/Insectivorous
- G = Granivorous
- I = Insectivorous
- IG = Insectivorous/Granivorous
- M = Miscellaneous (Carnivorous, Carrion eaters)
- NI = Nectarivorous/Insectivorous
- O = Omnivorous

Figure 4. Guild composition (%) of individual birds and species in (a) young, (b) intermediate, (c) old *Gmelina* stands, (d) pastures, and (e) native stands, May-July 1999, southwestern Costa Rica.

(a)



(b)



(c)

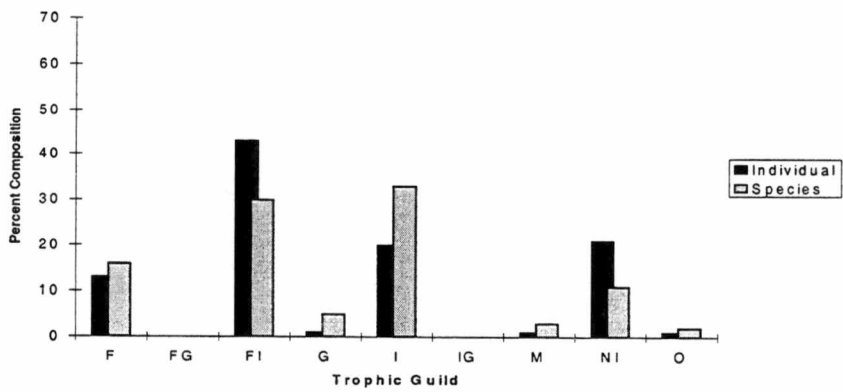
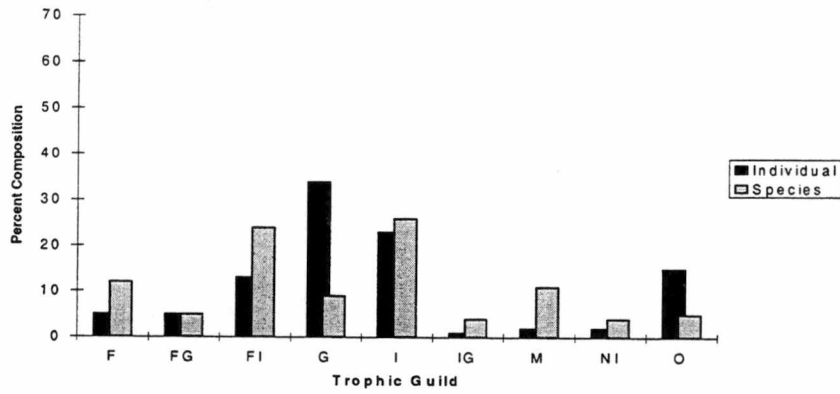
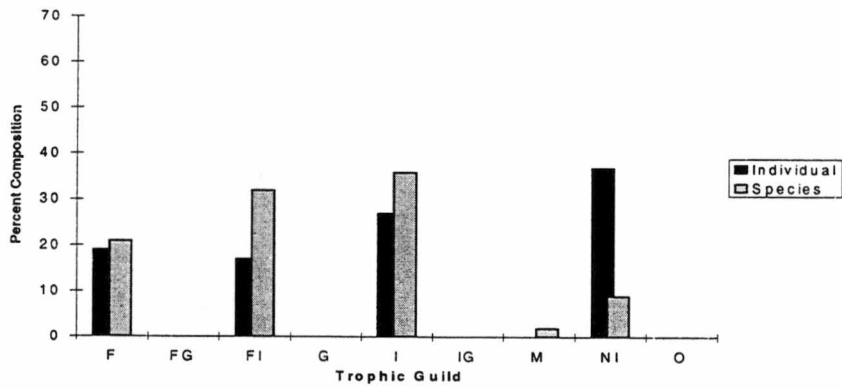


Figure 4. (continued)

(d)



(e)

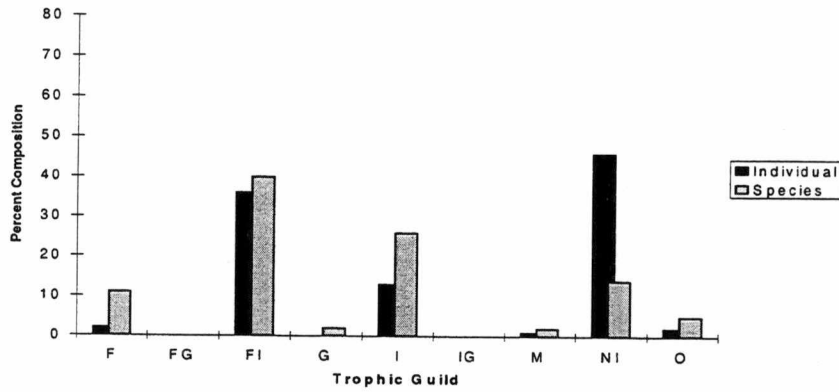


F = Frugivorous  
 FG = Frugivorous/Granivorous  
 FI = Frugivorous/Insectivorous  
 G = Granivorous  
 I = Insectivorous  
 IG = Insectivorous/Granivorous  
 M = Miscellaneous (Carnivorous, Carrion eaters)  
 NI = Nectarivorous/Insectivorous  
 O = Omnivorous

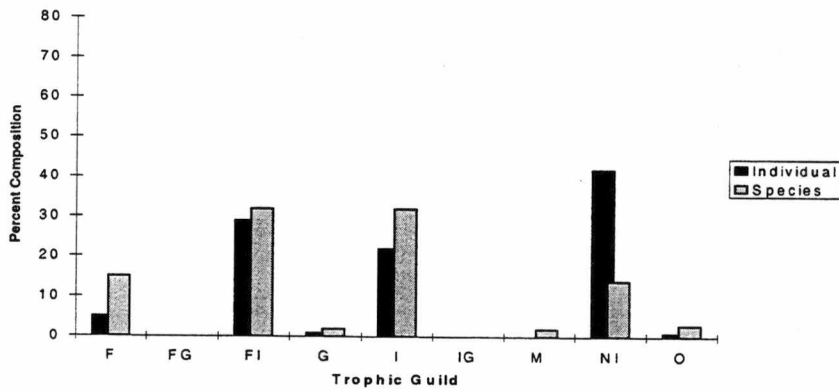


Figure 5. Guild composition (%) of individual birds and species in (a) *Gmelina* stands surrounded by other *Gmelina* stands, (b) *Gmelina* stands adjacent to native forest, (c) *Gmelina* stands isolated from other forests, (d) pastures, and (e) natives stands, May-July 1998, southwestern Costa Rica.

(a)



(b)



(c)

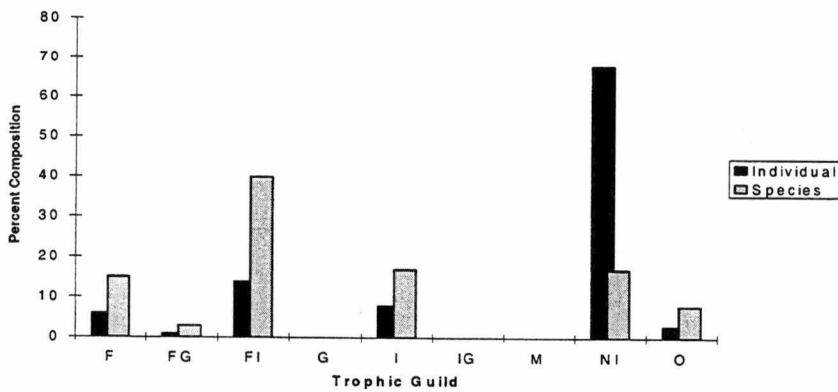
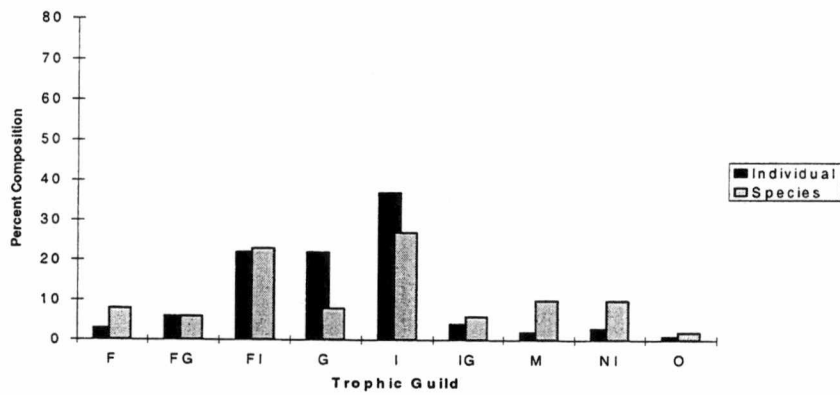
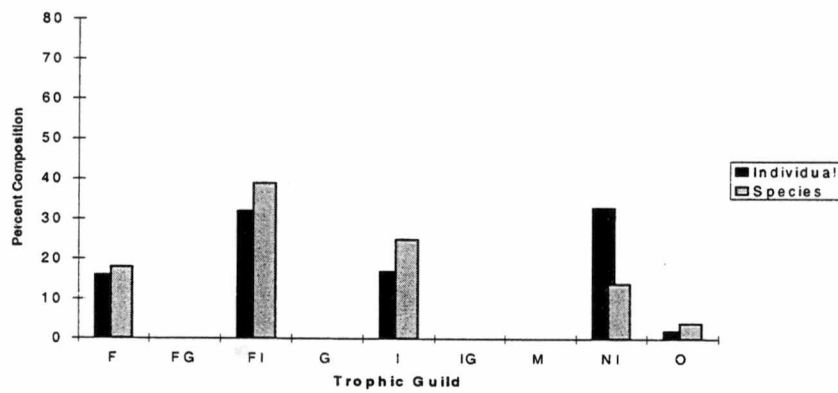


Figure 5. (continued)

(d)



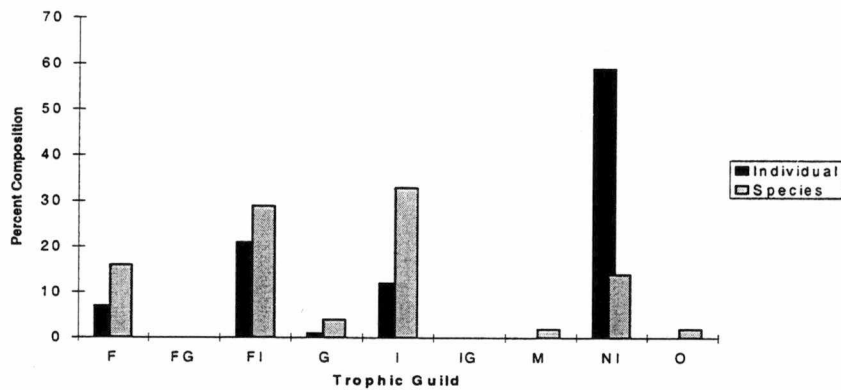
(e)



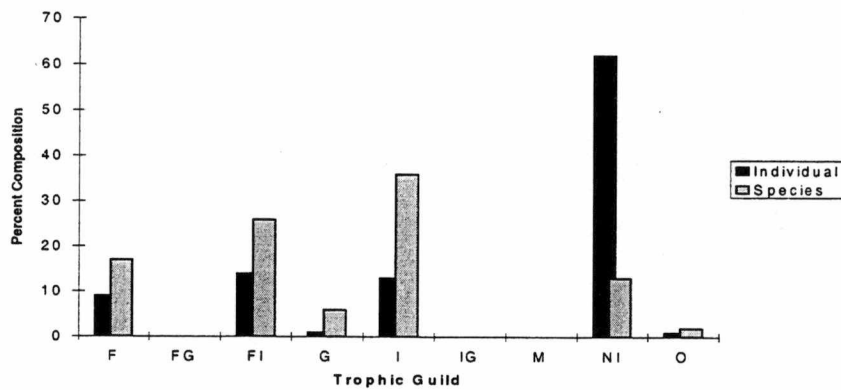
- F = Frugivorous
- FG = Frugivorous/Granivorous
- FI = Frugivorous/Insectivorous
- G = Granivorous
- I = Insectivorous
- IG = Insectivorous/Granivorous
- M = Miscellaneous (Carnivorous, Carrion eaters)
- NI = Nectarivorous/Insectivorous
- O = Omnivorous

Figure 6. Guild composition (%) of individual birds and species in (a) *Gmelina* stands surrounded by other *Gmelina* stands, (b) *Gmelina* stands adjacent to native forest, (c) *Gmelina* stands isolated from other forests, (d) pastures, (e) native stands, May-July 1999, southwestern Costa Rica.

(a)



(b)



(c)

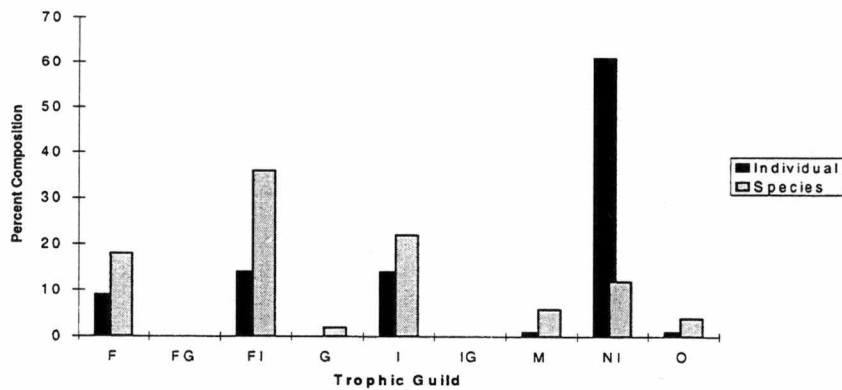
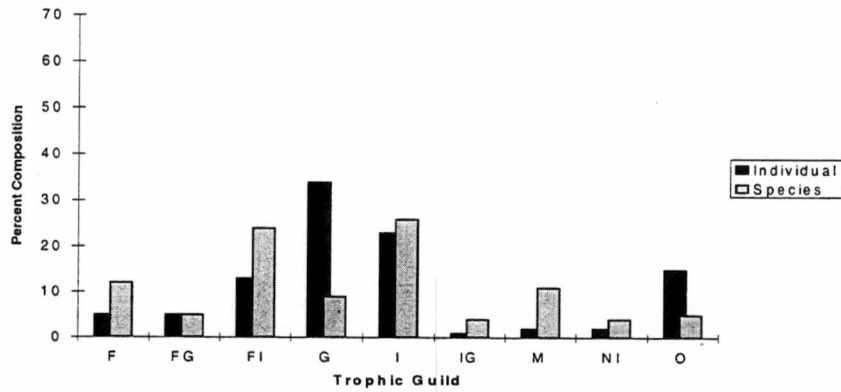
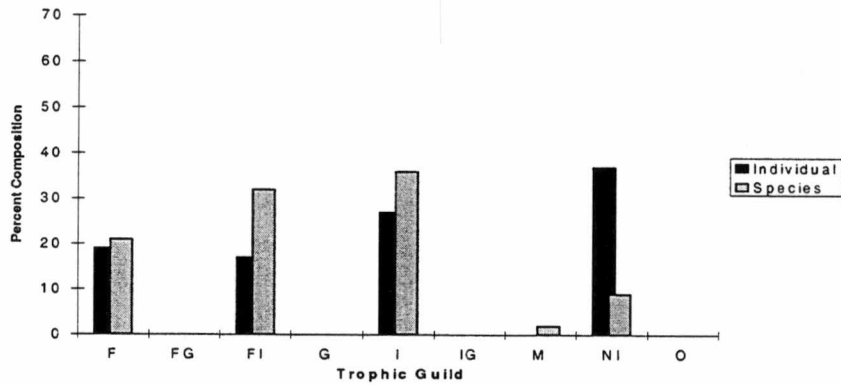


Figure 6. (continued)

(d)



(e)



- F = Frugivorous
- FG = Frugivorous/Granivorous
- FI = Frugivorous/Insectivorous
- G = Granivorous
- I = Insectivorous
- IG = Insectivorous/Granivorous
- M = Miscellaneous (Carnivorous, Carrion eaters)
- NI = Nectarivorous/Insectivorous
- O = Omnivorous

**Appendix B.**

**Common and scientific names of resident bird species observed in  
*Gmelina arborea* plantations, pastures, and native forests, May-July 1998 and 1999,  
southwestern Costa Rica.**

Table B 1 Resident birds found on 50-m-radius point counts in *Gmelina* stands, pastures, and native stands, May-July 1998 and 1999, southwestern Costa Rica. Species are presented in taxonomic order.

Common Name	Scientific Name	Trophic Guild	G <sup>a</sup>	N <sup>b</sup>	P <sup>c</sup>
Great Tinamou	<i>Tinamus major</i>	Frugivore	x	x	x
Little Tinamou	<i>Crypturellus soui</i>	Frugivore	x	x	
Cattle Egret	<i>Bubulcus ibis</i>	Piscivore			x
Green Heron	<i>Butorides s. virescens</i>	Piscivore	x		x
Little Blue Heron	<i>Egretta caerulea</i>	Piscivore	x		x
Great Egret	<i>Casmerodius albus</i>	Piscivore			x
Black-bellied Whistling-Duck	<i>Dendrocygna autumnalis</i>	Granivore	x		x
Turkey Vulture	<i>Cathartes aura</i>	Carrion	x	x	
Black Vulture	<i>Coragyps atratus</i>	Carrion			x
Double-toothed Kite	<i>Harpagus bidentatus</i>	Insectivore	x		
Roadside Hawk	<i>Buteo magnirostris</i>	Insectivore	x	x	x
Yellow-headed Caracara	<i>Milvago chumachuma</i>	Carnivore/Carrion	x		x
Laughing Falcon	<i>Herpetotheres cachinnans</i>	Carnivore	x		x
Gray-necked Wood-Rail	<i>Aramides cajanea</i>	Insectivore	x		x
White-throated Crake	<i>Laterallus albigularis</i>	Insectivore	x	x	x
Gray-breasted Crake	<i>Laterallus exilis</i>	Insectivore	x		x
Purple Gallinule	<i>Porphyryula martinica</i>	Frugivore/Granivore			x
Northern Jacana	<i>Jacana spinosa</i>	Insectivore	x		x
Pale-vented Pigeon	<i>Columba cayennensis</i>	Frugivore	x	x	x
Red-billed Pigeon	<i>Columba flavirostris</i>	Frugivore			x
Short-billed Pigeon	<i>Columba nigrirostris</i>	Frugivore	x	x	x
Ruddy Ground-Dove	<i>Columbina talpacoti</i>	Granivore	x		x

Table B 1 (Continued)

Common Name	Scientific Name	Trophic Guild	G <sup>a</sup>	N <sup>b</sup>	P <sup>c</sup>
Blue Ground-Dove	<i>Claravis pretiosa</i>	Granivore	x		x
White-tipped Dove	<i>Leptotila verreauxi</i>	Frugivore	x		x
Gray-fronted Dove	<i>Leptotila rufaxilla</i>	Frugivore	x	x	x
Gray-chested Dove	<i>Leptotila cassini</i>	Frugivore	x		
Scarlet Macaw	<i>Ara macao</i>	Frugivore	x		
Orange-chinned Parakeet	<i>Brotogeris jugularis</i>	Frugivore	x		x
Red-lored Parrot	<i>Amazona autumnalis</i>	Frugivore	x	x	
Mealy Parrot	<i>Amazona farinosa</i>	Frugivore		x	
Squirrel Cuckoo	<i>Piaya cayana</i>	Insectivore	x	x	x
Smooth-billed Ani	<i>Crotophaga ani</i>	Insectivore	x		x
Striped Cuckoo	<i>Tapera naevia</i>	Insectivore			x
Common Barn-Owl	<i>Tyto alba</i>	Carnivore			x
Bronzy Hermit	<i>Glaucis aenea</i>	Nectarivore/Insectivore	x	x	x
Band-tailed Barbthroat	<i>Threnetes ruckeri</i>	Nectarivore /Insectivore	x	x	x
Long-tailed Hermit	<i>Phaethornis superciliosus</i>	Nectarivore /Insectivore	x	x	x
Little Hermit	<i>Phaethornis longuemareus</i>	Nectarivore /Insectivore	x	x	
White-necked Jacobin	<i>Florisuga mellivora</i>	Nectarivore /Insectivore	x		x
Violet-headed Hummingbird	<i>Klais guimeti</i>	Nectarivore /Insectivore	x		
Crowned Woodnymph	<i>Thalurania colombica</i>	Nectarivore /Insectivore	x		
Blue-throated Goldentail	<i>Hylocharis eliciae</i>	Nectarivore /Insectivore	x		
Beryl-crowned Hummingbird	<i>Amazilia decora</i>	Nectarivore /Insectivore	x	x	
Rufous-tailed Hummingbird	<i>Amazilia tzacatl</i>	Nectarivore /Insectivore	x	x	x
Slaty-tailed Trogon	<i>Trogon massena</i>	Frugivore/Insectivore	x	x	

Table B 1 (Continued)

Common Name	Scientific Name	Trophic Guild	G <sup>a</sup>	N <sup>b</sup>	P <sup>c</sup>
Baird's Trogon	<i>Trogon bairdi</i>	Frugivore/Insectivore	x	x	
Violaceous Trogon	<i>Trogon violaceus</i>	Frugivore/Insectivore	x	x	
Ringed Kingfisher	<i>Ceryle torquata</i>	Piscivore		x	x
Blue-crowned Motmot	<i>Momotus momota</i>	Frugivore/Insectivore	x	x	
Rufous-tailed Jacamar	<i>Galbula ruficauda</i>	Insectivore	x		
White-necked Puffbird	<i>Bucco macrorhynchos</i>	Insectivore	x		
Fiery-billed Aracari	<i>Pteroglossus frantzii</i>	Frugivore/Insectivore	x		
Chestnut-mandibled Toucan	<i>Ramphastos swainsonii</i>	Frugivore/Insectivore	x	x	
Golden-naped Woodpecker	<i>Melanerpes chrysauchen</i>	Frugivore/Insectivore		x	
Red-crowned Woodpecker	<i>Melanerpes rubricapillus</i>	Frugivore/Insectivore	x	x	x
Lineated Woodpecker	<i>Dryocopus lineatus</i>	Frugivore/Insectivore	x		
Pale-billed Woodpecker	<i>Campephilus guatemalensis</i>	Frugivore/Insectivore	x	x	
Tawny-winged Woodcreeper	<i>Dendrocincla anabatina</i>	Insectivore	x	x	
Wedge-billed Woodcreeper	<i>Glyphorhynchus spirurus</i>	Insectivore	x	x	
Barred Woodcreeper	<i>Dendrocolaptes certhia</i>	Insectivore		x	
Buff-throated Woodcreeper	<i>Xiphorhynchus guttatus</i>	Insectivore	x	x	
Black-striped Woodcreeper	<i>Xiphorhynchus lachrymosus</i>	Insectivore	x	x	
Streak-headed Woodcreeper	<i>Lepidocolaptes souleyetii</i>	Insectivore	x	x	
Pale-breasted Spinetail	<i>Synallaxis albescens</i>	Insectivore	x		x
Slaty Spinetail	<i>Synallaxis brachyura</i>	Insectivore	x		x
Buff-throated Foliage-gleaner	<i>Automolus ochrolaemus</i>	Insectivore	x	x	
Scaly-throated Leaf-tosser	<i>Sclerurus guatemalensis</i>	Insectivore		x	
Great Antshrike	<i>Taraba major</i>	Insectivore	x	x	x



Table B 1 (Continued)

Common Name	Scientific Name	Trophic Guild	G <sup>a</sup>	N <sup>b</sup>	P <sup>c</sup>
Black-hooded Antshrike	<i>Thamnophilus bridgesi</i>	Insectivore	x	x	
Dotted-winged Antwren	<i>Microrhophias quixensis</i>	Insectivore	x	x	
Dusky Antbird	<i>Cercomacra tyrannina</i>	Insectivore	x		
Chestnut-backed Antbird	<i>Myrmeciza exsul</i>	Insectivore	x	x	
Bicolored Antbird	<i>Gymnopathys leucaspis</i>	Insectivore	x	x	
Black-faced Antthrush	<i>Formicarius analis</i>	Insectivore	x	x	
White-winged Becard	<i>Pachyramphus polychopterus</i>	Frugivore/Insectivore	x	x	x
Masked Tityra	<i>Tityra semifasciata</i>	Frugivore/Insectivore	x	x	
Black-crowned Tityra	<i>Tityra inquisitor</i>	Frugivore/Insectivore	x		x
Rufous Piha	<i>Lipaugus unirufus</i>	Frugivore	x	x	
Red-capped Manakin	<i>Pipra mentalis</i>	Frugivore	x	x	
Blue-crowned Manakin	<i>Pipra coronata</i>	Frugivore	x	x	
Orange-collared Manakin	<i>Manacus aurantiacus</i>	Frugivore/Insectivore	x		
Fork-tailed Flycatcher	<i>Tyrannus savana</i>	Frugivore/Insectivore			x
Tropical Kingbird	<i>Tyrannus melancholicus</i>	Frugivore/Insectivore	x		x
Piratic Flycatcher	<i>Legatus leucophaeus</i>	Frugivore	x	x	x
Boat-billed Flycatcher	<i>Megarhynchus pitangua</i>	Omnivore	x	x	x
Bright-rumped Attila	<i>Attila spadiceus</i>	Insectivore	x	x	
Streaked Flycatcher	<i>Myiodynastes maculatus</i>	Frugivore/Insectivore	x		
Gray-capped Flycatcher	<i>Myiozetetes granadensis</i>	Frugivore/Insectivore	x		x
Social Flycatcher	<i>Myiozetetes similis</i>	Frugivore/Insectivore	x		x
Great Kiskadee	<i>Pitangus sulphuratus</i>	Omnivore	x	x	x
Rufous Mourner	<i>Rhytipterna holerythra</i>	Insectivore		x	

Table B 1 (Continued)

Common Name	Scientific Name	Trophic Guild	G <sup>a</sup>	N <sup>b</sup>	P <sup>c</sup>
Dusky-capped Flycatcher	<i>Myiarchus tuberculifer</i>	Insectivore	x		
Sulphur-rumped Flycatcher	<i>Myiobius sulphureipygius</i>	Insectivore	x	x	
Common Tody-Flycatcher	<i>Todirostrum cinereum</i>	Insectivore	x		x
Slate-headed Tody-Flycatcher	<i>Todirostrum sylvia</i>	Insectivore	x		
Northern Bentbill	<i>Oncostoma cinereigulare</i>	Insectivore	x	x	
Yellow Tyrannulet	<i>Capsiempis flaveola</i>	Frugivore/Insectivore	x		x
Yellow-bellied Elaenia	<i>Elaenia flavogaster</i>	Frugivore/Insectivore	x		x
Southern Beardless-Tyrannulet	<i>Camptostoma obsoletum</i>	Frugivore/Insectivore	x	x	
Ochre-bellied Flycatcher	<i>Mionectes oleagineus</i>	Frugivore/Insectivore	x	x	
Gray-breasted Martin	<i>Progne chalybea</i>	Insectivore			x
Southern Rough-winged Swallow	<i>Stelgidopteryx ruficollis</i>	Insectivore			x
Plain Wren	<i>Thryothorus modestus</i>	Insectivore	x	x	x
Riverside Wren	<i>Thryothorus semibadius</i>	Insectivore	x	x	x
Black-bellied Wren	<i>Thryothorus fasciatoventris</i>	Insectivore	x	x	x
House Wren	<i>Troglodytes aedon</i>	Insectivore	x		x
Clay-colored Robin	<i>Turdus grayi</i>	Frugivore/Insectivore	x	x	
Tropical Gnatcatcher	<i>Poliophtila plumbea</i>	Insectivore	x	x	
Scrub Greenlet	<i>Hylophilus flavipes</i>	Frugivore/Insectivore	x		x
Tawny-crowned Greenlet	<i>Hylophilus ochraceiceps</i>	Insectivore	x	x	
Lesser Greenlet	<i>Hylophilus decurtatus</i>	Frugivore/Insectivore	x	x	
Bananaquit	<i>Coereba flaveola</i>	Nectarivore/Insectivore	x	x	x
Scarlet-rumped Cacique	<i>Cactus uropygialis</i>	Frugivore/Insectivore	x	x	
Bronzed Cowbird	<i>Molothrus aeneus</i>	Insectivore/Granivore			x

Table B 1 (Continued)

Common Name	Scientific Name	Trophic Guild	G <sup>a</sup>	N <sup>b</sup>	P <sup>c</sup>
Great-tailed Grackle	<i>Quiscalus mexicanus</i>	Omnivore	x		x
Red-breasted Blackbird	<i>Sturnella mliuaris</i>	Insectivore/Granivore			x
Eastern Meadowlark	<i>Sturnella magna</i>	Insectivore/Granivore			x
Thick-billed Euphonia	<i>Euphonia lanurostris</i>	Frugivore	x	x	x
Golden-hooded Tanager	<i>Tangara larvata</i>	Frugivore/Insectivore	x		x
Green Honeycreeper	<i>Chlorophanes spiza</i>	Frugivore/Insectivore		x	
Blue-gray Tanager	<i>Thraupis episcopus</i>	Frugivore/Insectivore	x		x
Palm Tanager	<i>Thraupis palmarum</i>	Frugivore/Insectivore	x		x
Scarlet-rumped Tanager	<i>Ramphocelus passerinii</i>	Frugivore/Insectivore	x	x	x
Black-cheeked Ant-Tanager	<i>Habia atrimaxillaris</i>	Frugivore/Insectivore	x		
Buff-throated Saltator	<i>Saltator maximus</i>	Frugivore/Insectivore	x	x	x
Streaked Saltator	<i>Saltator manimus</i>	Frugivore/Insectivore			x
Blue-black Grosbeak	<i>Cyanocompsa cyanoides</i>	Granivore	x	x	x
White-collared Seedeater	<i>Sporophila torqueola</i>	Frugivore/Granivore	x		x
Variable Seedeater	<i>Sporophila aurita</i>	Frugivore/Granivore	x		x
Yellow-bellied Seedeater	<i>Sporophila nigricollis</i>	Granivore	x		
Thick-billed Seed-Finch	<i>Oryzoborus funereus</i>	Granivore	x		x
Blue-black Grassquit	<i>Volatinia jacarina</i>	Granivore	x		x
Orange-billed Sparrow	<i>Arremon auranturostris</i>	Frugivore/Insectivore	x	x	
Black-striped Sparrow	<i>Arremonops conurostris</i>	Frugivore/Insectivore	x	x	x

a Resident birds found within *Gmelina* plantations surveyed

b Resident birds found within native stands surveyed

c Resident birds found within pastures surveyed

Table B 2 Resident birds found on 50-m-radius point counts in *Gmelina arborea* stands by age class and landscape context, May-July 1998 and 1999, southwestern Costa Rica

Common Name	Scientific Name	Yng <sup>a</sup>	Int <sup>b</sup>	Old <sup>c</sup>	GMEL <sup>d</sup>	ADJ <sup>e</sup>	ISOL <sup>f</sup>
Great Tinamou	<i>Tinamus major</i>			x	x	x	x
Little Tinamou	<i>Crypturellus soui</i>		x	x	x	x	x
Green Heron	<i>Butorides s virescens</i>	x					
Little Blue Heron	<i>Egretta caerulea</i>	x					
Black-bellied Whistling-Duck	<i>Dendrocygna autumnalis</i>	x					
Turkey Vulture	<i>Cathartes aura</i>						x
Double-toothed Kite	<i>Harpagus bidentatus</i>					x	
Roadside Hawk	<i>Buteo magnirostris</i>	x	x	x	x	x	x
Yellow-headed Caracara	<i>Milvago chumachuma</i>			x	x	x	x
Laughing Falcon	<i>Herpetotheres cachunnans</i>	x					x
Gray-necked Wood-Rail	<i>Aramides cajanea</i>	x		x	x		x
White-throated Crake	<i>Laterallus albigularis</i>	x	x	x	x		
Gray-breasted Crake	<i>Laterallus exilis</i>		x		x		
Northern Jacana	<i>Jacana spinosa</i>	x					
Pale-vented Pigeon	<i>Columba cayennensis</i>	x	x	x	x	x	x
Short-billed Pigeon	<i>Columba nigrirostris</i>	x		x	x	x	x
Ruddy Ground-Dove	<i>Columbina talpacoti</i>	x		x	x		x
Blue Ground-Dove	<i>Claravis pretiosa</i>	x		x	x	x	
White-tipped Dove	<i>Leptotila verreauxi</i>	x	x	x	x	x	x
Gray-fronted Dove	<i>Leptotila rufaxilla</i>	x				x	x
Gray-chested Dove	<i>Leptotila cassini</i>	x				x	
Scarlet Macaw	<i>Ara macao</i>						x

Table B 2 (Continued)

Common Name	Scientific Name	Yng <sup>a</sup>	Int <sup>b</sup>	Old <sup>c</sup>	GMEL <sup>d</sup>	ADJ <sup>e</sup>	ISOL <sup>f</sup>
Orange-chinned Parakeet	<i>Brotogeris jugularis</i>			x	x		
Red-lored Parrot	<i>Amazona autumnalis</i>		x	x	x		x
Squirrel Cuckoo	<i>Piaya cayana</i>		x	x	x	x	
Smooth-billed Ani	<i>Crotophaga ani</i>	x		x	x		
Bronzy Hermit	<i>Glaucis aenea</i>	x	x	x	x	x	x
Band-tailed Barbthroat	<i>Threnetes ruckeri</i>		x	x	x	x	x
Long-tailed Hermit	<i>Phaethornis superciliosus</i>	x	x	x	x	x	x
Little Hermit	<i>Phaethornis longuemareus</i>			x	x	x	x
White-necked Jacobin	<i>Florisuga mellivora</i>					x	
Violet-headed Hummingbird	<i>Klais guimeti</i>					x	
Crowned Woodnymph	<i>Thalurania colombica</i>					x	
Blue-throated Goldentail	<i>Hylocharis eliciae</i>					x	
Beryl-crowned Hummingbird	<i>Amazilia decora</i>			x	x	x	x
Rufous-tailed Hummingbird	<i>Amazilia tzacatl</i>	x	x	x	x	x	x
Slaty-tailed Trogon	<i>Trogon massena</i>			x	x	x	x
Bard's Trogon	<i>Trogon bairdu</i>			x	x	x	x
Ringed Kingfisher	<i>Ceryle torquata</i>		x		x		
Blue-crowned Motmot	<i>Momotus momota</i>					x	x
Rufous-tailed Jacamar	<i>Galbula ruficauda</i>			x	x		
White-necked Puffbird	<i>Bucco macrorhynchos</i>					x	
Fiery-billed Aracari	<i>Pteroglossus frantzii</i>						x
Chestnut-mandibled Toucan	<i>Ramphastos swainsonii</i>					x	
Red-crowned Woodpecker	<i>Melanerpes rubricapillus</i>	x		x	x	x	x

Table B 2 (Continued)

Common Name	Scientific Name	Yng <sup>a</sup>	Int <sup>b</sup>	Old <sup>c</sup>	GMEL <sup>d</sup>	ADJ <sup>e</sup>	ISOL <sup>f</sup>
Lineated Woodpecker	<i>Dryocopus lineatus</i>	x		x	x		x
Pale-billed Woodpecker	<i>Campephilus guatemalensis</i>					x	x
Tawny-winged Woodcreeper	<i>Dendrocincla anabatna</i>	x	x	x	x	x	
Wedge-billed Woodcreeper	<i>Glyphorhynchus spirurus</i>		x			x	
Buff-throated Woodcreeper	<i>Xiphorhynchus guttatus</i>	x	x	x	x	x	x
Black-striped Woodcreeper	<i>Xiphorhynchus lachrymosus</i>					x	
Streak-headed Woodcreeper	<i>Lepidocolaptes souleyetii</i>	x		x	x	x	x
Pale-breasted Spinetail	<i>Synallaxis albescens</i>	x					
Buff-throated Foliage-gleaner	<i>Automolus ochrolaemus</i>					x	
Great Antshrike	<i>Taraba major</i>	x				x	x
Black-hooded Antshrike	<i>Thamnophilus bridgesi</i>			x	x	x	x
Dotted-winged Antwren	<i>Microrhoptias quixensis</i>					x	x
Dusky Antbird	<i>Cercomacra tyrannina</i>				x	x	
Chestnut-backed Antbird	<i>Myrmeciza exsul</i>			x	x	x	x
Bicolored Antbird	<i>Gymnopithys leucaspis</i>					x	
Black-faced Antthrush	<i>Formicarius analis</i>					x	x
White-winged Becard	<i>Pachyramphus polychopterus</i>	x		x	x		
Masked Tityra	<i>Tityra semifasciata</i>	x		x	x	x	x
Black-crowned Tityra	<i>Tityra inquisitor</i>			x	x	x	x
Rufous Piha	<i>Lipaugus unirufus</i>					x	

Table B 2 (Continued)

Common Name	Scientific Name	Yng <sup>a</sup>	Int <sup>b</sup>	Old <sup>c</sup>	GMEL <sup>d</sup>	ADJ <sup>e</sup>	ISOL <sup>f</sup>
Red-capped Manakin	<i>Pipra mentalis</i>					x	
Blue-crowned Manakin	<i>Pipra coronata</i>					x	
Orange-collared Manakin	<i>Manacus aurantiacus</i>			x	x	x	
Tropical Kingbird	<i>Tyrannus melancholicus</i>	x	x	x	x	x	x
Piratic Flycatcher	<i>Legatus leucophaeus</i>	x		x	x	x	
Boat-billed Flycatcher	<i>Megarhynchus pitangua</i>	x		x	x	x	x
Bright-rumped Attila	<i>Attila spadiceus</i>	x	x	x	x	x	x
Streaked Flycatcher	<i>Myiodynastes maculatus</i>			x	x		x
Gray-capped Flycatcher	<i>Myiozetetes granadensis</i>	x	x	x	x		x
Social Flycatcher	<i>Myiozetetes similis</i>	x		x	x	x	x
Great Kiskadee	<i>Pitangus sulphuratus</i>	x	x	x	x	x	x
Dusky-capped Flycatcher	<i>Myiarchus tuberculifer</i>	x	x	x	x	x	
Sulphur-rumped Flycatcher	<i>Myiobius sulphureipygius</i>					x	
Common Tody-Flycatcher	<i>Todirostrum cinereum</i>	x		x	x		
Northern Bentbill	<i>Oncostoma cinereigulare</i>	x				x	
Yellow Tyrannulet	<i>Capsiempis flaveola</i>	x					
Yellow-bellied Elaenia	<i>Elaenia flavogaster</i>	x		x	x		
Southern Beardless-Tyrannulet	<i>Camptostoma obsoletum</i>					x	
Ochre-bellied Flycatcher	<i>Mionectes oleagineus</i>			x	x	x	
Gray-breasted Martin	<i>Progne chalybea</i>	x					
Plain Wren	<i>Thryothorus modestus</i>	x	x	x	x	x	
Riverside Wren	<i>Thryothorus semibadius</i>	x	x	x	x	x	x

Table B 2 (Continued)

Common Name	Scientific Name	Yng <sup>a</sup>	Int <sup>b</sup>	Old <sup>c</sup>	GMEL <sup>d</sup>	ADJ <sup>e</sup>	ISOL <sup>f</sup>
Black-bellied Wren	<i>Thryothorus fasciatoventris</i>	x	x	x	x	x	
House Wren	<i>Troglodytes aedon</i>	x	x	x	x		
Clay-colored Robin	<i>Turdus grayi</i>	x	x	x	x	x	
Tropical Gnatcatcher	<i>Polioptila plumbea</i>						x
Scrub Greenlet	<i>Hylophilus flavipes</i>	x					
Tawny-crowned Greenlet	<i>Hylophilus ochraceiceps</i>						x
Lesser Greenlet	<i>Hylophilus decurtatus</i>	x					x
Bananaquit	<i>Coereba flaveola</i>			x	x		
Scarlet-rumped Cacique	<i>Cacicus uropygialis</i>			x	x	x	x
Great-tailed Grackle	<i>Quiscalus mexicanus</i>	x					
Thick-billed Euphonia	<i>Euphonia lanurostris</i>			x	x	x	x
Golden-hooded Tanager	<i>Tangara larvata</i>	x		x	x	x	
Green Honeycreeper	<i>Chlorophanes spiza</i>	x					
Blue-gray Tanager	<i>Thraupis episcopus</i>	x		x	x	x	x
Palm Tanager	<i>Thraupis palmarum</i>	x					
Scarlet-rumped Tanager	<i>Ramphocelus passerinii</i>	x	x	x	x	x	
Black-cheeked Ant-Tanager	<i>Habia atrimaxillaris</i>						x
Buff-throated Saltator	<i>Saltator maximus</i>	x	x	x	x	x	x
Streaked Saltator	<i>Saltator manimus</i>		x				
Blue-black Grosbeak	<i>Cyanocopsa cyanoides</i>	x					x
White-collared Seedeater	<i>Sporophila torqueola</i>	x					
Variable Seedeater	<i>Sporophila aurita</i>	x					



Table B 2 (Continued)

Common Name	Scientific Name	Yng <sup>a</sup>	Int <sup>b</sup>	Old <sup>c</sup>	GMEL <sup>d</sup>	ADJ <sup>e</sup>	ISOL <sup>f</sup>
Yellow-bellied Seedeater	<i>Sporophila nigrifrons</i>	x					
Thick-billed Seed-Finch	<i>Oryzoborus funereus</i>	x				x	
Blue-black Grassquit	<i>Volatinia jacarina</i>					x	
Orange-billed Sparrow	<i>Arremon auranturostris</i>	x	x	x	x	x	x
Black-striped Sparrow	<i>Arremonops conirostris</i>	x	x	x	x	x	x

a Birds recorded in young age class *Gmelina* plantations.

b Birds recorded in intermediate age class *Gmelina* plantations

c Birds recorded in old age class *Gmelina* plantations

d Birds recorded in *Gmelina* stands surrounded by other *Gmelina* plantations

e Birds recorded in *Gmelina* stands adjacent to native stands

f Birds recorded in *Gmelina* stands isolated from other forested areas

Table B 3 Resident birds found on 50-m-radius point counts in *Gmelina arborea* stands (young, intermediate, old<sup>a</sup>), pastures, and native stands, May-July 1998 and 1999, southwestern Costa Rica. Species are grouped according to those that occupy similar habitats

Common Name	Scientific Name	Pasture	Yng <sup>b</sup>	Int <sup>c</sup>	Old <sup>d</sup>	Native
Cattle Egret	<i>Bubulcus ibis</i>	x				
Great Egret	<i>Casmerodius albus</i>	x				
Black Vulture	<i>Coragyps atratus</i>	x				
Purple Gallinule	<i>Porphyryla martinica</i>	x				
Red-billed Pigeon	<i>Columba flavirostris</i>	x				
Striped Cuckoo	<i>Tapera naevia</i>	x				
Common Barn-Owl	<i>Tyto alba</i>	x				
Fork-tailed Flycatcher	<i>Tyrannus savana</i>	x				
Gray-breasted Martin	<i>Progne chalybea</i>	x				
Southern Rough-winged Swallow	<i>Stelgidopteryx ruficollis</i>	x				
Bronzed Cowbird	<i>Molothrus aeneus</i>	x				
Red-breasted Blackbird	<i>Sturnella militaris</i>	x				
Eastern Meadowlark	<i>Sturnella magna</i>	x				
Streaked Saltator	<i>Saltator manimus</i>	x				
Green Heron	<i>Butorides s. virescens</i>	x	x			
Little Blue Heron	<i>Egretta caerulea</i>	x	x			
Black-bellied Whistling-Duck	<i>Dendrocygna autumnalis</i>	x	x			
Northern Jacana	<i>Jacana spinosa</i>	x	x			
Pale-breasted Spinetail	<i>Synallaxis albescens</i>	x	x			
Slaty Spinetail	<i>Synallaxis brachyura</i>	x	x			
Yellow Tyrannulet	<i>Capsiempis flaveola</i>	x	x			
Scrub Greenlet	<i>Hylophilus flavipes</i>	x	x			

Table B 3 (continued)

Common Name	Scientific Name	Pasture	Yng <sup>b</sup>	Int <sup>c</sup>	Old <sup>d</sup>	Native
Great-tailed Grackle	<i>Quiscalus mexicanus</i>	x	x			
Palm Tanager	<i>Thraupis palmarum</i>	x	x			
White-collared Seedeater	<i>Sporophila torqueola</i>	x	x			
Variable Seedeater	<i>Sporophila aurita</i>	x	x			
Laughing Falcon	<i>Herpetotheres cachinnans</i>	x	x			x
Gray-necked Wood-Rail	<i>Aramides cajanea</i>	x	x			x
Ruddy Ground-Dove	<i>Columbina talpacoti</i>	x	x			x
Blue Ground-Dove	<i>Claravis pretiosa</i>	x	x			x
Smooth-billed Ani	<i>Crotophaga ani</i>	x	x			x
Social Flycatcher	<i>Myiozetetes similis</i>	x	x			x
Common Tody-Flycatcher	<i>Todirostrum cinereum</i>	x	x			x
Yellow-bellied Elaenia	<i>Elaenia flavogaster</i>	x	x			x
Golden-hooded Tanager	<i>Tangara larvata</i>	x	x			x
Blue-gray Tanager	<i>Thraupis episcopus</i>	x	x			x
Thick-billed Seed-Finch	<i>Oryzoborus funereus</i>	x	x			x
Gray-breasted Crake	<i>Laterallus exilis</i>	x		x		x
Ringed Kingfisher	<i>Ceryle torquata</i>	x		x		x
Yellow-headed Caracara	<i>Mitvago chumachuma</i>	x				x
Orange-chinned Parakeet	<i>Brotogeris jugularis</i>	x				x
White-necked Jacobin	<i>Florisuga mellivora</i>	x				x
Black-crowned Tityra	<i>Tityra inquisitor</i>	x				x
Blue-black Grassquit	<i>Volatinia jacarina</i>	x				x
White-tipped Dove	<i>Leptotila verreauxi</i>	x	x	x		x
Tropical Kingbird	<i>Tyrannus melancholicus</i>	x	x	x		x

Table B 3 (continued)

Common Name	Scientific Name	Pasture	Yng <sup>b</sup>	Int <sup>c</sup>	Old <sup>d</sup>	Native
Gray-capped Flycatcher	<i>Myiozetetes granadensis</i>	x	x	x	x	
House Wren	<i>Troglodytes aedon</i>	x	x	x	x	
Short-billed Pigeon	<i>Columba nigrirostris</i>	x	x		x	x
White-winged Becard	<i>Pachyrhamphus polychopterus</i>	x	x		x	x
Piratic Flycatcher	<i>Legatus leucophaeus</i>	x	x		x	x
Boat-billed Flycatcher	<i>Megarhynchus pitangua</i>	x	x		x	x
Blue-black Grosbeak	<i>Cyanocompsa cyanoides</i>	x	x		x	x
Roadside Hawk	<i>Buteo magnirostris</i>	x	x	x	x	x
White-throated Crake	<i>Laterallus albigularis</i>	x	x	x	x	x
Pale-vented Pigeon	<i>Columba cayennensis</i>	x	x	x	x	x
Bronzy Hermit	<i>Glaucis aenea</i>	x	x	x	x	x
Long-tailed Hermit	<i>Phaethornis superciliosus</i>	x	x	x	x	x
Rufous-tailed Hummingbird	<i>Amazilia tzacatl</i>	x	x	x	x	x
Red-crowned Woodpecker	<i>Melanerpes rubricapillus</i>	x	x	x	x	x
Great Kiskadee	<i>Pitangus sulphuratus</i>	x	x	x	x	x
Plain Wren	<i>Thryothorus modestus</i>	x	x	x	x	x
Riverside Wren	<i>Thryothorus semibadius</i>	x	x	x	x	x
Black-bellied Wren	<i>Thryothorus fasciatoventris</i>	x	x	x	x	x
Scarlet-rumped Tanager	<i>Ramphocelus passerinii</i>	x	x	x	x	x
Buff-throated Saltator	<i>Saltator maximus</i>	x	x	x	x	x
Black-striped Sparrow	<i>Arremonops conirostris</i>	x	x	x	x	x
Squirrel Cuckoo	<i>Piaya cayana</i>	x		x	x	x
Band-tailed Barbthroat	<i>Threnetes ruckeri</i>	x		x	x	x

Table B 3 (continued)

Common Name	Scientific Name	Pasture	Yng <sup>b</sup>	Int <sup>c</sup>	Old <sup>d</sup>	Native
Great Tinamou	<i>Tinamus major</i>	x			x	x
Bananaquit	<i>Coereba flaveola</i>	x			x	x
Thick-billed Euphonia	<i>Euphonia lanurostris</i>	x			x	x
Masked Tityra	<i>Tityra semifasciata</i>		x		x	x
Yellow-bellied Seedeater	<i>Sporophila nigricollis</i>		x			
Dusky-capped Flycatcher	<i>Myiarchus tuberculifer</i>		x	x	x	
Gray-chested Dove	<i>Leptotila cassini</i>		x		x	
Lineated Woodpecker	<i>Dryocopus lineatus</i>		x		x	
Double-toothed Kite	<i>Harpagus bidentatus</i>				x	
Scarlet Macaw	<i>Ara macao</i>				x	
Violet-headed Hummingbird	<i>Klais guimeti</i>				x	
Crowned Woodnymph	<i>Thalurania colombica</i>				x	
Blue-throated Goldentail	<i>Hylocharis eliciae</i>				x	
Rufous-tailed Jacamar	<i>Galbula ruficauda</i>				x	
White-necked Puffbird	<i>Bucco macrorhynchos</i>				x	
Fiery-billed Aracari	<i>Pteroglossus frantzii</i>				x	
Dusky Antbird	<i>Cercomacra tyrannina</i>				x	
Orange-collared Manakin	<i>Manacus aurantiacus</i>				x	
Streaked Flycatcher	<i>Myiodynastes maculatus</i>				x	
Black-cheeked Ant-Tanager	<i>Habia atrimaxillaris</i>				x	
Tawny-winged Woodcreeper	<i>Dendrocincla anabatna</i>		x	x	x	x
Buff-throated Woodcreeper	<i>Xiphorhynchus guttatus</i>		x	x	x	x
Streak-headed Woodcreeper	<i>Lepidocolaptes souleyeti</i>		x	x	x	x
Bright-rumped Attila	<i>Attila spadiceus</i>		x	x	x	x

Table B 3 (continued)

Common Name	Scientific Name	Pasture	Yng <sup>b</sup>	Int <sup>c</sup>	Old <sup>d</sup>	Native
Clay-colored Robin	<i>Turdus grayi</i>		x	x	x	x
Orange-billed Sparrow	<i>Arremon auranturostris</i>		x	x	x	x
Little Tinamou	<i>Crypturellus soui</i>			x	x	x
Red-lore Parrot	<i>Amazona autumnalis</i>			x	x	x
Wedge-billed Woodcreeper	<i>Glyphorhynchus spirurus</i>			x	x	x
Beryl-crowned Hummingbird	<i>Amazilia decora</i>				x	x
Slaty-tailed Trogon	<i>Trogon massena</i>				x	x
Baird's Trogon	<i>Trogon bairdi</i>				x	x
Violaceous Trogon	<i>Trogon violaceus</i>				x	x
Blue-crowned Motmot	<i>Momotus momota</i>				x	x
Chestnut-mandibled Toucan	<i>Ramphastos swainsonii</i>				x	x
Pale-billed Woodpecker	<i>Campephilus</i> <i>guatemalensis</i>				x	x
Black-striped Woodcreeper	<i>Xiphorhynchus</i> <i>lachrymosus</i>				x	x
Buff-throated Foliage-gleaner	<i>Automolus ochrolaemus</i>				x	x
Black-hooded Antshrike	<i>Thamnophilus bridgesi</i>				x	x
Dotted-winged Antwren	<i>Microrhopias quixensis</i>				x	x
Chestnut-backed Antbird	<i>Myrmeciza exsul</i>				x	x
Bicolored Antbird	<i>Gymnopathys leucaspis</i>				x	x
Black-faced Antthrush	<i>Formicarius analis</i>				x	x
Rufous Piha	<i>Lipaugus unirufus</i>				x	x
Red-capped Manakin	<i>Pipra mentalis</i>				x	x
Blue-crowned Manakin	<i>Pipra coronata</i>				x	x

Table B.3 (continued)

Common Name	Scientific Name	Pasture	Yng <sup>b</sup>	Int <sup>c</sup>	Old <sup>d</sup>	Native
Rufous Mourner	<i>Rhytipterna holerythra</i>				x	x
Sulphur-rumped Flycatcher	<i>Myiobius sulphureipygius</i>				x	x
Northern Bentbill	<i>Oncostoma cinereigulare</i>				x	x
Southern Beardless-Tyrannulet	<i>Camptostoma obsoletum</i>				x	x
Ochre-bellied Flycatcher	<i>Mionectes oleagineus</i>				x	x
Tropical Gnatcatcher	<i>Poliophtila plumbea</i>				x	x
Mealy Parrot	<i>Amazona farinosa</i>					x
Golden-naped Woodpecker	<i>Melanerpes chrysauchen</i>					x
Barred Woodcreeper	<i>Dendrocolaptes certhia</i>					x
Scaly-throated Leaf-tosser	<i>Sclerurus guatemalensis</i>					x

a Old category includes stands used in landscape context test

b. Birds recorded in young age class *Gmelina* plantations

c Birds recorded in intermediate age class *Gmelina* plantations

d Birds recorded in old age class *Gmelina* plantations

e Birds recorded in *Gmelina* stands surrounded by other *Gmelina* plantations

f Birds recorded in *Gmelina* stands adjacent to native stands

g Birds recorded in *Gmelina* stands isolated from other forested areas

**Appendix C.**

**Pairwise comparisons of statistical tests for habitat  
characteristics of *Gmelina* and native stands**



Table C.1a. P values from pairwise comparisons (ANOVA) of basal area among *Gmelina* stands (according to age classes) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	Intermediate	Old	Native	Intermediate	Old	Native
Young	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Intermediate	-	0.0095	0.0740	-	0.0009	0.3099
Old	-	-	0.7488	-	-	0.0231

Table C.1b. P values from pairwise comparisons (ANOVA) of average DBH of *Gmelina* trees among *Gmelina* stands (according to age classes), May-July 1998 and 1999, southwestern Costa Rica.

	1998		1999	
	Intermediate	Old	Intermediate	Old
Young	0.0001	0.0001	-	-
Intermediate	-	0.0040	-	0.0001
Old	-	-	-	-

Table C.1c. P values from pairwise comparisons (ANOVA) of average DBH of non-*Gmelina* trees among *Gmelina* stands (according to age classes) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	Intermediate	Old	Native	Intermediate	Old	Native
Young	-	-	-	0.0244	0.0333	0.0993
Intermediate	-	-	-	-	0.3628	0.1239
Old	-	-	0.7232	-	-	0.1614

Table C.1d. P values from pairwise comparisons (ANOVA) of average DBH of all trees among *Gmelina* stands (according to age classes) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	Intermediate	Old	Native	Intermediate	Old	Native
Young	0.0004	0.0001	0.0001	0.0161	0.0001	0.0001
Intermediate	-	0.0430	0.0001	-	0.0903	0.0001
Old		-	0.0001		-	0.0001

Table C.1e. P values from pairwise comparisons (ANOVA) of understory density among *Gmelina* stands (according to age classes) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	Intermediate	Old	Native	Intermediate	Old	Native
Young	0.0001	0.0032	0.0141	0.1363	0.4392	0.2919
Intermediate	-	0.0594	0.1894	-	0.3444	0.0178
Old		-	0.0001		-	0.0615

Table C.1f. P values from pairwise comparisons (ANOVA) of understory height among *Gmelina* stands (according to age classes) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	Intermediate	Old	Native	Intermediate	Old	Native
Young	0.0293	0.0950	0.0001	0.9571	0.7818	0.0222
Intermediate	-	0.2753	0.0001	-	0.8472	0.0366
Old		-	0.0001		-	0.0228

Table C.1g. P values from pairwise comparisons (ANOVA) of canopy density among *Gmelina* stands (according to age classes) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	Intermediate	Old	Native	Intermediate	Old	Native
Young	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Intermediate	-	0.8651	0.9911	-	0.0019	0.2684
Old	-	-	0.8809	-	-	0.0001

Table C.1h. P values from pairwise comparisons (ANOVA) of canopy height among *Gmelina* stands (according to age classes) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	Intermediate	Old	Native	Intermediate	Old	Native
Young	0.0001	0.0001	0.0001	0.0004	0.0001	0.0001
Intermediate	-	0.6622	0.0001	-	0.0102	0.0033
Old	-	-	0.0001	-	-	0.3538

Table C.1i. P values from pairwise comparisons (ANOVA) of presence of water within 150 meters of point count stations among *Gmelina* stands (according to age) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	Intermediate	Old	Native	Intermediate	Old	Native
Young	0.5238	0.4354	0.1738	0.4194	0.0720	0.1914
Intermediate	-	0.1266	0.4651	-	0.4478	0.0488
Old	-	-	0.0191	-	-	0.0023

Table C.1j. P values from pairwise comparisons (ANOVA) of presence of non-*Gmelina* trees near point count stations among *Gmelina* stands (according to age), May-July 1998 and 1999, southwestern Costa Rica.

	Intermediate	1998	1999	
		Old	Intermediate	Old
Young	0.4608	0.8920	0.6506	0.3183
Intermediate	-	0.4380	-	0.1616

Table C.1k. P values from pairwise comparisons (ANOVA) of presence of primary edges near point count stations among *Gmelina* stands (according to age) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	Intermediate	1998		Intermediate	1999	
		Old	Native		Old	Native
Young	0.1407	0.0309	0.0367	1.0000	0.6470	0.1687
Intermediate	-	0.7667	0.5087	-	0.8142	0.2580
Old	-	-	0.5935	-	-	0.2706

Table C.1l. P values from pairwise comparisons (ANOVA) of presence of secondary edges near point count stations among *Gmelina* stands (according to age), May-July 1998 and 1999, southwestern Costa Rica.

	Intermediate	1998	1999	
		Old	Intermediate	Old
Young	0.0997	0.1268	0.3358	0.6796
Intermediate	-	0.0007	-	0.4918

Table C.2a. P values from pairwise comparisons (ANOVA) of basal area among *Gmelina* stands (according to landscape contexts) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.0073	0.3914	0.9737	0.2641	0.6825	0.0210
ADJ	-	0.0816	0.0999	-	0.4638	0.1909
ISOL		-	0.6140		-	0.0474

Table C.2b. P values from pairwise comparisons (ANOVA) of average DBH of *Gmelina* among *Gmelina* stands (according to landscape contexts), May-July 1998 and 1999, southwestern Costa Rica.

	1998		1999	
	ADJ	ISOL	ADJ	ISOL
GMEL	0.6591	0.0017	0.0001	0.0001
ADJ	-	0.0088	-	0.8888

Table C.2c. P values from pairwise comparisons (ANOVA) of average DBH of non-*Gmelina* trees among *Gmelina* stands (according to landscape contexts) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.6161	0.1072	0.8506	0.4826	0.0002	0.3175
ADJ	-	0.0868	0.2387	-	0.0090	0.9485
ISOL		-	0.0129		-	0.0005

Table C.2d. P values from pairwise comparisons (ANOVA) of average DBH of all trees among *Gmelina* stands (according to landscape contexts) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.3629	0.0986	0.0001	0.0959	0.1618	0.0001
ADJ	-	0.0151	0.0001	-	0.7096	0.0001
ISOL		-	0.0001		-	0.0001

Table C.2e. P values from pairwise comparisons (ANOVA) of understory density among *Gmelina* stands (according to landscape contexts) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.0001	0.6913	0.0001	0.4829	0.0045	0.0287
ADJ	-	0.0001	0.2099	-	0.0011	0.1284
ISOL		-	0.0001		-	0.0001

Table C.2f. P values from pairwise comparisons (ANOVA) of understory height among *Gmelina* stands (according to landscape contexts) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.0019	0.2408	0.0001	0.9758	0.7801	0.0063
ADJ	-	0.0001	0.0001	-	0.8219	0.0092
ISOL		-	0.0001		-	0.0036

Table C.2g. P values from pairwise comparisons (ANOVA) of canopy cover density among *Gmelina* stands (according to landscape contexts) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.0047	0.5711	0.6256	0.0001	0.5570	0.0016
ADJ	-	0.0014	0.0253	-	0.0001	0.0001
ISOL		-	0.9022		-	0.0067

Table C.2h. P values from pairwise comparisons (ANOVA) of canopy height among *Gmelina* stands (according to landscape contexts) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.1268	0.6957	0.0001	0.1039	0.1036	0.2275
ADJ	-	0.0692	0.0001	-	0.9035	0.0167
ISOL		-	0.0001		-	0.0160

Table C.2i. P values from pairwise comparisons (ANOVA) of percent slope of point count stations among *Gmelina* stands (according to landscape context) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.0001	0.8243	0.0001	0.0001	1.0000	0.0001
ADJ	-	0.0001	0.0001	-	0.0001	0.0001
ISOL		-	0.0001		-	0.0001

Table C.2j. P values from pairwise comparisons (ANOVA) of slope aspect of point count stations among *Gmelina* stands (according to landscape context) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.0001	0.5556	0.0001	0.0001	1.0000	0.0001
ADJ	-	0.0001	0.4180	-	0.0001	0.6399
ISOL	-	-	0.0001	-	-	0.0001

Table C.2k. P values from pairwise comparisons (ANOVA) of presence of water within 150 meters of point count stations among *Gmelina* stands (according to landscape context) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.0069	0.0136	0.0239	0.0008	0.0180	0.0001
ADJ	-	0.8466	0.5847	-	0.2265	0.1561
ISOL	-	-	0.5035	-	-	0.0120

Table C.2l. P values from pairwise comparisons (ANOVA) of presence of non-*Gmelina* trees near point count stations among *Gmelina* stands (according to landscape context), May-July 1998 and 1999, southwestern Costa Rica.

	1998		1999	
	ADJ	ISOL	ADJ	ISOL
GMEL	0.8193	0.2862	0.0630	0.1263
ISOL	-	0.4177	-	0.6532



Table C.2m. P values from pairwise comparisons (ANOVA) of presence of primary edges near point count stations among *Gmelina* stands (according to landscape context) and native stands, May-July 1998 and 1999, southwestern Costa Rica.

	1998			1999		
	ADJ	ISOL	Native	ADJ	ISOL	Native
GMEL	0.2860	0.9110	0.4749	0.1509	0.0148	0.3567
ADJ	-	0.3660	0.1734	-	0.4074	0.7803
ISOL	-	-	0.4421	-	-	0.3203

Table C.2n. P values from pairwise comparisons (ANOVA) of presence of secondary edges near point count stations among *Gmelina* stands (according to landscape context), May-July 1998 and 1999, southwestern Costa Rica.

	1998		1999	
	ADJ	ISOL	ADJ	ISOL
GMEL	0.0001	0.0001	0.0001	0.0001
ISOL	-	0.9842	-	0.5157

## VITA

Allison Mains was born in Wickliffe, Ohio in 1969 and was raised in the coastal plains of North Carolina. In 1987, Allison graduated from Fayetteville Terry Sanford of Fayetteville, NC. She attended North Carolina State University, Raleigh and graduated with a Bachelor's of Science degree in Zoology in May 1991. Before returning to school, she participated in a number of research related jobs in various areas of the country. She received her Master's of Science degree in Ecology and Evolutionary Biology from the University of Tennessee, Knoxville in August 2000. Allison's primary interest is management of non-game species with emphasis on avian conservation.