Review

Biodiversity Conservation in Traditional Coffee Systems of Mexico

PATRICIA MOGUEL* AND VICTOR M. TOLEDO†‡

*Universidad Michoacana de San Nicolás de Hidalgo, Morelia, Michoacán, Mexico
†Instituto de Ecología, National University of Mexico, Apdo. 41-H Sta. María Guido, Morelia, Michoacán 58090, Mexico

Abstract: *In Mexico, coffee is cultivated on the coastal slopes of the central and southern parts of the country in areas where two or more types of vegetation make contact. Based on management level and vegetational and structural complexity, it is possible to distinguish five main coffee production systems in Mexico: two kinds of traditional shaded agroforests (with native trees), one commercially oriented polyspecific shaded system, and two "modern" systems (shaded and unshaded monocultures). Traditional shaded coffee is cultivated principally by small-scale, community-based growers, most of whom belong to some indigenous culture group. Through an exhaustive review of the literature, we found that traditional shaded coffee plantations are important repositories of biological richness for groups such as trees and epiphytes, mammals, birds, reptiles, amphibians, and arthropods. We evaluated the conservation role of these traditional shaded systems by estimating the percentage of the whole coffee area under traditional management, by reviewing the ecological and geographical distribution of coffee areas in Mexico, and by connecting the geographical distribution of these coffee areas with recognized centers of species richness and endemism. The assesment revealed that in Mexico, coffee fields are located in a biogeographically and ecologically strategic elevational belt that is an area of overlap between the tropical and temperate elements and of contact among the four main types of Mexican forests. We also found that between 60% and 70% of these coffee areas are under traditional management and that at least 14 of 155 priority regions selected by experts as having high numbers of species and endemics overlap with or are near traditional coffee-growing areas.*

Conservación de la Biodiversidad en Sistemas de Cultivo Tradicional de Café en México

Resumen: *En México, el café se cultiva sobre las vertientes del Golfo de México y del Pacífico en el centro y sur del país, ahí donde dos o más tipos de vegetación se ponen en contacto. De acuerdo al nivel de manejo y a la estructura de la vegetación, es posible distinguir cinco principales sistemas de producción de café en México: dos tradicionales donde el café se produce bajo la sombra de la vegetación original, uno intermedio donde la sombra la proveen árboles no nativos, y dos "modernos" (monocultivos con y sin sombra). El café cultivado bajo la sombra del dosel original de los bosques o selvas predomina en México, y es producido fundamentalmente por pequeños productores, muchos de los cuales pertenecen a alguna cultura indígena. A partir de una revisión exhaustiva de la literatura, el presente artículo muestra la riqueza biológica de las plantaciones tradicionales de café bajo sombra, en grupos tales como árboles y epífitas, mamíferos, aves, reptiles, anfibios y artrópodos. Para ponderar la importancia conservacionista de estos sistemas agroforestales, las secciones finales del artículo se dedican a estimar el porcentaje de las áreas cafetaleras bajo manejo tradicional, y a revisar la distribución geográfica de las zonas cafetaleras en relación con las áreas ricas en especies o endemismos. El análisis reveló que en México las áreas productores de café se localizan en porciones de gran importancia biogeográfica y ecológica, ahí donde se ponen en contacto los elementos tropicales y templados; que entre el 60 y 70% de las áreas cafetaleras se encuentran bajo manejo tradicional; y que por lo menos 14 de 155 regiones prioritarias recomendadas para su conservación se sobreponen o están próximas a áreas con café bajo sombra y manejo tradicional.*

‡*Address correspondence to V. M. Toledo.*
Paper submitted April 7, 1997; revised manuscript accepted April 15, 1998.

Conservation Biology, Pages 11–21
Volume 13, No. 1, February 1999

Introduction

Biodiversity will not be conserved effectively in natural areas alone. There are just under 7000 nationally protected areas in the world, covering some 650 million ha, which represents less than 5% of the earth's land surface (Ryan 1992). The rest of the terrestrial environment is affected by human activities, including agriculture and urbanization. According to Pimentel et al. (1992), about 75% of the earth's ecosystems are manipulated to obtain products used by humans. Consequently, it is necessary to complement the natural reserve system with a matrix of areas managed by ecological principles, both for self-sufficiency and commodity production as well as for conservation of biological diversity (Harris 1984; Pimentel et al. 1992).

Studies of biological diversity have focused mainly on undisturbed ecosystems, with less attention given to changes in biodiversity in managed or agricultural ecosystems. Landscape structure, field area and margins, and polycultures that are part of the indigenous agricultural strategy appear to increase the biodiversity of traditional agroecosystems (Altieri et al. 1987; Oldfield & Alcorn 1987; Toledo 1990). Thus, there is increasing evidence that the mosaic structure of landscapes under indigenous management maintains and even improves biodiversity (Alcorn 1991, 1994; Gonzalez-Bernaldez 1991; Brown & Brown 1992; Reichhardt et al. 1994; Toledo et al. 1994).

Forest exploitation can range from little-disturbed natural forests to agroindustrial, monospecific plantations. Between these two extremes are the traditional agroforests under indigenous management, which combine relatively high and sustainable economic benefits with a seemingly diversified, productive system. In Mexico, traditional growers dominate in terms of number and amount of land planted in coffee. As in other regions of Latin America (Perfecto et al. 1996), they maintain multilayered, shaded coffee agroforests, which contrast sharply with the modern, agroindustrial, sun coffee plantations with their chemical inputs and year-round labor.

In the context of worldwide coffee production, Mexico is ranked fourth in terms of volume, fifth in amount of land, and ninth in yield performance. Mexico is, in addition, the world's first country to export organic coffee, accounting for one-fifth of the total volume. Coffee is also an important agricultural export commodity for the country, ranking fifth nationally in terms of harvested area.

According to the Coffee Census of the Instituto Mexicano del Café (INMECAFE), the state agency responsible for the trade and production of coffee in Mexico that was dismantled in 1990, by 1989 coffee was produced in about 4300 localities, and it was cultivated in 357 municipalities and 12 states. The main coffee-producing states in Mexico, in decreasing order of importance, are Chiapas, Oaxaca, Veracruz, Puebla, Hidalgo, Guerrero, and San Luis Potosí.

In México, coffee is cultivated in a variety of settings, ranging from 300 to almost 2000 m above sea level and in areas exhibiting a wide range of climates, soils, and vegetation types. Coffee production is most successful between 600 and 1200 m, on relatively steep slopes, and in the transitional zone between tropical and temperate ecotones.

It is estimated that the number of coffee producers reaches approximately 200,000, with a total of 1.5 million people economically involved in the cultivation of coffee (Nolasco 1985). In 1989 the cultivated areas covered 700,000 ha (Census of INMECAFE) and over 850,000 ha in 1991, according to the last National Agricultural Census (Censo Nacional Agropecuario y Ejidal). Ninety percent of the coffee growers worked small holdings covering less than 5 ha, and 70% worked less than 2 ha (Santoyo et al. 1995).

A substantial part of organic coffee production (conducted without agro-chemical inputs and in environmentally friendly agroforests) occurrs in indigenous communities of Oaxaca, Chiapas, Guerrero, and other states. In the coffee-producing municipalities there is an indigenous population of 1.87 million belonging to 28 ethnic groups (Moguel 1996; Moguel & Toledo 1996).

Coffee Production Systems in Mexico

There are five main coffee production systems in Mexico, distinguished according to management level and vegetational and structural complexity (Fuentes-Flores 1979; Nolasco 1985; Fig. 1): traditional rustic or "mountain," traditional polyculture, commercial polyculture, shaded monoculture, and unshaded monoculture. The traditional rustic or "mountain" coffee system substitutes coffee bushes for the plants growing on the floor of tropical or temperate forests. This system removes only the lower strata of the forest. As a result the original tree cover is maintained, under which coffee bushes are inserted. In Mexico this type of management may be observed in relatively isolated areas, where Indian or local communities typically have introduced coffee into the native forest ecosystems. This system is adopted by indigenous groups and features minimal management, no agrochemical products such as pesticides and herbicides, and a markedly low yield.

The traditional polyculture system is a shaded coffee plantation that involves the most advanced stage of manipulation of the native forest ecosystem. As in the previous case, coffee is introduced under the cover of the original forest but in a different way. Coffee is grown alongside numerous useful plant species, forming a sophisticated system of managing native and introduced species—for instance, by favoring the growth of or eliminating certain tree species. The result is an exuberant "coffee garden" with a great variety of arboreal, shrub-like, and herbaceous species, both wild and domesticated. In this system, coffee platantions reach maximum vegetational and architectural complexity and the highest "useful diversity." Commercial

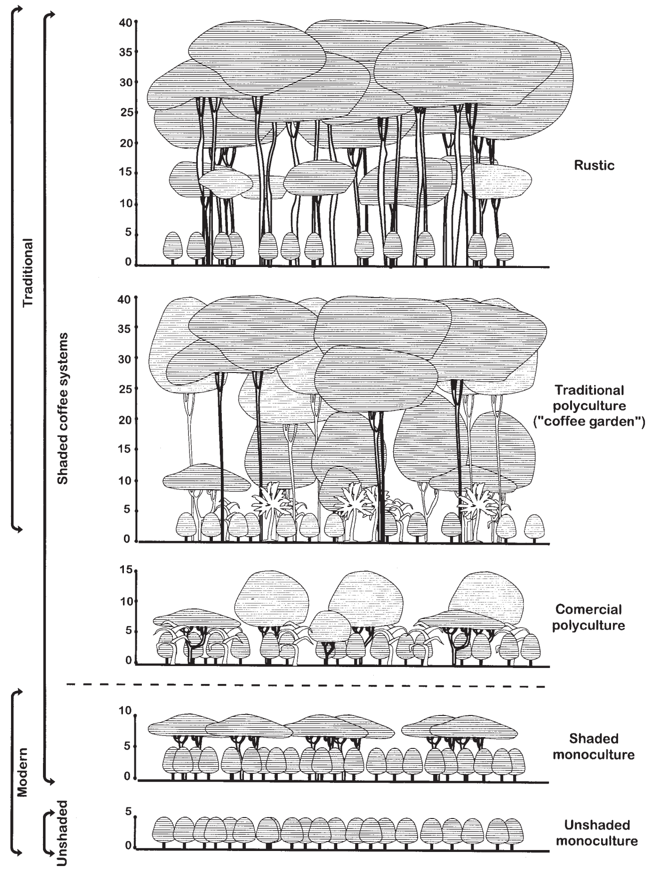

Figure 1. The five coffee-growing systems of Mexico, showing vegetational complexity, height of canopy, and variety of components.

products include coffee and an array of products for market and local subsistence, such as foodstuffs, medicines, and raw materials. According to Alcorn (1983), among the Huastec Indians, coffee gardens contain over 300 useful species, principally medicines, foods, construction materials, and forage.

The commercial polyculture system involves complete removal of the original forest canopy trees and the introduction of a set of shade trees appropriate for coffee cultivation. Rather than the original trees, the forest cover of this cultivation type comprises tree species that provide shade (such as many leguminous plants which add nitrogen to the soil) or are useful commercially, such as the nonnative trees rubber (*Castilla elástica*), pepper (*Pimenta dioica* sp), cedar (*Cedrela odorata*), jiniquil (*Inga* spp), chalahuite (*Inga* spp), and colorín (*Erythrina* spp). These trees make up the arboreal cover of polyculture plots where coffee, citrus fruits, bananas, and other cash crops are grown. This system has a better coffee yield and makes use of agrochemical products somewhat frequently; production is directed exclusively to the market.

The shaded monoculture system, along with the following system, exemplifies the modern cultivation systems introduced by INMECAFE in Mexico. Leguminous trees (species of *Inga*) are used almost exclusively to provide shade for coffee bushes. The result is a monospecific coffee plantation beneath a canopy that is equally specialized. The use of agrochemical products is obligatory, and the production unit is focused on generating products that are exclusively market-oriented.

The unshaded monoculture system has no tree cover at all, and the coffee bushes are exposed to direct sunlight. This approach represents a system that is totally agricultural and has lost the agroforestal character displayed in the previous systems. Converted into a specialized plantation, this coffee-producing system requires high inputs of chemical fertilizers and pesticides, the use of machinery, and an intensive work force throughout the yearly cycle. The highest yields are obtained under this system.

Ecological and Biological Implications of Coffee Systems in Mexico

These five systems represent a gradient from the most traditional, low-input, and vegetationally and structurally diverse systems—although coffee gardens present the maximum useful diversity—to the least diverse and most intensive, technified, and modern systems. The five designs can be divided first in terms of the use of trees as shade, separating shaded from unshaded (or sun) coffee systems. This division also makes for a basic management contrast: agroforestry versus agricultural systems (no arboreal species at all). A second criterion distinguishes polycultures from monocultures. The last two systems—shaded and unshaded monocultures—contrast sharply with the polycultures where coffee is grown under a canopy of several tree species and has as neighbors various cultivated species (such as citrus, bananas, and plantains).

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

The architectural, vegetational, and structural complexity of these five systems and their corresponding systemic and ecophysiological features have different ecological consequences, not only on a microenvironmental scale (Jimenez-Avila 1981; Jimenez-Avila & Gomez-Pompa 1982; Nestel 1995) but also on the scale of the regional ecosystem. For instance, the presence or absence of shade in the coffee plantation not only is the most significant difference in terms of the ecology and economy of coffee systems (Beer 1987), but is also a key factor in the maintenance of the landscape equilibrium of the region. Some evidence has linked the complete elimination of tree cover with a less stable physical environment because of increased soil and air temperature, lowered soil water content, decreased of soil microorganism abundance and diversity, and decreased soil fertility. In addition, a diverse shade forest creates more habitats for macrofauna and microfauna (Nestel 1995). Consequently, the different coffee systems, representing different ecological designs and degrees of ecosystem manipulation, affect in different ways and to various degrees ecological and biological processes such as hydrologic balance, soil quality, forest cover, CO_2 equilibrium, and, of course, biological diversity.

Biodiversity in Traditional Coffee Systems

We conducted an exhaustive review of the literature that reports quantitative data on the flora and fauna inhabiting the shaded and unshaded coffee systems of Mexico. When possible, the data presented in each reference were classified according to the type of coffee system involved, as defined previously. Our review indicates that information exists for at least five main groups of organisms: plants, arthropods, birds, amphibians and reptiles, and terrestrial mammals. In addition, we conducted a brief review of the "useful phytodiversity" (ethnobotany) of these traditional agroforests.

Plants

Unlike intensive agricultural systems (monospecific crops and pastures), traditional coffee systems only partially displace original forests and thus can be considered humanized forest remnants. Therefore, the vegetational architecture of polyspecific shaded coffee systems maintains a certain plant diversity.

Quantitative vegetational analysis of traditional coffee fields reveals interesting patterns. First, the systems under indigenous management present a complex vegetational structure formed by herbs, shrubs, and three strata of trees. Plant richness in such coffee sites ranges between 90 and 120 species. These figures are obtained from studies of two coffee systems: one of four sites with oak and tropical dry forest in Atoyac, Guerrero (Rendón & Turrubiarte 1985) and the other in a coffee system derived from a tropical rain forest near Coatepec, Veracruz (Molino 1986).

In these studies, herbs represent between two and four times the number of tree species, with shrubs being represented by only a few species (Table 1). The number of trees in these traditional agroforests ranges between a minimum of 13–18 species to a maximum of 48–58. Coffee sites in the more humid regions of the Gulf of Mexico contain a higher average of tree species (31.7) than the drier Pacific sites (22.9) (Table 2). The few available data reveal that no correlation exists between tree species richness and elevation, suggesting that arboreal diversity is basically an effect of human manipulation (Table 2).

In addition to herbs, shrubs, and trees, traditional coffee agroforests also house an important number of epiphytes. Although no complete inventory of epiphytes in coffee plantations is yet available, Williams-Linera et al. (1995) reported 25 orchid species growing in shade trees of two sites, and Márquez et al. (1976) encountered 90 epiphytic species in 10 coffee sites distributed on the coastal slopes of the Gulf of Mexico. Because Valdivia (1977) found 153 species of epiphytes living in only 45 tree species of a tropical rain forest, we speculate that about three epiphyte species can be found for each recorded tree species. In Mexico, montane cloud forests and lowland rain forests are richer in epiphytes than are other communities, and a high percentage of coffee in traditional agroforests grows only under trees of these two types of forest.

By housing useful or potentially useful species of plants (and animals), shaded coffee systems and especially coffee gardens are also notable reservoirs of utilitarian biodiversity. Ethnobotanical studies reveal that coffee systems

Table 1. Number of plant species in four coffee plantation sites under traditional management in Atoyac, Guerrero.*

			Trees			
Habitat	*Herbs*	*Shrubs*	*Canopy*	*Medium size*	*Understory*	*Total*
Oak forest	101	7	18	13	12	132
Tropical dry forest	55	1	16	15	13	85
Tropical dry forest	58	11	10	7	17	92
Oak forest and tropical dry forest	84	8	18	20	34	126

**Source: Rendón and Turrubiarte (1985).*

Table 2. Number of tree species in shaded plantations of Pacific and Gulf of Mexico coastal slopes, located at different elevations (meters above sea level).*

Pacific slopes	*Number of species*	*Gulf of Mexico slopes*	*Number of species*
El Molote (1570–1700)	13, 16	Huatusco (900–1300)	28
El Porvenir (810–1010)	22, 24	Coatepec (900–1300)	36
El Quemado (250–970)	23, 24, 29, 34	Misantla (900–1300)	12, 58
El Cucuyachi (620–850)	18, 26	Tlapacoyan (less than 900)	30
		Tamazunchale (less than 900)	26
		Córdoba (less than 900)	16, 48
Average	22.9		31.7

**Pacific slopes: Rendón and Turrubiarte (1985) and Nuñez (1987). Gulf of Mexico slopes: Márquez et al. (1976) and Molino (1986).*

under indigenous management can contribute a high number of useful species for both consumption and market (Table 3), a consequence of the ecological manipulation of native forests, which produces a complex array of vegetational architectures (Molino 1986).

In a detailed survey of 10 strategic traditional coffee sites on the Gulf of Mexico side on the states of San Luis Potosi, Puebla, and Veracruz, Márquez et al. (1976) found 90 useful species of trees. In contrast, Cházaro-Bazañez (1982) reported the same number of melipherous plants in a coffee site in Coatepec, Veracruz, and Alcorn (1983) provided a global figure of over 300 useful species for the coffee gardens of the Huastec Indians.

Arthropods

The arthropod fauna from ground level to 2 m in a polyspecific shade plantation (coffee garden) near Tapachula, Chiapas (La Victoria, at 430 m elevation), was studied in detail by Ibarra-Nuñez (1990). A total of 39,566 individuals was collected, belonging to 609 (morpho)species and 258 families. Almost 80% of this arthropod community is represented by species of Diptera, Hymenoptera, Coleoptera, Homoptera, and Araneae, all of which except Coleoptera are abundant. By functional roles, there is a clear dominance of four trophic groups of arthropods: phytophagous (mainly Homoptera), parasites (wasps and others), predators (spiders), and polyphagous (mainly ants). In terms of relative numbers, the structure of the arthropod community found in this coffee plantation resembles its natural counterpart—namely, the arthropod fauna of tropical rain forests found in a similar survey (Janzen 1973).

The high structural complexity and diversity of the coffee arthropod community revealed by Ibarra-Nuñez's study suggests that a certain equilibrium exists in the shaded plantation. For instance, although phytophagous arthropods—potential pests for coffee and other introduced crops—represent 25% of the species and 37% of the individuals, the plantation had no problems with insect pests. This may be explained by the high numbers of predators and parasites, which composed almost 25% of the individuals and 42% of species. The dominant groups of predators and polyphagous arthropods—web-building spiders and probably ants—seem to play a key role as pest controllers, a function already suggested by other authors (Robinson & Robinson 1974). Insect-pest outbreaks and large fluctuations in insect-pest populations are correlated with the reduction of plant and structural diversity in agroecosystems (for coffee see Nestel & Dickschen 1990; Perfecto et al. 1996).

There also have been studies of the soil macrocoleoptera fauna (Morón 1987; Nestel et al. 1993) and of xylophilous beetles (Morón 1988) of traditional coffee plantations. Although no specific study on the subject exists, a large number of butterfly specimens has been collected inside shaded coffee fields in central and southern Mexico (J. LLorente-Bousquets, personal communication). In general, the areas with higher endemism and richness of butterflies (Papilionoidea) in Mexico coincide with many of the main shaded coffee regions, such as Tamazunchale in San Luis Potosí, Sierra de Manantlán in Jalisco, Teocelo and Jalapa in Veracruz, Sierra de Atoyac in Guerrero, and Sierra de Juarez in Oaxaca (LLorente-Bousquets et al 1996).

Table 3. Number of useful plant species in three multilayered shaded coffee sites.*

Use	*Coatepec*	*Cosaultlán*	*Central Veracruz*
Foods	17	51	24
Medicinal	25	10	5
Forage	4	3	—
Domestic use	14	—	—
Magic and religious use	3	—	—
Ornamental	4	8	4
Construction	7	4	2
Other	—	6	28
Total	74	82	55

**Sources: Coatepec, Pisanty and Carabias (1979); Conautlán, Molino (1986); Central Veracruz, Escamilla et al. (1993).*

Birds

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

A spectrum of bird diversity apparently exists, having its extremes in the traditional shaded coffee gardens and the technified, sun-grown coffee plantations. Specifically, 136 and 82–184 bird species were recorded in traditional coffee fields of Central Veracruz and Soconusco, Chiapas, respectively (Aguilar-Ortiz 1982; Martinez & Peters 1996), whereas 104 and 107 species were present in a commercial polyculture with several or a few canopy species (Greenberg et al., in press), 50 species in monogeneric shaded coffee, and between 6 and 12 species in a sun-grown monoculture (Martinez & Peters 1996).

In general, birds inhabiting shaded coffee agroforests represent a mixture of forest species—particularly those in the canopy—and second-growth species (Greenberg 1993). Birds are attracted to coffee agroforests not only for the coffee cherries but also for several other foods, including fruits, nectar, and insects. Because coffee plantations normally occur adjacent to original or mature forests, it is difficult to determine the ability of the plantation alone to support reproducing bird populations. Therefore, the connectivity or isolation of the shaded coffee patches might be key factors determining the maintenance of bird species diversity. Martinez and Peters (1996) found 184 species of birds in a traditional coffee field located alongside a tropical forest, a figure which fell to 82 species in a similar coffee garden isolated from any forest remnants.

A comparative analysis by Aguilar-Ortiz (1982) in a 28-ha area of a traditional coffee parcel and the surrounding forests revealed that the avifauna of the traditional coffee system has a similar richness (136 species) to that of the adjacent cloud forest (138) and tropical dry forest (133) and is notably higher than that of the pine forest (96). By analyzing the composition of the coffee avifauna, the same author found that 70% of the species are generalists and only 30% are species restricted to a specific type of habitat. The avifauna of the coffee garden is formed by habitat-restricted species coming from the adjacent cloud forests (19%), pine forests (1%), and tropical dry forests (10%). Based on Aguilan-Ortiz's study, traditional coffee systems are apparently operating as new vegetational habitats where bird species not only create new avifaunal pools producing new combinations of species, but they also maintain and even increase bird species diversity. The same study revealed that birds inhabiting the traditional coffee system are mostly species of the canopy and the medium stratum with frugivorous, insectivorous, and nectarivorous feeding habits.

According to Greenberg (1994), Terborgh (1989), and Borrero (1986), of all agricultural systems in the Neotropics, shade coffee plantations have some of the highest numbers of individuals and species of migratory birds. This phenomenon is particularly important in Mexico for two reasons: first, Mexican territory is the most significant winter destination of those migrants considered potentially endangered species (Terborgh 1989), and second, most of the coffee-growing areas coincide with the winter habitat of migrants. In addition, shaded coffee plantations play an important role as a dry-season refuge for both migrants and local species (Greenberg et al., in press).

Amphibians and Reptiles

There is only one published study reporting data on the herpetofauna of a coffee site, in Santiago Jalahui, Oaxaca (Rendón-Rojas 1994). Based on 64 hours of exclusively diurnal collections, the researchers report the presence of 16 species (5 amphibians and 11 reptiles). Although the author recognizes the inventoried site as shade coffee growing under an assembly of native trees, no data are given about the vegetational structure, species composition, and sampled area of the site. When compared with inventories in undisturbed tropical rain forests—for example in Los Tuxtlas, Veracruz (94 species; Perez-Higareda et al. 1987), or Selva Lacandona, Chiapas (77 species; Lazcano-Barrero et al. 1992), the results of this study reveal a depauperate herpetofauna at the coffee site. Because of the low number of collections and the absence of nocturnal observations, however, the report is not conclusive. Thus, detailed inventories are needed to evaluate the diversity of herpetofauna in shade coffee plantations.

Mammals

A total of 24 nonflying, midsize mammalian species were reported by Gallina et al. (1996) in a site with traditional managed coffee in Central Veracruz (Region of Xalapa). These include marsupials (4 species), edentata (2), rabbits (1), big and midsize rodents (4), and carnivores (13). Small mammals such as rats, mice, and bats were not considered in the study, and large mammals such as deer and big cats were not recorded. Half of the recorded species are terrestrial, with 21% arboreal and 25% scansorial.

Because over 50% of the recorded species include fruit as part of their diets, mammals must be playing a key role as seed dispersers. Also, many species of the coffee mastofauna probably are acting as pest controllers because 46% are insectivorous and 25% have small rodents as their main source of food.

Although the number of mammalian species found in traditional coffee fields is low compared with the original pool of species present in natural forests, species considered rare or threatened, such as the chupamiel (*Tamandua mexicana*), the nutria (*Lutra longicaudis*), and the viztlacuache (*Coendu mexicanus*), are among those found in coffee agroforests. Thus, coffee gardens mimic forests sufficiently to attract at least some species of endangered wildlife. It is probable that new and more complete studies will reveal these traditional agroforests as suitable refuge areas for other mammalian fauna.

Discussion

The empirical data we reviewed confirm that traditional, indigenously managed shaded coffee agroforests are important repositories of biological diversity. As a whole, this highly managed diversity produces great structural complexity in the shaded coffee agroecosystem. The number of herbs, and especially the number of arboreal species, seem to be the key components determining the biological diversity of the coffee agroecosystem. Tree species not only support a rich epiphytic flora; they also attract and maintain birds and mammals by offering edible fruits, nectar, and insects, and also arthropods such as xylophilous beetles. Herbal richness is probably decisive for the diversity of many groups of arthropods.

A remarkable feature of traditional shaded coffee fields is the high number of resident, migratory, and endemic bird species reported by available inventories (between 136 and 184 species). The high avian diversity of these coffee systems exceeds notably the average number of birds of cloud forests (100–110), humid oak-pine forests (50–80), oak forests (60), and pine forests (50) (Fig. 2). Their relativity high diversity probably results from their ecotonical character, which produces a unique anthropogenic avifauna consisting of mixtures of both lowland and highland elements. Similar patterns probably exist for the shaded coffee mastofauna and some arthropod groups (ants, spiders, and butterflies), although no study is yet available to test this prediction.

The high number of plant and animal species housed by traditional shaded coffee fields indicates that these agroforests can play a conservation role as protected anthropogenic habitats for species of the original forests. The importance of shade coffee as a refuge for biodiversity is linked mainly to its location in biologically rich areas that have been particularly affected by deforestation (Perfecto et al. 1996). In the following sections we evaluate this potential conservation role by (1) estimating the percentage of the whole coffee area under traditional management (multispecific shaded systems), (2) reviewing the ecological and geographical distribution of coffee areas in Mexico, and (3) comparing the geographical distribution of coffee-growing areas with recognized centers of species richness and endemism.

Estimating Shaded and Unshaded Coffee Areas

Although no study has yet accurately documented the geographic distribution of the five systems across the total coffee-growing area of Mexico, it is possible to offer some estimates. The most important factor determining the present distribution of these five designs is the process of technological modernization promoted by INMECAFE from 1970 to 1986. Technological packages encouraged by INMECAFE included intensive use of agrochemicals, an increase in the density of coffee shrubs per unit of land, use of new varieties, and, especially, the reduction or complete removal of shade trees.

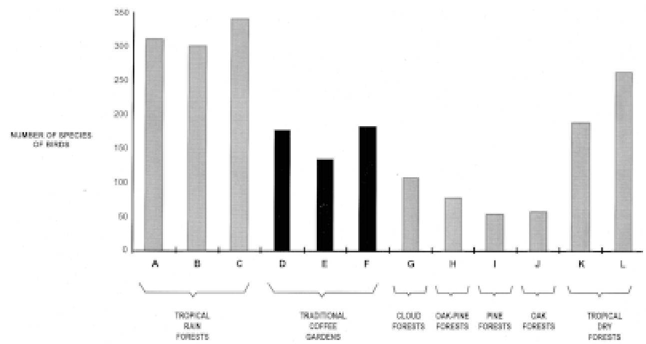

Figure 2. Species richness of birds in the main Mexican types of forests (plus one site in Guatemala) and in three shaded coffee sites: A, Los Tuxtlas, Veracruz (Coates-Estrada & Estrada 1985); B, Petén, Guatemala (Escalante et al. 1993); C, Montes Azules, Chiapas (González-García 1992); D, Ocosingo, Chiapas (accumulated number of species for two plantations; Greenberg et al., in press); E, Central Veracruz (Aguilar-Ortiz 1982); F, Soconusco, Chiapas (Martinez & Peters 1996); G, average number of three localities (Hernández-Baños et al. 1995); H, I, and J, Omiltemi, Guerrero (Navarro 1992); K, Yucatán (Escalante et al. 1993); and L, Chamela, Jalisco (Ceballos 1995).

According to Nestel (1995), most of INMECAFE's activities—75% of the total new seedlings and 85% of technical assistance—were concentrated in three states: Chiapas, Oaxaca, and Veracruz. A national survey showed that approximately 50% of the farms were already producing coffee under the shade of a single tree by the first years of the 1980s (Nolasco 1985). Curiously, Nolasco does not report the existence of farms producing coffee under unshaded conditions.

A survey we conducted on a sample of more than 52% of the total coffee area of Mexico (370,000 ha out of 700,000), encompassing seven main coffee regions, presents a more accurate overview. The survey was based on field observations reported by Santoyo-Cortés et al. (1995) and on the analysis of municipal statistics of each region obtained from the 1989 Coffee Census of INMECAFE. According to our survey, 11% of the sampled coffee area had been transformed into an intensive, unshaded monoculture, 42% remained as shaded monoculture, 10% was com-

Table 4. Area for each coffee system (Fig. 1) in 124 municipalities of seven coffee-growing regions of Mexico.*

		Coffee system (ha)				
Region (number of municipalities)	*Total area (ha)*	*Rustic*	*Traditional polyculture*	*Commercial polyculture*	*Shaded monoculture*	*Sunny monoculture*
Cuetzalan, Puebla (7)	16,448	—	13,982	8,224	822	822
Xicotepec, Puebla (4)	35,168	—	7,034	3,516	7,034	17,584
Central Veracruz (46)	96,968	969	31,017	11,632	52,341	969
Pochutla-Pluma Hidalgo, Oaxaca (11)	33,756	21,941	1,688	1,688	8,439	—
Lacandon Forest and Northern Chiapas (29)	79,875	2,396	22,365	6,390	47,925	799
Soconusco, Chiapas (13)	72,661	—	10,899	3,634	36,330	21,789
Atoyac, Guerrero (4)	33,152	23,206	9,146	—	—	—
Total (124)	367,988	48,412	96,931	35,084	152,891	41,972
Percentage		13	26	10	42	11

**Adapted from Santoyo-Cortés et al. (1995) and the Coffee Census of INMECAFE (Greenberg et al., in press).*

mercial polycultures, and 39% was traditional coffee polycultures created inside the original forests (Table 4).

Our survey included zones representing the two main areas of sun coffee in Mexico (Xicotepec, Puebla, and Soconusco, Chiapas), but it omitted important portions of traditional managed areas, such as the indigenous regions of Las Huastecas in Hidalgo and San Luis Potosí, the Chinantla, Sierra Mazateca, Sierra de Juarez, Región Chatina, and Mixteca in Oaxaca, as well as all the tracts of shaded coffee of Colima and Nayarit. Thus, the survey overrepresents shaded and unshaded monocultures. Therefore, 60–70% of shaded polyculture and 30–40% of shaded and unshaded monocultures seem more realistic estimates than Nolasco's (1985) and are nearer to Nestel's (1995) approximation that 30% of the landscape vegetation in the coffee regions of Mexico changed from highly diversified coffee agroforestry systems to coffee (shaded and unshaded) monocultures. It can be established that in Mexico over two-thirds of the coffee areas are under traditional management.

Geographic Distribution of Coffee-Growing Areas

The humidity and thermal requirements of coffee crops dictate that in Mexico coffee plantations be cultivated within a specific elevational range on the coastal slopes of the central and southern mountains. These elevational limits vary by region, however, according to geographic orientation. Mexican coffee is cultivated on both the Atlantic and Pacific coastal slopes, which differ markedly in terms of climate.

In general terms, Atlantic slopes are wetter than their Pacific counterparts because Atlantic slopes are under the influence of the trade winds that bring humidity almost all year from the Gulf of Mexico (from north and east). In contrast, Pacific slopes have a monsoon-type regime, with humid air currents flowing toward the mainland during half the year and dry air flowing seaward during the next 6 months. Consequently, Pacific slopes are generally humid, and interior slopes are xeric. These climatic features are a key factor influencing vegetational differences on both slopes: tropical rain forests and cloud forests dominate on the Atlantic side, tropical dry forests and pine-oak forests on the Pacific.

Situated generally between 600 and 1200 m elevation, coffee fields are located in a biogeographic and ecologically strategic altitudinal belt in which tropical and temperate elements overlap and the four main types of Mexican forests come in contact. Therefore, coffee fields support, depending on the geographic orientation, various types of vegetation. An ecogeographical analysis conducted by Moguel (1995) of the 356 coffee-growing municipalities showed that coffee areas located on the Atlantic slopes correspond mainly to regions originally covered by tropical rain forests (50–76% of the total), whereas those on Pacific slopes (in Nayarit, Colima, and Guerrero) are cultivated where tropical dry forests dominate (45–83% of the total area) (Table 5). Coffee in cloud forest areas is important in Hidalgo and Chiapas but less notable in Puebla, Veracruz, Guererro, and Oaxaca. Coffee in pine-oak forests is important in Puebla and Guerrero (Table 5).

Traditional Coffee Gardens and Conservation Priority Areas

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

An extensive overlap between coffee-growing areas and several regions with high numbers of species and endemics can be illustrated. For instance, 14 of the 155 regions regarded as crucial to the conservation of Mexico's biodi-

Table 5. Percentage of tropical and temperate forests displaced or affected by coffee fields in the nine Mexican states producing coffee.*

	Tropical forest		*Temperate forest*	
State	*Rain*	*Dry*	*Cloud*	*Pine-oak*
Gulf of Mexico slopes				
San Luis Potosí	76	14	4	6
Puebla	51.5	1	7	40.5
Hidalgo	47	—	24	29
Veracruz	68.5	18.5	7	6
Pacific slopes				
Nayarit	—	82.5	—	17.5
Colima	—	83	—	17
Guerrero	—	45	5	50
Both slopes				
Oaxaca	76	14	4	6
Chiapas	54.5	12	15.3	18

**Compiled with information from our data bank on coffee municipalities and the ecological regions of Mexico.*

versity by a selected group of experts (Comisión Nacional para el Estudio y Uso de la Biodiversidad, or CONABIO) overlap with or are near various coffee-growing areas. Based on this information and other criteria, 14 main coffee regions in México can be identified as hot spots for conservation (Fig. 3). With the exception of portions of the Sierra Norte of Puebla and the Region of Soconusco in Chiapas (SNP and SOC in Fig. 3), where sun coffee has been planted in large tracts, traditional shaded fields still dominate these regions.

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

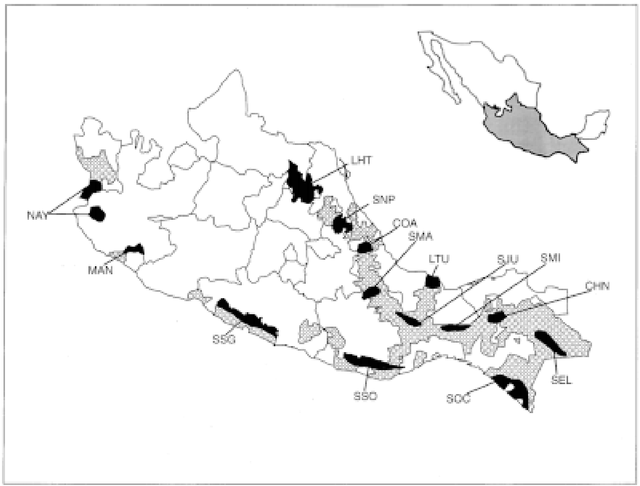

Figure 3. Location of regions with high conservation value inside or near the coffee areas of Mexico. Numbers indicate priority of areas recommended by the Comisión Nacional Para el Estudio y Uso de la Biodiversidad: LHT, Las Huastecas, San Luis Potosí, Hidalgo, and Veracruz (includes priority areas number 104 [Tlanchinol] and 105 [Huayacocotla]); SNP, Sierra Norte de Puebla, 118 (Cuetzalan); COA, Coatepec-Xalapa, Veracruz; SMA, Sierra Mazateca, Oaxaca; SJU, Sierra de Juarez; Oaxaca, 127 (Sierra Norte de Oaxaca); SMI, Sierra Mixe, Oaxaca, 132 (Sierra Mixe); LTU, Los Tuxtlas, Veracruz, 110 (Sierra de Los Tuxtlas); CHN, Altos de Chiapas, 138 (Huitepec-Tzontehuitz) and 141 (Bosques Mesófilos of Los Altos); SEL, Selva Lacandona, Chiapas, 145 (El Momón-Margaritas-Montebello) and 146 (Lacandona); SOC, Soconusco, Chiapas, 142 (Triunfo-Encrucijada-Palo Blanco), 143 (Tacaná-Boquerón-Mozotal), and 144 (Chicomuselo-Motozintla); SSO, Sierra Sur, Oaxaca, 130 (Chacagua-Manialtepec) and 131 (Sierra Sur); SSG, Sierra Sur, Guerrero, 120 (Sierra Madre del Sur); MAN, Manantlán, Jalisco, and Colima, 99 (Manatlán); and NAY, Sierra Madre of Nayarit, and Jalisco, 96 (Sierra de Vallejo-Talpa).

Acknowledgments

We thank D. Nestel, A. Navarro, E. Escamilla, M. Altieri, A. Nuñez, V. Sosa, M. A. Morón, R. Rice, R. Greenberg, E. Valdivia, F. Bandeira, and J. Llorente-Bousquets for sharing their data and perspectives with us. We thank R. Rice, I. Perfecto, D. Perry, E. Main, and one anonymous reviewer for valuable suggestions on the manuscript. We also are grateful to J. Garza and M. J. Ordoñez for the design of the computerized data bank of Mexican coffee areas and to C. Sereno and R. A. Pineda for technical assistance. Figures were prepared by S. Aceves. Some financial support for field research was provided by R. Ogarrio. Research for this paper was funded by CONABIO through the Instituto de Ecología of the National University of Mexico. Finally, the paper was edited by W. Merrill.

Literature Cited

Aguilar-Ortiz, F. 1982. Estudio ecológico de las aves del cafetal. Pages 103–127 in E. Jimenez-Avila and A. Gomez-Pompa, editors. Estudios ecológicos en el agroecosistema cafetalero. Instituto Nacional de Investigaciones sobre Recursos Bióticos, Xalapa, Veracruz, México.

Alcorn, J. B. 1983. El Te'lom huasteco: presente, pasado y futuro de un sistema de silvicultura indígena. Biótica **8**:315–331

Alcorn, J. B. 1991. Ethics, economies and conservation. Pages 317–349 in M. Oldfield and J. B. Alcorn, editors. Biodiversity: culture, conservation and ecodevelopment. Westview Press, Boulder, Colorado.

Alcorn, J. B. 1994. Noble savage or noble state? Northern myths and southern realities in biodiversity conservation. Etnoecológica **3:**7–19.

Altieri, M., L. Merrick, and M. K. Anderson. 1987. Peasant agriculture and the conservation of crop and wild plant resources. Conservation Biology **1:**49–53

Andrade, G. I., and H. Rubio. 1994. Sustainable use of the tropical rain forest: evidence from the avifauna in a shifting cultivation habitat mosaic in the Colombian Amazon. Conservation Biology **8:**545–554.

Beer, J. 1987. Advantages, disadvantages and desirable characteristics of shade trees for coffee, cocoa and tea. Agroforestry Systems **5:** 3–13.

Borrero, J. H. 1986. La sustitución de cafetales de sombrío por caturrales y su efecto negativo sobre la fauna de vertebrados. Caldasia **15:**725–732.

Brown, K. S., and G. G. Brown. 1992. Habitat alteration and species loss in Brazilian forests. Pages 119–142 in T. C. Whitmore and J. A. Sayer, editors. Tropical deforestation and species extinction. Chapman & Hall, New York.

Ceballos, G. 1995. Vertebrate diversity, ecology, and conservation in Neotropical dry forests. Pages 195–207 in S. H. Bullock, editor. Seasonally dry tropical forests. Cambridge University Press, Cambridge, United Kingdom.

Cházaro-Bazañez, M. de J. 1982. Flora apícola de la zona cafetalera de Coatepec, Veracruz. Pages 95–102 in E. Jimenez-Avila and A. Gomez-Pompa, editors. Estudios ecológicos en el agroecosistema cafetalero. Instituto Nacional de Investigaciones sobre Recursos Bióticos, Xalapa, Veracruz, México.

Coates-Estrada, R., and A. Estrada. 1985. Lista de las aves de la Estación de Biología Los Tuxtlas. Instituto de Biología, Universidad National Autónoma de México, México, D.F.

Escalante, P., A. G. Navarro, and A. T. Peterson. 1993. A geographic, ecological and historical analysis of land bird diversity of Mexico. Pages 281–307 in T. P. Ramamorthy, R. Bye, A. Lot, and J. Fa, editors. Biological diversity of Mexico: origins and distributions. Oxford Univeristy Press, New York.

Escamilla, P. E., A. L. Licona V., S. Díaz C., V. H. Santoyo-Cortés, L. Rodriguez R. 1993. Los sistemas de producción de café en el centro de Veracruz, México: un análisis tecnológico. Pages 15–18 in Simposio "Modernización tecnológica, cambio social y crisis cafetaleras," Heredia, Costa Rica. Universidad Nacional de Costa Rica e Instituto Costarricense del Café, San José.

Fuentes-Flores, R. 1979. Coffee production systems in Mexico. Pages 60–71 in F. De las Salas, editor. Workshop on agroforestry systems in Latin America. Centro Agronómico Tropical de Investigación y En señanza, Turrialba, Costa Rica.

Gallina, S., S. Mandujano, and A. Gonzalez-Romero. 1996. Conservation of mammalian biodiversity in coffee plantations of Central Veracruz, Mexico. Agroforestry Systems **33:**13–27

Gonzalez-Bernaldez, F. 1991. Diversidad biológica, gestión de ecosistemas y nuevas políticas agrarias. Pages 23-32 in F. F. Pineda, M. A. Casado, J. M. de Miguel, and J. Montalvo, editors. Diversidad biológica. Fundación R. Areces, Madrid.

González-García, F. 1992. Avifauna de la Selva Lacandona, Chiapas, México. Pages 173–200 in M. A. Vázquez-Sánchez and M. A. Ramos, editors. Reserva de la Biosfera Montes Azules, Selva Lacandona: investigación para su conservación. Ecosfera, México, D.F.

Greenberg, R. 1993. Gallery forest protection in Mesoamérica: a conservation priority for migratory birds. Pages 3–5 in J. K. Doyl and J. Schelhas, editors. Forest remnants in the tropical landscape: benefits and policy implications. Smithsonian Migratory Bird Center, Smithsonian Institution, Washington, D.C.

Greenberg, R. 1994. Phenomena, comment and notes. Smithsonian **11:**24–26.

Greenberg, R., P. Bichier, and J. Sterling. In press. Bird populations in rustic and planted shade coffee plantations in eastern Chiapas. Biotropica.

Harris, L. D. 1984. The fragmented forest: island biogeography theory and the preservation of biotic diversity. The University of Chicago Press, Chicago.

Hernández-Baños, B. E., A. T. Peterson, A. Navarro-Siguenza, and P. Escalante. 1995. Bird faunas of the humid montane forests of Mesoamerica: biogeographic patterns and priorities for conservation. Bird Conservation International **5:**251–277

Ibarra-Nuñez, G. 1990. Los artrópodos asociados a cafetos en un cafetal mixto del Soconusco, Chiapas, México. Folia Entomológica Mexicana **79:**207–231

Janzen, D. H. 1973. Sweep samples of tropical foliage insects: effects of seasons, vegetation types, elevation, time of day and insularity. Ecology **5:**687–708.

Jimenez-Avila, E. 1981. Ecología del Agroecosistema Cafetalero. Ph.D. dissertation. Universidad Nacional Autónoma de México, México, D.F.

Jimenez-Avila, E., and A. Gomez-Pompa, editors. 1982. Estudios ecológicos en el agroecosistema cafetalero. Instituto Nacional de Investigaciones sobre Recursos Bióticos, Xalapa, Veracruz, México.

Lazcano-Barrero, M. E., E. Góngora-Arones, and R. Vogt. 1992. Anfibios y reptiles de la Selva Lacandona. Pages 145–171 in M. A. Vázquez-Sánchez and M. A. Ramos, editors. Reserva de la Biosfera Montes Azules, Selva Lacandona: investigación para su conservación. Special publication Ecosfera 1. Universidad Nacional Autónoma de México, México, D.F.

LLorente-Bousquets, J., A. L. Martinez, I. Vargas-Fernandez, and J. Soberón-Mainero. 1996. Papilionoidea (Lepidoptera). Pages 531–548 in J. LLorente-Bousquets, A. García-Aldrete, and E. Gonzalez-Soriano, editors. Biodiversidad, taxonomía y biogeografía de artrópodos de México. Universidad Nacional Autónoma de México, México, D.F.

Márquez, W., P. Valdivia, and A. Gomez-Pompa. 1976. Resúmen de los Tipos de Vegetacion Natural de las Zonas Cafetaleras de los Estados de Veracruz, Puebla, Hidalgo y Tamaulipas. Technical report. Instituto Nacional de Investigaciones sobre Recursos Bióticos, Xalapa, Veracruz, México.

Martinez, E., and W. Peters G. 1996. La cafeticultura biológica: la finca Irlanda como estudio de caso de un diseño agroecológico. Pages 159–183 in J. Trujillo, F. de León-Gonzalez, R. Calderón, and P. Torres-Lima, editors. Ecología aplicada a la agricultura: temas selectos de México. Universidad Autónoma Metroplitana, México, D.F.

Moguel, P. 1995. Diagnóstico de la región cafetalera en México por zonas ecológicas. Technical report. Instituto de Ecología, Universidad Nacional Autónoma de México, México, D.F.

Moguel, P. 1996. Biodiversidad y cultivos agroindustriales: el caso del café. Technical report. Instituto de Ecología, Universidad Nacional Autónoma de México, México, D.F.

Moguel, P., and V. M. Toledo. 1996. El café en México: ecología, cultura indígena y sustentabilidad. Ciencias **43:**40–51.

Molino, J. F. 1986. Agroforets Cafeieres du municipio de Cosautlan (Etat de Veracruz, Mexique). Programme LIDER, Institute Agronomique Mediterranéen, Montpellier, France.

Morón, M. A. 1987. The necrophagous scarabaeinae beetles from a coffee plantation in Chiapas, Mexico: habitats and phenology. The Colleopterists Bulletin **46:**225–232.

Morón, M. A. 1988. La macro-coleopterofauna saproxilofila del Soconusco, Chiapas, México. Folia Entomológica Mexicana **74:**145–158.

Navarro, A. G. 1992. Altitudinal distribution of birds in the Sierra Madre del Sur, Guerrero, Mexico. The Condor **94:**29–39.

Nestel, D. 1995. Coffee in Mexico: international market, agricultural landscape and ecology. Ecological Economics **15:**165–179.

Nestel, D., and F. Dickschen. 1990. The foraging kinetics of ground ant communities in different mexican coffee agroecosystems. Oecologia **84:**58–63.

Nestel, D., F. Dickschen, and M. A. Altieri. 1993. Diversity patterns of soil macro-Coleoptera in Mexican shaded and unshaded coffee agroecosystems: an indication of habitat perturbation. Biodiversity and Conservation **2:**70–78.

Nolasco, M. 1985. Café y sociedad en México. Centro de Ecodesarrollo, México, D.F.

Nuñez, A. 1987. El agroecosistema cafetalero en tres ejidos de la Costa Grande de Guerrero. Tesis de Lic. en Biología. Facultad de Ciencias, Universidad Nacional Autónoma de México, México, D. F.

Oldfield, M., and J. B. Alcorn. 1987. Conservation of traditional agroecosystems. Bioscience **37:**199–206.

Perez-Higareda, G., C. R. Vogt, and O. V. Flores. 1987. Lista anotada de los anfibios y reptiles de Los Tuxtlas, Veracruz. Instituto de Biología, Universidad Nacional Autónoma de México, México, D.F.

Perfecto, I., R. Rice, R. Greenberg, and M. E. Van der Voort. 1996. Shade coffee: a disappearing refuge for biodiversity. BioScience **46(8):**598–608.

Peterson, A. T., A. Flores-Villela, L. León-Paniagua, J. E. LLorente-Bousquets, M. A. Luis, A. G. Navarro-Siguenza, M. G. Torres, and I. Vargas-Fernandez. 1993. Conservation priorities in Mexico: moving up in the world. Biodiversity Letters **1:**33–38.

Pimentel, D., U. Stachow, D. A. Takacs, and H. W. Brubaker. 1992. Conserving biological diversity in agricultural/forestry systems. Bioscience **42:**354–362.

Pisanty, I., and J. Carabias. 1979. Utilización de los recursos naturales en la zona de Xico, Veracruz: los cafetales. Departamento de Biología, Facultad de Ciencias, Universidad Nacional Autónoma de México, México, D.F.

Ramamoorthy, T. P., R. Bye, A. Lot, and J. Fa, editors. 1993. Biological diversity of Mexico: origins and distribution. Oxford University Press, New York.

Reichhardt, L., E. Mellink, G. P. Nahan, and A. Rea. 1994. Habitat heterogeneity and biodiversity associated with indigenous agriculture in the Sonoran Desert. Etnoecológica **3:**21–36.

Rendón, A., and B. N. Turrubiarte. 1985. El cultivo del café: caracterización del manejo y estructurade cuatro huertos en el ejido "El Quemado," Municipio de Atoyac de Alvarez, Guerrero. Tesis de Lic. en Biología Facultad de Ciencias, Universidad Nacional Autónoma de México, México, D.F.

Rendón-Rojas, M. G. 1994. Estudio de la herpetofauna en la zona cafetalera de Santiago Jalahui, Oaxaca. Tesis de Lic. Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional, México, D.F.

Robinson, M. H., and B. Robinson. 1974. A census of web-building spiders in a coffee plantation of New Guinea. Tropical Ecology **15:**95–107.

Ryan, J. C. 1992. Conserving biological diversity. Pages 9–26 in L. Brown, editor. State of the world 1992. Worldwatch Institute, Washington, D.C.

Santoyo-Cortés, V. H., S. Diaz-Cárdenas, and B. Rodriguez-Padrón. 1995. Sistema agroindustrial café en México: diagnóstico, problemática y alternativas. Universidad Autónoma Chapingo, México, D.F.

Terborgh, J. 1989. Where have all the birds gone? Princeton University Press, Princeton, New Jersey.

Thiollay, J. M. 1995. The role of traditional agroforests in the conservation of rain forest bird diversity in Sumatra. Conservation Biology **9:** 335–353.

Toledo, V. M. 1990. The ecological rationality of peasant production. Pages 51–58 in M. Altieri and S. Hecht, editors. Agroecology and small-farm Development. CRC Press, Boca Raton, Florida.

Toledo, V. M., B. Ortiz, and S. Medellín. 1994. Biodiversity islands in a sea of pastureland: indigenous resource management in the humid tropics of Mexico. Etnoecológica **3:**37–50.

Valdivia, P. 1977. Estudio botánico y ecológico de la región de Uxapanapa, Veracruz: las epífitas. Biótica **2:**55–81.

Wille, C. 1994. The birds and the beans. Audubon **80:**58–64.

Williams-Linera, G., V. Sosa, and T. Platas. 1995. The fate of epiphytic orchids after fragmentation of a Mexican cloud forest. Selbyana **16:** 36–40.