SHADE COFFEE PLANTATIONS AS WILDLIFE REFUGE FOR MANTLED HOWLER MONKEYS (*Alouatta palliata*) IN NICARAGUA

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1. INTRODUCTION

1.1. Forest Fragmentation and Ecological Corridors in Central America

Flanked on either coast by contrasting ocean bodies and north and south by two continents, Central America is a unique and intriguing account of natural and cultural history (Coates, 1997). The Central American isthmus is a corridor of biological and cultural networks both between and within countries making it a diverse and complex region. Once a vast mosaic of diverse ecosystems, including coral reefs, savannas, semi-arid lowlands, rain-forested foothills, cloud forest, and pine-forested volcanoes (Wallace, 1997), the ever-increasing pressures of human densities and economic practices of the 20th century threatened the survival of these fragile systems and the natural resources they supported (Heckadon-Moreno, 1997). The colonization into forested areas and their subsequent transformation into agro-forested lands resulted in a corridor of fragmented forest patches, often associated with continued land modification, human poverty, and political turmoil (Illueca, 1997).

The history and pattern of land modification in Nicaragua has a similar theme of that of Central America as a whole. Since 1950, Nicaragua's forests, which once covered 8 million ha, have been reduced in size by 50% (Heckadon-Moreno, 1997). Moreover, the dry forests of the Pacific lowlands have nearly disappeared and the pine savannas of the Caribbean's Miskito Coast have been severely degraded. The first centers of human colonization and land use modification were the Pacific and central mountainous zones,

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resulting in a landscape of human habitation and forest fragmentation along the Pacific coastline. However, as farming and cattle pressures for land expansion intensified, modern colonization centers have begun to spread eastward into the large forested areas of BOSAWAS (area named for the abbreviation of the Bocay, Sang Sang, and Waspuk rivers) Biosphere Reserve and the Indio-Maiz Biological Reserve (Heckadon-Moreno, 1997). Despite the serious threat of continued colonization in these critical areas, Nicaragua retains some of the largest tracks of forested area in Central America, and efforts to safeguard them will contribute to the preservation of biodiversity for the region.

1.2. The Agroforestry of Coffee

Coffee is the second largest source of export earnings for the majority of the world and the most valuable tropical agricultural commodity (Talbot, 1995). In Latin America alone, nearly 50% of its perennial croplands are devoted to coffee, covering approximately 2.7 million ha and resulting in one-third of global coffee crop production (Perfecto et al., 1996). Traditionally, coffee has been grown under the shade of forest trees protecting the coffee plants from the harsh sun and rain of the tropics. In some areas of the world (e.g., the Pacific corridor of northern Latin America) where both deforestation rates and human densities are high, "shade" coffee plantations represent a significant percentage of the remaining forest cover in these areas (Pimentel et al., 1992; Toledo et al., 1994; Wille, 1994).

Coffee production and consumption has been on the rise since 1950 with an even greater demand in recent years for gourmet coffees (World Resources Institute, 1998). In the 1970s, partly due to protection against the coffee leaf rust fungus and in part due to the desire to increase production yields, farmers began converting their shade coffee plantations to "technified" or "sun" coffee production systems (Rice, 1997; Toledo and Moguel, 1997; Pendergrast, 1999) (Figure 1a). Although sun coffee produces higher yields, there are many associated direct and indirect costs ranging from increased agrochemical use to the loss of watersheds and rapid soil erosion. In the last 10 years, 40% of shade grown plantations in Mexico, Central America, Colombia, and the Caribbean were converted to technified coffee production systems, directly contributing to the loss of biodiversity in these areas (Perfecto et al., 1996).

1.2.1. Coffee Production Systems

Moguel and Toledo (1999) describe five distinct categories of coffee production systems, ranging from the least to the greatest modification of the original landscape. On the one end of the spectrum are unshaded monoculture plantations (i.e., sun coffee), which are the least floristically complex and most intense level of agroindustry. In sun coffee cultivation, the forest is cleared of trees to allow coffee bushes to grow in the direct sun. While this system typically produces a greater yield of coffee crop per acre, it is highly labor intensive and requires chemical fertilizers and pesticides to protect the plants from the loss of natural defenses. At the other end of the spectrum is the traditional rustic or mountain coffee cultivation (i.e., traditional shade coffee), which minimizes the alteration of the forest while maintaining the greatest structural complexity. In this cultivation system only the understory plants are cleared for the coffee bushes while the forest cover is kept intact, thus having a minimal impact on the original ecosystem. Because there are more natural defenses in place for shade coffee, many farmers reduce

Figure 1. Monocultural sun coffee plantation (top foreground) in comparison to a traditional rustic shade coffee plantation (bottom) in Nicaragua (Photos by Colleen McCann).

or eliminate chemical treatments providing an organic form of agricultural management (Figure 1b).

The differences between sun and shade grown coffee systems are far reaching and extend beyond the structure of the forest to a variety of environmental parameters. The outcome of these agricultural management systems is a cumulative impact on forest structure, species richness and diversity, temperature and humidity fluctuations, watershed quality, soil erosion rates, carbon dioxide sequestration, chemical fertilization and its associated health concerns, crop production costs, plant productivity, and the mode of land ownership (Rice and Ward, 1996; Rice, 1997). Put simply, traditional shade coffee plantations are typically grown organically by small-scale farmers (the majority of plantations less than 5 ha) and support a high diversity of wildlife in addition to the ecological and biological systems that maintain them. On the contrary, sun coffee often comprises large-scale production systems of monocultural plantations that require extensive agrochemical input and labor with ensuing negative impacts on the environment (Perfecto et al., 1996).

1.3. Managing Habitat on Coffee Plantations

The importance of coffee plantations as secondary habitat for migratory birds has long been recognized (Wilcove et al., 1986; Calvo and Blake, 1998). In a study of the role of coffee plantations for a variety of bird species in the Western Ghats, India, Shahabuddin (1997) has shown that coffee plantations appear to be valuable refuges for many forest-dwelling species. The conversion of a multi-species forest ecosystem to a monocultural coffee plantation resulted in several microhabitat changes and a significant decrease in species composition between forest and plantation habitats. However, species richness was not affected by this conversion in habitat, and plantations were found to be important foraging grounds for avifauna, serving as buffer habitat between fragmented forest (Note: but in some primate species it may act as a barrier; see G. Umapathy in this volume). This study indicates that coffee plantations can play an important role as refuges between natural forest habitat patches, providing a dispersal corridor between patches and serving as marginal habitat for some species and breeding habitat for other species (Shahabuddin, 1997). Coffee plantations can also serve as buffer zones around protected areas; their forest-like habitats reduce edge effects and provide a reservoir area for native fauna. As a result of studies like these, public education programs linking wise consumer purchases of coffee with Neotropical bird conservation on shade coffee plantations in Central America are underway (Anonymous, 1997). Until now, focusing on the conservation of charismatic primates living on coffee plantations was untried.

1.4. The Status of Primates in Nicaragua

Largely due to political and economic instability, very few studies have investigated the conservation status of primates in Nicaragua (Rylands et al., 1995; Rodriguez-Luna et al., 1996a; Crockett et al., 1997). Nicaragua's primate fauna is reported to include three species: the mantled howler monkey (*Alouatta palliata*), the black-handed spider monkey (*Ateles geoffroyi*), and the white-faced capuchin (*Cebus capucinus*) (Coimbra-Filho and Mittermeier, 1981; Wolfheim, 1983; Konstant et al., 1985; Mittermeier et al., 1988; Rowe, 1996). Additionally, it is suspected that there are at least two subspecies of both capuchins (*C. c. limitaneus* and *C. c. imitator*) and spider monkeys (*A. g. geoffroyi* and *A.*

g. frontatus) (Coimbra-Filho and Mittermeier, 1981; Konstant et al., 1985; Mittermeier et al., 1988; Rylands et al., 1995). According to Mace-Lande classifications (Rylands et al., 1995), *A. g. frontatus* is listed as "Vulnerable," while the others are placed in the category of "Lower Risk" (Rodriguez-Luna et al., 1996).

Despite the fact that Nicaragua is the largest nation in Central America, published information on the status of its wildlife remains scarce (Crockett et al., 1997). In the most recent "Mesoamerican Action Plan," there were no accounts cited of the status of Nicaragua's primate populations (Rodriguez-Luna et al., 1996a); moreover, there were no reports of any long-term field studies on primates in Nicaragua, Honduras, or El Salvador (Rodriguez-Luna et al., 1996b). More recently, primatological research has been initiated in the country. Several short-term studies have been conducted on a population of naturally-occurring howlers on Ometepe Island in Lake Nicaragua (Garber et al., 1999). Additionally, we conducted a 14-month field study of the behavioral ecology of howlers living in one of Mombacho's shade coffee plantations.

In one of the few published accounts of Nicaragua's primates, Crockett et al. (1997) reported a preliminary assessment of the conservation status of Nicaragua's primates. They report both sightings of primates and information collected from local residents for 11 of the protected areas listed for Nicaragua in the "Mesoamerican Action Plan." Out of the 11 protected areas visited, howler monkeys were seen or reported in 10 sites. In the Mombacho Volcano Nature Reserve, howler monkeys were heard, and local residents reported their presence. Based on the 11 areas visited, approximately 40 troops were sighted, and several more heard, with troop size ranging from 4 to 20 individuals (mean = 10.7). During this survey, there was only one sighting of spider monkeys occurring in one of the larger reserves, but local reports suggest that they may be present in two or three other protected areas. Capuchins, on the other hand, were not sighted in several areas where they were reported to be present. However, local reports strongly suggest that *Cebus* definitely exists in one or two of the larger reserves, and they may likely exist west of published distributions, in southwest Nicaragua. Based on this preliminary survey, Crockett et al. (1997) argue that while sufficient numbers of primates and large forested areas still exist in Nicaragua, it is important to determine the status of potential areas for protection before critical areas are lost. Nicaragua plays an important role in the conservation of Central America's flora and fauna, and thus, more systematic censuses of the region's flora and fauna need to be conducted to preserve Nicaragua's wildlife.

1.5. Howler Monkey Behavioral Ecology

Howlers (genus *Alouatta*; Figure 2) are the most widely distributed and well studied of New World monkeys (Crockett and Eisenberg, 1987; Neville et al., 1988; Kinzey, 1997). Several systematic, long-term studies of feeding ecology have focused on the Central American mantled howler (Chapman, 1987; Estrada, 1984; Glander, 1978, 1981; Larose, 1996; Milton, 1980; Stoner, 1993), all of which suggest that they are highly selective folivore-frugivores. Foliage is a vital component of the diet, and all howlers regularly consume leafy material (Milton, 1998). However, most populations consume substantial amounts of fruit, typically between 25% and 55% of annual feeding records. Fruit exploitation strongly reflects the availability of fruit in the habitat, with consumption patterns largely tracking seasonal availability (Glander, 1978, 1981; Milton, 1980; Stoner, 1993). Flowers may also be preferred food sources that are heavily exploited during their brief periods of availability. A high degree of dietary diversity,

Figure 2. Adult female mantled howler monkey (*A. palliata*), in a shade coffee plantation in Mombacho Volcano, Nicaragua. Photo by Colleen McCann.

spatially between sites and temporally within highly seasonal sites, characterizes the species (Marsh, 1999). Such flexibility may explain the ability of howlers to colonize many habitats: they have been found in primary and regenerating rainforest, dry deciduous, riparian, coastal lowland, mangrove, and cloud forests (Wolfheim, 1983). Howlers of all species will occupy marginal areas when necessary (e.g., Baldwin and Baldwin, 1972; Schwarzkoph and Rylands, 1989; Limeira, 1997), including areas of shade coffee cultivation (Estrada and Coates-Estrada, 1996; Garber et al., 1999). Nevertheless, they demonstrate a marked preference for primary and riparian habitats, presumably due to a higher density of food species (Glander, 1978; Stoner, 1993).

Although most species of howlers live in small groups (generally less than 10 individuals) with, on average, one adult male and two adult females, members of *Alouatta palliata* differ significantly in troop size and composition (Crockett and Eisenberg, 1987). At other study sites, mantled howlers generally have group sizes of 10 to 20 individuals, with two to four adult males and three to nine adult females. Densities of mantled howlers range from 15 per km^2 (Stoner, 1993) to 92 per km^2 (Milton, 1980), although densities can reach extremely high levels under conditions of habitat destruction and range contraction (Baldwin and Baldwin, 1976). Despite their wide geographical range and apparent flexibility, *A. palliata* are threatened (Crockett and Eisenberg, 1987), and Landsat image modeling suggests that their habitat could be lost by the year 2025

(Kinzey, 1997). Although several populations of mantled howlers persist in Nicaragua (Crockett et al., 1997; Garber et al., 1999), the current conservation status of these populations is uncertain. Given that howlers in Nicaragua are known to exist in coffee plantations, where they cause no crop damage, and that shade coffee encompasses a large portion of the remaining forest cover on Nicaragua's Pacific coast, conservation in shade coffee plantations is likely key in maintaining populations of howlers and other primates in western Nicaragua.

1.6. Conservation Issue

In this study we investigated the conservation status and ecology of mantled howler monkeys (*Alouatta palliata*) living on coffee plantations surrounding the Mombacho Volcano Nature Reserve, Nicaragua. The Reserve is managed by a local non-government organization (NGO), Fundación Cocibolca, dedicated to the preservation of Nicaraguan wildlife. The results of the investigation are currently being applied to the development of management recommendations to Fundación Cocibolca on ways both to protect the monkeys and to increase primate habitat on these agricultural lands. We suggest that the mantled howler monkey can serve as an umbrella species in the Mombacho area, and by managing for its care, the landowners will simultaneously increase wildlife habitat for many other species living in the Mombacho Volcano region.

2. METHODS

2.1. Study Site

The Mombacho region includes the northern expanse of Costa Rican seasonal moist forests (Dinerstein et al., 1995). Mombacho Volcano is a moderate sized, quiescent volcano with one of the two remaining cloud forests found in southwestern Nicaragua (Atwood, 1984; Figure 3). The Mombacho Volcano Nature Reserve is situated on top of the volcano in a 650-ha area between 850 m in elevation and the summit at 1,360 m (Figure 4). The Reserve consists of tall evergreen forests at its lower elevations and elfin cloud forests at the summit. An agricultural belt of coffee plantations surrounds the Reserve in the 300- to 600-m elevation zone. The majority of the coffee plantations grow shade coffee, utilizing the large trees of the seasonal broadleaf forest to shade the growing coffee bushes from direct sunlight. In a preliminary study we observed mantled howler monkeys living in these coffee plantations, but not in the Reserve proper (McCann and Koontz, 1997). The lower slopes of Mombacho support a highly disturbed tropical dry forest with forest type strongly influenced by elevational gradient. The belt of coffee plantations is surrounded by another agricultural zone, comprised mostly of cattle ranches, in the 100- to 300-m elevation zone. Together, the coffee plantations and cattle ranches form the unofficial buffer zone of the Mombacho Reserve.

2.2. Habitat Reconnaissance of Mombacho Coffee Plantations

The habitat reconnaissance of the coffee plantations was conducted in March through June of 1998 and 1999. The habitat assessment consisted of a systematic survey of the vegetation within each coffee plantation using the existing trails. Each coffee plantation

Figure 3. Nicaragua, showing the area of Mombacho with an asterisk.

Figure 4. Mombacho Volcano Nature Reserve and surrounding area. Photo by Colleen McCann.

served as a single sampling unit (N = 25). Approximately 20% of each plantation was surveyed for habitat assessment. This was done to get a rapid assessment of the vegetational make-up of each plantation and to determine if the existing habitat could support primate populations. At every 50 m the vegetation was recorded within a 25-m radius at that sample point. Vegetation was recorded based on eight broad categories (Table 1). The habitat assessment also included a systematic survey of the vegetation within the Reserve proper using the existing trails that extend from the highest altitudes of the Reserve down to the plantations that buffer it. Vegetation categories included scrub, elfin, and cloud forest with tree height ranging from 1 to 25 m.

2.3. Howler Monkey Census

The howler monkey census was conducted concurrently with the habitat reconnaissance. There were two sampling periods during each sample day: the morning sampling periods were conducted between 0630 and 1130 hours; the afternoon sampling periods were conducted between 1400 and 1800 hours. When howlers were sighted, the following data were recorded: the date, the time, the location (in UTM coordinates, determined with a global positioning system [GPS] unit), the elevation (based on available topographic maps), the number of individuals in the group, estimated age and sex of the individuals, the vegetation category they were located in (Table 1), and the tree species they were located in. When howlers were heard howling, the following data were recorded: the time, the date, the GPS location, the compass bearing from the GPS fix to the howling, and the estimated distance from the GPS fix to the howling; these data were used to calculate the estimated longitude, latitude (UTM coordinates), and elevation (derived from topographic maps) of each group's location. Although we did not visit all areas of the plantations surveyed, because howlers' calls travel over long distances, we assumed that we had near-100% coverage of the study area. The same data were recorded if other primate species (*Ateles geoffroyi* and *Cebus capucinus*) were sighted or heard.

Table 1. Vegetation categories used in habitat reconnaissance.

Vegetation Category	Description
Shade Coffee 1	Shade trees less than 15 m in height, open canopy
Shade Coffee 2	Shade trees between 15 and 25 m in height, with mostly or completely closed canopy
Shade Coffee 3	Shade trees more than 25 m in height, closed canopy
Other agriculture	Areas of cultivation such as banana, cacao, or cattle pasture
Regeneration 1	Abandoned coffee plantation
Regeneration 2	Abandoned cattle pasture with tree height less than 15 m
Regeneration 3	Abandoned cattle pasture with tree height greater than 15 m
Forest	Relatively undisturbed area with no evidence of agricultural use, tree height greater than 25 m, and contiguous canopy closure

2.4. Local Interviews

In addition to the survey data, additional information was obtained from local individuals living and working in Mombacho, particularly the coffee plantation laborers. The majority of individuals were migrant workers who typically live in the area and come to the plantation for work. We selected individuals of different ages and levels of employment (supervisor versus laborer) to get a broad view on primate populations in the area past and present. For each plantation two to three worker interviews were conducted (N = 63). A standard set of questions was asked to each person (Table 2).

3. ANALYSIS

The analysis of the spatial distribution of howler monkeys living in the Mombacho region was based on a method adapted from the "centroid cluster analysis method" described in Stoner (1994). This method is especially useful in situations when it is not possible to confirm that each data location represents a distinct group, and thus, overestimates of population numbers is a concern. For example, we might record three bouts of howling within a plantation over several hours (or days) and have no way of knowing if this is the same group or three groups. To improve predictions we used a nearest-neighbor clustering algorithm to construct groups in an unbiased way, based on the spatial distribution of all recorded howler locations. After these statistical groups were established, (1) we mapped the individual locations; (2) we depicted the statistical groups by first calculating the geographic central point ("centroid") for each group and then inscribing a 25-ha home range size for each mapped group (mantled howler home range sizes vary from 5 to 60 ha (Stoner, 1994), and are 15 to 20 ha at La Luz, a shade coffee plantation on Mombacho's southwestern side (Williams-Guillén, unpublished data); we chose a relatively large home range size for this preliminary mapping so that our population estimate for Mombacho howlers would be conservative); and (3) we compared the statistically-derived groups with our field notes to determine if any of the assigned data locations were not possible (e.g., two sighted groups known to be different being assigned to the same statistical group, or two simultaneously heard groups being assigned to the same statistical group). This analysis was used to provide an estimate of the number of groups in the study area and relative abundance among plantations. By

Table 2. Questions asked of interviewees in the Mombacho region.

Topic	Questions
Presence/absence of howlers in plantation	• Are howlers present on this plantation? • If so, how many? • When and where did you last see or hear howlers? • How many monkeys do you usually see in a group?
Attitudes towards primates	• What do people think of monkeys? • Do people hunt the monkeys?
Presence of other primates	• Are there other spider or capuchin monkeys on the plantation? • If not, were they present in the past?
Changes in primate populations	• Are there more or fewer monkeys in the area now than 5 to 10 years ago? • If there have been changes in the numbers of monkeys, why?

multiplying the number of groups by our observed average group size, we calculated an estimate of the howler population size for the Mombacho study area.

4. RESULTS

4.1. Habitat Reconnaissance

There are approximately 25 plantations that surround the Mombacho Reserve. They range in size from 25 to 225 ha, with the average plantation measuring less than 100 ha. We estimate that approximately 20% of each plantation was surveyed for the habitat assessment. The results of the survey showed that the landscape is composed of 64% agricultural lands (56% coffee plantations, 8% other agriculture, e.g., banana, cacao, cattle), 15% regenerating forests (e.g., abandoned cattle and coffee areas), and 21% forests (Table 3). Within the areas surveyed, 61% of the habitat was categorized as low-moderate disturbance ([see Table 3 for description of categories] vegetation categories: C2, C3, R3, F) and 39% was considered highly disturbed (vegetation categories: C1, A, R1, R2) and is poor primate habitat. There were noticeable differences in habitat quality between specific quadrants of the Mombacho region that warranted further analysis. For example, the eastern side of the Volcano had much higher percentage of forested areas within the plantations than did the Pacific side, closer to the capital city, Managua (e.g., 46% and 26% compared to 6% and 8%, respectively).

The Mombacho Reserve is one of the few remaining cloud forests in southwestern Nicaragua. The habitat composition of the Reserve is quite distinct from that of the surrounding area due to the effects of high elevation and wind. Within the Reserve proper, 40% consisted of forest, 10% elfin forest, 34% scrub forest, and 16% agricultural use (15% coffee and 1% other agriculture) despite the fact that the Reserve is a protected area (Roque Espinoza, 1999).

Table 3. Habitat status within the Mombacho Volcano Nature Reserve region.

Quadrant (Number of Plantations)	Vegetation Category (% of Surveyed Habitat)							
	Coffee 1 (C1)	Coffee 2 (C2)	Coffee 3 (C3)	Other Agriculture (A)	Regen. 1 (R1)	Regen. 2 (R2)	Regen. 3 (R3)	Forest (F)
Southwest (N = 7)	14	38	18	6	12	4	2	6
Southeast (N = 4)	11	12	21	3	3	3	1	46
Northwest (N = 10)	19	27	21	10	7	6	2	8
Northeast (N = 4)	16	18	7	11	3	0	19	26
TOTAL AREA (N = 25)	Coffee = 56%			11%	Regeneration = 15%			21%

4.2. Howler Monkey Census

We sighted howlers 62 times and heard them howling 137 times during the census of the 25 plantations. Additionally, seven groups of capuchins (*Cebus capucinus*) were sighted and an additional two heard. No spider monkeys (*Ateles geoffroyi*) were sighted or heard during the census despite that local Nicaraguans report their presence in the Mombacho region.

Using the clustering method described above, a total of 101 howler groups were determined to be present in the survey area. However, after comparing the statistical results with our field notes, the group assignments for 13 of 199 locations needed to be adjusted due to multiple recordings of the same group or due to clustering of observations known to represent different groups. As a consequence, the final analysis yielded 97 groups of howlers living in the survey area (Figure 5). Finally, based on an average group size of 9.9, the total number of individual howlers living in the survey area is therefore estimated to be 960. There are approximately 13 howlers per km^2 in the Mombacho region; densities for *A. palliata* generally range from 15 to 92 individuals per km^2 (Stoner, 1994). Although howler densities in Mombacho are comparatively low, they are within the range of variation observed in other areas of Central America.

The mean group size of the Mombacho howler monkeys was 9.9 $\pm$ 6.2 s.d. and ranged from 1 to 24 (N = 51) (Table 4). The average capuchin group size was 8.8 $\pm$ 6.3 s.d. (range = 2 to 18). The composition of the Mombacho howler population consisted of 16% adult males, 39% adult females, 30% subadults/juveniles, and 15% infants. Out of the 51 groups sighted, 62% had only one adult male present and 75% of the groups sighted had one or more infants present.

4.3. Howler Monkey Distribution

During the initial field season we were informed by local inhabitants that the howler monkeys not only live in the Mombacho Reserve buffer areas, but also range into the Reserve itself, particularly in the dry season. We therefore expanded the survey to include the Reserve proper. Out of the 97 howler groups located in this survey, only 13 were recorded within the Reserve itself, representing only 13% of the population. This emphasizes the importance of the buffer area in sustaining the howler population in the Mombacho region. Although the Reserve is a protected area, the vegetation, primarily

Table 4. Size and composition of howler monkey groups in Mombacho Volcano.

Quadrant	Number of Groups	Average Group Size (±s.d.)	% Adult Males	% Adult Females	% Juveniles	% Infants
Southwest	11	9.0 (±6.3)	15	41	26	15
Southeast	13	12.4 (±6.4)	16	40	29	15
Northwest	18	7.8 (±4.7)	14	33	36	17
Northeast	9	11.6 (±7.7)	18	44	25	13
TOTAL AREA	51	9.9 (±6.2)	16	39	30	15

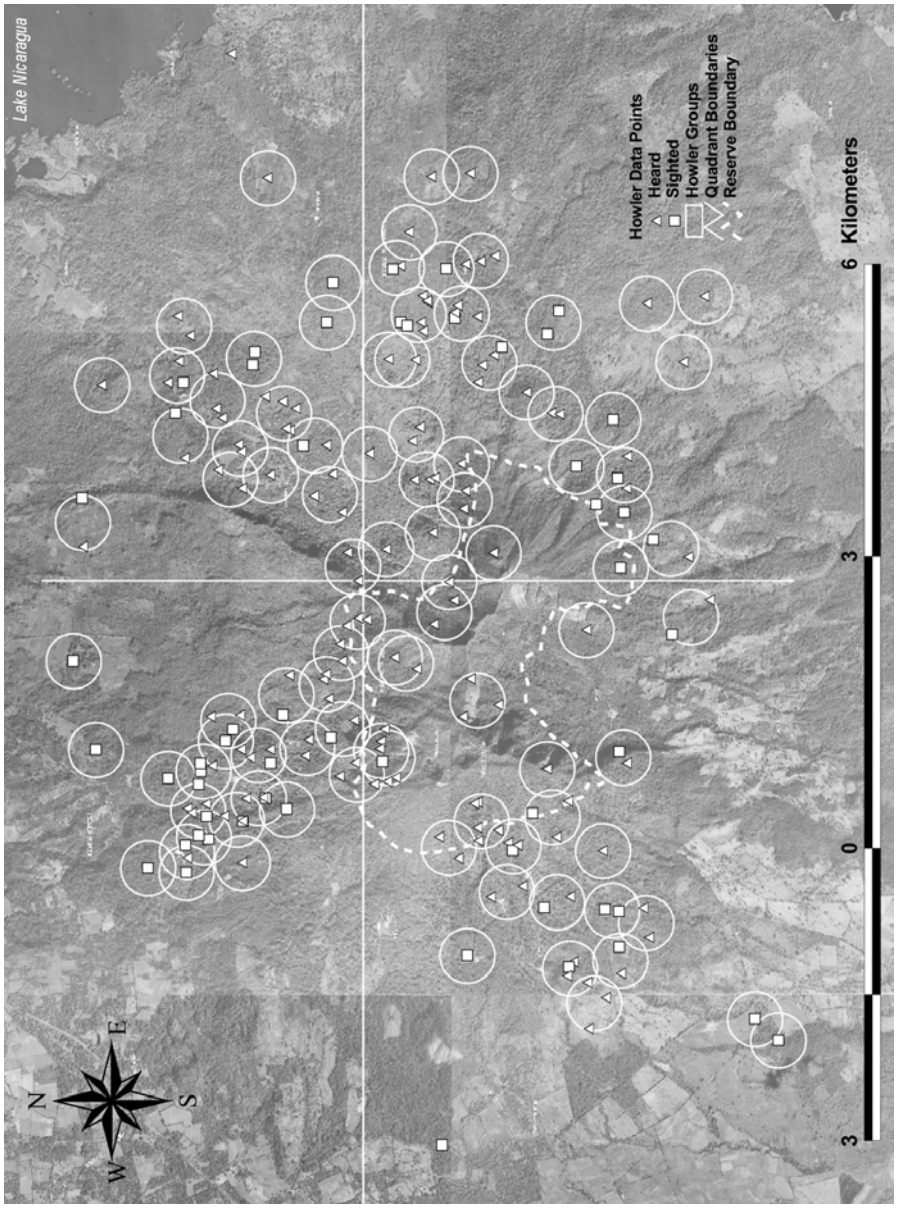

Figure 5. The location of howler monkey groups in the Mombacho Volcano region. Map courtesy of the Instituto Nicaraguense de Estudios Territoriales.

scrub and elfin forest with the majority of trees less than 25 m in height, is quite distinct from the tree community at lower elevations, which comprises semi-deciduous broadleaf forest with an unstratitfied canopy of 15 to 20 m in height (see tree species list in Appendix 1). Given these characteristics, the Reserve does not appear to be the preferred habitat of the mantled howler monkey and does not provide an abundance of food resources for them compared to the buffering areas surrounding the Reserve (Roque Espinoza, 1999). However, the Reserve may represent alternate habitat during times of food scarcity. Moreover, the ultimate importance of the Reserve may be in its function as a biological corridor for the Mombacho howler monkey population, without which the individual groups would become increasingly isolated and subject to the vagaries of population decline.

Five out of the seven capuchin groups sighted were in the Reserve proper. Additionally, while the remaining two sighted groups were located outside of the Reserve in the buffer area, they were found in forested areas. Thus, the presence of undisturbed forest areas appears to be the preferred habitat of the capuchin monkeys in the Mombacho region.

4.4. Howler Monkey Density and Habitat Quality

The final analysis of habitat quality and howler monkey density seems to indicate that while the number of howler groups appears to be the same in each quadrant of Mombacho, group size is lower in the western region of the volcano where there is a higher degree of human-modified habitat (Table 5). This region is a preferred coffee growing area because it is located on the more accessible Pacific side of the volcano, off of the Pan-American highway less than 30 km from Managua; the western regions therefore experience greater human impact than the eastern side of the volcano. A Spearman rank correlation test demonstrates a significantly positive association between

Table 5. Howler monkey population and its relation to habitat type.

Quadrant	Total Number Groups	Average Group Size (±s.d.)	Estimated Population	% Unimale Groups	% Groups with Infants	% Habitat Highly Perturbed (±s.d.)	% Habitat Mod/Low Perterbed (±s.d.)
Southwest	22	9.0 (±6.3)	198.0	63%	64%	46% (±6.8)	54% (± 7.9)
Southeast	30	12.4 (±6.4)	372.0	54%	85%	25% (±3.1)	75% (± 18.5)
Northwest	24	7.8 (±4.7)	187.2	83%	77%	49% (±3.3)	51% (± 6.6)
Northeast	21	11.6 (±7.7)	243.6	33%	67%	37% (±5.6)	63% (± 9.6)
Western Region	46	8.3 (±5.3)	381.8	76%	70%	48% (±26.2)	52% (± 29.2)
Eastern Region	51	12.0 (±6.8)	612.1	45%	78%	31% (±17.3)	69% (± 28.7)
TOTAL AREA	97	9.9 (±6.2)	960.3	62%	75%	39% (±32.9)	61% (± 51.4)

each quadrant's estimated howler population and the percent of low and moderate disturbance habitat available ($r_s = 1.0000$, $p < 0.001$, N = 4).

Additionally, these areas differed not only in the abundance of howlers, but in their group compositions. There was a considerable difference between the western and eastern regions in the number of one-male versus multi-male groups. In the more disturbed western quadrants, 76% of the howler groups only included one adult male, while in the eastern quadrants, 55% of the groups had two or more males present. A Spearman rank correlation demonstrates a significantly negative relationship between the number of males in all observed bisexual groups and the percentage of highly disturbed habitat available within each plantation ($r_s = -0.31990$, $p = 0.0442$, N = 40). Given these variables, it is not unexpected that a difference in habitat quality may be resulting in a corresponding difference in howler density, group size, and composition. While howlers have been shown to adapt to disturbed habitats, the level of disturbance can have a significant effect on population dynamics.

4.5. Local Interviews

A total of 63 interviews with local people living in the Mombacho area were conducted during the survey. Regarding the presence of primates in Mombacho, 93% of those interviewed reported their presence on coffee plantations; 89% reported seeing or hearing howlers everyday; 39% reported seeing or hearing capuchins everyday; and only 3% reported seeing or hearing spider monkeys everyday. In response to questions on the size of the howler population living in the Mombacho area, numbers ranging from 20 to greater than 1,000 were reported. When asked about the number of howler groups, 23% reported that greater than three groups currently lived on the plantation where they work while 77% of those interviewed reported one to three groups. When asked about the average group size, 43% reported 5 to 15 howlers per group and 57% reported groups greater than 20.

Questions regarding the current primate population status compared to a decade ago provided insights into past pressures on populations and current trends of protection. In response to the changes in primate populations in Mombacho over time, 61% reported that there are more monkeys now than 10 years ago; 18% reported fewer monkeys; and 21% reported no change in status. Of the 61% that reported more monkeys present, 82% credit the increase to their protected status, while 18% believe it is due to their greater birth rates. Out of the 18% that reported a decrease in population numbers, 60% reported a yellow fever epidemic 20 years ago as the causal factor. The remaining 40% reported that the observed decrease in population size is a result of continued hunting practices.

The overall response to the interview questions revealed that local attitudes towards howler monkeys are relatively positive, howlers do not pose a threat to the agricultural crops in the area. This is an important key factor for creating community involvement in a management plan for preserving wildlife. (Note: see Reynolds et al. for problems with chimpanzees, this volume.)

5. DISCUSSION

Based on our results, at least 960 howlers are living in the Mombacho area, most of them not in the protected area at the volcano's summit, but in the shade coffee plantations

that dominate Mombacho's lower elevations. Their abundance in these areas suggests that shade coffee plantations serve as a vital refuge for howlers in Mombacho, and perhaps more widely in Nicaragua's heavily deforested Pacific coast. As a follow up to this work and to gather more information for creating an effective management plan, we conducted a 14-month study of the behavioral ecology of three groups of howlers in Finca La Luz, a fairly typical shade coffee plantation on Mombacho's western flanks (Williams-Guillén and McCann, in preparation). Our results suggest that although patches of regeneration and less disturbed forest are exploited, the Mombacho howlers do indeed rely primarily on trees in areas of active shade coffee cultivation for food, travel, and rest. Shade coffee plantations are, therefore, serving as a vital refuge for howlers in this area.

However, the howlers in these agroforests show important differences from conspecifics in their ecology and demography; variation in these characteristics seems to correlate with the degree of habitat disturbance. Although howlers are abundant in comparable semi-deciduous and semi-evergreen habitat in Costa Rica (Glander, 1978) and Panama (Milton, 1980), they frequently exist at lower densities in high evergreen forests (Estrada, 1984; Stoner, 1994). Densities in Mombacho are more comparable to those of much wetter, less seasonal sites.

Perhaps most intriguing are the unusual group compositions of howlers in Mombacho. In general, *A. palliata* is found in multimale groups with one to three adult males per female (Crockett and Eisenberg, 1987). Howlers in Mombacho, in contrast, show a high frequency of unimale groups, in spite of average group sizes that fall well within the range of variation for the species. The average female to male ratio of all the sighted bisexual groups was 2.94, which is fairly typical of the species (Crockett and Eisenberg, 1987). However, our experience with further study of howlers in Finca La Luz has led us to believe that the more inconspicuous females were routinely undercounted during our census. At the site of our long-term ecological study, the female/male ratio varied from 3.13 to 5.77 females per male, the highest ratios known for this species (Williams-Guillén, unpublished data).

A number of factors could account for the prevalence of unimale groups. Crockett and Eisenberg (1987) suggest that recently-formed howler groups are more likely to have only one male; given that the population of howlers in Mombacho is currently expanding, many of the smaller unimale groups may represent recently established social groups. Ostro et al. (2001) argue that amongst black howlers (*Alouatta pigra*) unimale social groupings are advantageous at low population densities, as there is less need for cooperative defense of breeding opportunities when the frequency of intergroup encounters is reduced. Although this explanation may also account for the prevalence of unimale groups in Mombacho, it does not explain the high female to male ratios seen in Mombacho's one-male groups. Such shifts in social organization may reflect changes in patch size and concomitant shifts in levels of female intragroup feeding competition. Many of the feeding trees used by howlers in shade coffee plantations are both large and widely spaced (Williams-Guillén, unpublished data). Their size may mean that more individuals can feed concurrently in a single patch than at other sites, allowing one or two males to monopolize access to females. However, this hypothesis remains untested.

Despite changes in group composition, with close monitoring and protection Mombacho's howler population will likely persist within these agroforests. On the contrary, the situation for the capuchin and spider monkey populations is less encouraging. While the majority of the interviewees reported the presence of spider

monkeys somewhere in the Mombacho region, they were never observed during the census period (however, most recently a few spider monkeys have been sighted by reliable witnesses within the reserve proper; Otterstrom, personal communication). Moreover, capuchins were recorded present on only seven occasions. It is important to note that both spider and capuchin monkeys are commonly observed as pets throughout Nicaragua despite their protected status (Hendrix, 2000). Any degree of hunting of isolated populations in fragmented habitats has serious consequences for the long-term survival of the population (Robinson and Bennett, 2000). Habitat fragmentation coupled with hunting has detrimental effects on small, fragile populations, such as those in Mombacho, which is all too often the cause of the rapid decrease or disappearance of a species from an area. In many cases, the local extinction of a species from an area is irreversible (Rosser and Mainka, 2002) and in the case of Mombacho's capuchin and spider monkeys, with no opportunity of gene flow from nearby populations, it may be too late to halt the process. Thus, critical to the preservation of Nicaragua's biological diversity is the protection of species in addition to the protection of the habitats that support them (Martínez-Sánchez et al., 2001).

6. CONCLUSION

As a result of this study, the following immediate recommendations for maintaining a viable howler population in the Mombacho region and preserving the habitat that supports it can be made. The hunting of wildlife is by far the most serious threat to wildlife populations (Redford, 1992; Oates et al., 2000; Robinson and Bennett, 2000; Bennett et al., 2002; Rosser and Mainka, 2002). To preserve the remaining wildlife of the Mombacho region, all hunting practices must be eliminated immediately. With an ever-increasing fragmentation of forests and the isolation of wildlife populations, small population management becomes a necessary part of wildlife management. With professional wildlife monitoring, the Mombacho howler population can survive as a managed population (Martínez-Sánchez et al., 2001).

The continued practice of shade-grown coffee on the plantations surrounding Mombacho Reserve can have a negligible impact on wildlife if certain practices are followed, such as the preservation of shade tree species that are vital to the survival of the howler population and other wildlife in the region. By encouraging agroforestry practices that have been shown to support wildlife populations, the number of species that can persist in these modified habitats is greatly increased (Oldfield and Alcorn, 1987). In an effort to promote the use of shade grown coffee as an environmentally-sound form of agroforestry, the idea of designating a plantation as certified "monkey-friendly" coffee is in development. In this way the link between the type of coffee plantation and the number of primate populations it supports can be made making direct associations between human agricultural practices and its effect on the persistence of wildlife species (Barborak, 1998).

Ultimately, the survival of the wildlife in Mombacho is dependent on community involvement. If the Mombacho howler population is to survive, it must be closely monitored and supported by the local community. The involvement of the local community is a critical element in the management of this area and can contribute greatly to the development of environmental education in the Mombacho region. (Note: see recommendations by Marsh et al. in final chapter of this volume.) With more than one

million Nicaraguans living nearby Mombacho, the importance of promoting conservation action as an educational tool is critical. Efforts to promote the preservation of wildlife resources must be accepted and supported by the local community in order to be effective in influencing the spread of the modification of Nicaragua's remaining forests.

Based on the recommendations above, a management plan is being developed with the ultimate goal of creating a community-based conservation program for the Mombacho region and its wildlife.

7. SUMMARY

Considering Mombacho Reserve's small size, the buffer zone of agricultural lands appears to be of critical importance for the continued existence of many of the Reserve's wildlife species. Establishing and managing key habitat elements in the buffer zone, therefore, has important implications for the long-term protection of the region's biodiversity (Barborak, 1998). While this project focused on surveying howler monkeys living on the coffee plantations, we expect that many other forms of biodiversity found in the plantations will benefit (e.g., Hagen and Johnston, 1992; Rappole, 1995; Greenberg, 1996; Perfecto et al., 1996; Greenberg et al., 1997; Calvo and Blake, 1998). The results of this survey could also generate considerable public interest from the one million Nicaraguans living within 50 km of Mombacho, and it could provide an environmental education platform for Fundacion Cocibolca. In addition, by demonstrating methods for increasing howler habitat on the Mombacho coffee plantations, the development of a management plan for these agricultural lands might serve as a model for increasing primate habitat in other areas of Central America.

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