CHANGES IN FOREST COMPOSITION AND POTENTIAL FEEDING TREE AVAILABILITY ON A SMALL LAND-BRIDGE ISLAND IN LAGO GURI, VENEZUELA

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1. INTRODUCTION

Fragmentation of tropical forests affects the viability of primate populations worldwide. A recent assessment of habitat loss in Latin America has estimated that 9.7% of extant forest was lost between 1980 and 1995 (Chapman and Peres, 2001). Forest fragmentation has many causes (e.g., human encroachment for settlements, agricultural practices, logging, and flooding, Alvarez et al., 1986; Cosson et al., 1999; Chapman and Peres, 2001), but these causes share a common phenomenon. Disruption of contiguous forest creates disjunct patches of forest separated by different types of land use, vegetation, or water, in the case of flooding (Alvarez et al., 1986; Saunders et al., 1991; Terborgh et al., 1997; Cosson et al., 1999). Forest remnants are both smaller, when compared to contiguous forest, and isolated from other forest patches (Saunders et al., 1991). The nature of the surrounding modified habitats—or matrix—imposes a variety of novel (and often detrimental) effects on the plant and animal species still residing within a given fragment (Cosson et al., 1999). In the case of land-bridge islands, water as a barrier has a powerful effect, both in terms of limiting dispersal of resident species and providing an unusable habitat for those species (Turner, 1996; Terborgh et al., 1997; Cosson et al., 1999).

Whatever the barrier, fragmentation causes an ‘ecological disruption’ because of a combination of edge effects, and fragment size, shape, and location (Saunders et al., 1991). Interactions between the forest interior and the adjacent habitat along the edge include abiotic effects (changes in such environmental conditions as air temperature, humidity, light intensity), direct biological effects (changes in species distribution and abundance due to the modifications of environmental conditions), and indirect biological

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effects (higher-order changes resulting from alterations in species interactions) (Murcia, 1995; Turton and Freiburger, 1997; Sizer and Tanner, 1999).

Studies of forest fragments have resulted in the discovery of a variety of problems associated with microhabitat changes. For example, increases in windthrow and ambient temperature, as well as reduced humidity near fragment boundaries, result in a sharp increase in tree mortality, tree damage, and the formation of canopy gaps. Such changes can bring about an increase in plant species adapted to gap and disturbed habitats, resulting in an associated decrease in old-growth canopy trees (Lovejoy et al., 1986; Kapos, 1989; Leigh et al., 1993; Kapos et al., 1997; Laurance et al., 1998a; Mesquita et al., 1999). Turner (1996) found that alterations in microclimate may limit the usefulness of the forest to residents, further reducing the size of the useable area and causing both an increase in forest plant mortality rates and a reduction in their recruitment near the edge. The fact that a species is present in a forest fragment immediately after its isolation does not ensure that it will continue to persist; successful reproduction and recruitment are required (Saunders et al., 1991). A lack of required pollinators and seed dispersers for some plant species can seriously affect the future reproduction of those species and can have far-reaching effects for the future integrity of a given forest fragment (Howe, 1984; Powell and Powell, 1987; Pannel, 1989; Turner, 1996).

2. PRIMATES IN FOREST FRAGMENTS

How do primates respond to habitat fragmentation? Two major characteristics of primates—home range size and the degree of frugivory in the diet of a species—influence the ability of different species to live in forest fragments (Tutin and White, 1999; Onderdonk and Chapman, 2000; Estrada and Coates-Estrada, 1996; Lovejoy et al., 1986). The interaction between fragment size, home range size, and diet type is complex; the limited area resulting from fragmentation reduces the diversity of plant species and the number of food plants available to consumers (Tutin and White, 1999). Fruit as a resource is highly heterogeneous in terms of its spatial and temporal distribution, and larger frugivorous primates usually require large tracts of forest to provide enough resources to support viable populations (Johns and Skorupa, 1987; Turner, 1996; Onderdonk and Chapman, 2000).

Fragmentation of contiguous habitat can 1) exclude a primate species from residence in a given forest fragment, effectively causing localized extinctions (Lovejoy et al., 1986), 2) alter the group sizes and population densities of species still able to inhabit the fragmented landscape (Milton, 1982; Estrada and Coates-Estrada, 1988, 1996; Terborgh et al., 1997; Tutin and White, 1999; Tutin, 1999), 3) alter the dietary strategies of species able to reside in fragments (Johns and Skorupa, 1987; Tutin, 1999), and 4) affect gene flow among resident populations (Estrada and Coates-Estrada, 1996; Pope, 1996; Cosson et al., 1999; Gravitol et al., 2001).

The ability of primates to deal with the challenges of living in a fragmented habitat is obviously variable and clear patterns that can characterize this response have yet to be found (Onderdonk and Chapman, 2000). The purpose of this paper is to examine changes in the vegetation of a 15 ha island in Lago Guri, Venezuela, using data collected in 1988-89 (Parolin, 1992, 1993; Peetz and Parolin, unpublished) and 2001-02. Since changes in the diversity of plant species and in the numbers of individuals of plant species used as food sources can negatively affect the viability of primates in fragments, we will also examine the frequency of white-faced saki (*Pithecia pithecia*) feeding trees occurring in the sample plots.

White-faced sakis (*Pithecia* spp.) are the smallest (c. 1.4 to 3.1 kg: Hershkovitz, 1987a) members of the Pitheciini that includes bearded sakis (*Chiropotes* spp.: 2.5 to 3.2 kg: Hershkovitz, 1985) and uacaris (*Cacajao* spp.: 2.7 to 3.4 kg: Hershkovitz, 1987b). Hershkovitz (1987a) recognized two groups of *Pithecia* sakis, the smaller-bodied, strongly sexually dichromatic Guianan group (*P. pithecia*, 2 ssp.:Figure 1a and b) and the larger-bodied and more subtly dichromatic Amazonian group (*P. monachus*, *P. irrorata*, *P. aequatorialis*, and *P. albicans*). The larger bearded sakis/uacaris are allopatric, but *Pithecia* spp. overlap much of the range of *Cacajao* (primarily west of the Rio Branco in Brazil and tributaries of the left bank of the Rio Amazonas) and *Chiropotes* (primarily east of the Rio Branco and Rio Madeira, both north and south of the Rio Amazonas) (Hershkovitz, 1985). All of the saki/uacaris share dental adaptations for opening hard fruit–robust, laterally flaring canines, procumbant incisors, crenulated molars of low cusp relief, and robust jaws (Kinzey, 1992). While they ingest a variety of food types including leaves, pith, flowers, and insects, they are primarily seed predators with a preference for large, multiseeded fruit of the Chrysobalanaceae, Lecythidaceae, Sapotaceae, and Bignoniaceae plant families (van Roosmalen et al., 1988; Norconk, 1996; Stevenson, 2001).

3. METHODS

3.1. Study Site

This report is part of a primate behavioral ecology study conducted in Lago Guri, Bolívar State, Venezuela, from 1987 to 2002. The Embalse de Guri or Lago Guri (Figure 2) is the catchment basin (3,919 km²: CVG-EDELCA, 1997) for the Raúl Leoni hydroelectric plant constructed in the company town of Guri (7º 45' N, 56º 10' W). The site is 90 km upriver of the confluence of the Caroní and Orinoco Rivers at Puerto Ordaz.

Hydroelectric plant construction and maintenance is under the auspices of the company EDELCA (Electrificación del Caroní), a subsidiary of CVG (Corporación Venezolana de Guayana). Planning and construction of the Raúl Leoni/Guri dam began in 1968 (Roo, 1987). Dam building and flooding of the sparsely populated, mildly hilly terrain between Guri and Puerto Ordaz continues with ground-breaking for the fourth dam (Tacoma) in 1999. This region of Venezuela was considered to be potentially valuable for the production of hydroelectric energy as early as 1912 (Roo, 1987). Vegetation on this northernmost rim of the Guianan Shield consists of tropical savannah and gallery forest, but perhaps most important, the Rio Caroní is a black-water river. The low level of suspended organic material in black-water rivers minimizes turbine damage and equipment maintenance required. Of the four hydroelectric plants on the Caroní River, the Guri plant is the most productive, providing energy to major cities in Venezuela, as well as to portions of Columbia and Brazil bordering southern Venezuela.

Figure 1. Adult female white-faced saki (left) and adult male white-faced saki (right). Photos by Ken Glander.

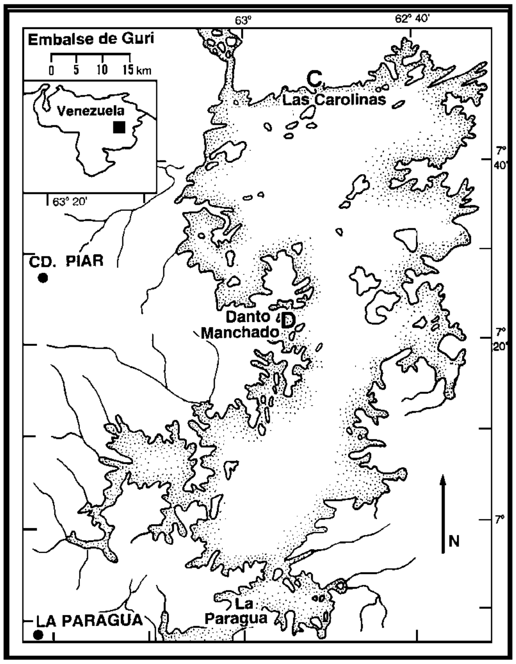

Figure 2. The "Embalse de Guri," or Caroní River basin was formed by inundation behind the Guri dam at the site of the Raúl Leoni hydroelectric plant. The location of the dam and hydroelectric plant are indicated by the narrow portion of the lake in the extreme northwest. The study island (Isla Redonda) was located in the portion of the lake referred to as "Las Carolinas." Only a few of the more then 200 islands are represented in this figure. Map by Gerardo Aymard.

Two rivers, the Caroní and the Caura, are the largest in eastern Venezuela. Both are black-water rivers draining the precambrian deposits of the Guianan Shield. The Caroní is by far the better known from the perspective of tourism and accessibility. This region is well known for its mineral deposits and stunning geological formations, the characteristic table-top mountains or tepuis.

There are four primate species in this region of Venezuela. We surveyed islands for the presence of howler monkeys (*Alouatta seniculus*) in 1988 and found individuals on almost every island that supported a patch of forest (Kinzey et al., 1989). We characterized the capuchins (*Cebus nigrivittatus*) as "widely distributed" in the lake from north to south, but less abundant than howlers.

The two sakis species, *Pithecia pithecia* and *Chiropotes satanas*, are not sympatric in Venezuela. Before flooding, saki distributions were separated by the Caroní River with white-faced sakis on the right bank and bearded sakis on the left bank. We have limited and anecdotal evidence of primate "migrations" between islands. In the early years of the study when rising and falling water levels were still fresh in the minds of our Venezuelan colleagues, we were repeatedly told stories of howlers drowning during high water periods, still hanging by their tails as water levels receded. Recently, dispersal of howlers between islands or between island and mainland, has occurred and was attributed to low water levels exposing land masses that were previously separated by water (Terborgh, personal communication). Nevertheless, it is not a common occurrence for howlers and we have no evidence that sakis have moved among water-bound islands.

Research for this study was conducted on a 12.8-hectare island (medium-sized, following Terborgh et al., 1997) called Isla Redonda (Figure 3). The island is a remnant hilltop that has been isolated from the nearby mainland since at least 1981 (CVG-EDELCA map, 1981) after the first stage of flooding (1963-1978) (CVG-EDELCA, 1997). The second stage of flooding began in 1978 and was completed in 1986. Parolin collected her first vegetation samples in 1988, approximately 10 years post isolation. Ghost forest (sensu Terborgh et al., 1997) surrounds the present day island, but does not connect the island to other islands or to the mainland even when the lake level is extremely low (personal observation, 2001).

Vegetation in the northern portion of the Caroní basin was characterized as low to medium deciduous non-flooded forests (5 to 25 m in height) and shrub savannas by Huber (1986). This description fits well with more detailed work on the island by Aymard et al. (1997). They described the vegetation of Isla Redonda as a dry tropical forest with trees of medium height (maximum height 23 m), consisting of predominantly small stems, growing on rocky quartzite and clayey ferruginous soils. Parolin (1992) characterized distinct regions of high, low, or mixed forest on the island, and Brush (2000) used the terms high or low forest with variable degrees of rockiness, canopy cover, and undergrowth density. Parolin's 1988-89 samples found the Leguminosae to be

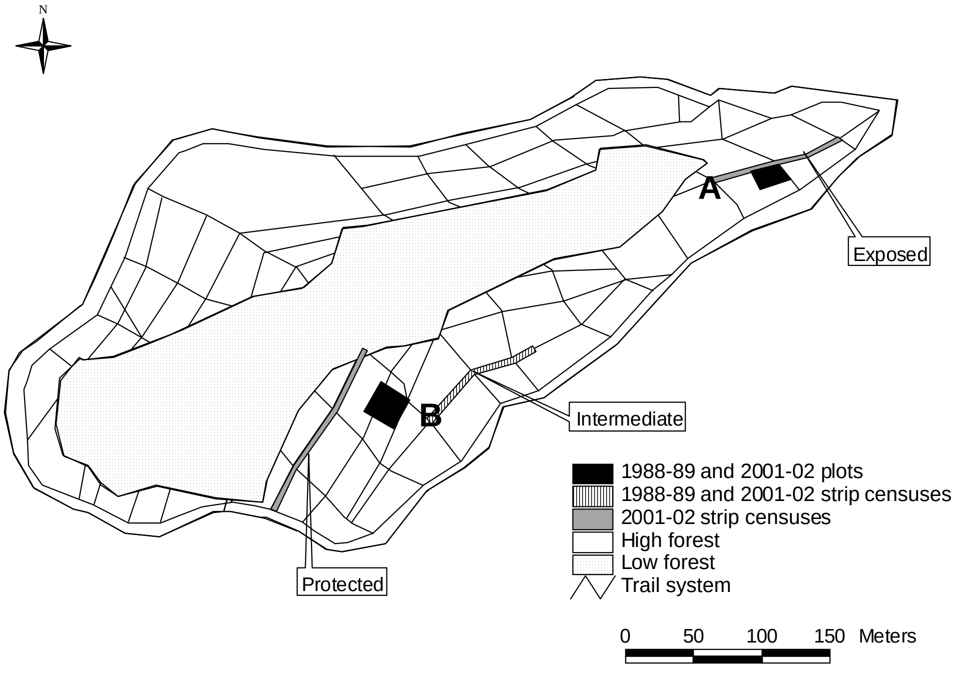

Figure 3. Trail and vegetation map of Isla Redonda. Three plots were measured in 1988-89 and replicated in 2001-02, labeled "protected," "intermediate," and "exposed." The protected and exposed plots measured 25 m^2. The intermediate plot measured 100 m long and 4 m wide.

the best represented family with three genera of Caesalpinioideae and one genus of Mimosoideae in the top 10 most abundant genera (Parolin, 1992). Annual rainfall averages 1,100 mm (CVG-EDELCA, unpublished).

3.2. Sampling Methods

Parolin measured and identified every stem ≥5.0 cm DBH (diameter at breast height) in 16, 25-m squared plots placed randomly around the island (Parolin, 1992). She and A. Peetz (unpublished) also conducted a strip sample 100 m long and 4 m wide on the south side of the island. In 2001-02, we replicated the measurements she took on two plots on the south side of the island and the strip sample (see Figure 3). In addition, we assigned each stem a leaf phenology score of 0 to 4, where 0 = no leaves, stem presumed dead, to 4 = fully leafed. In addition, we added two new strip samples in 2001 (100 m long and 4 m wide) in the vicinity of the two established plots (see Figure 3). All stems ≥0.5 cm maximum diameter (trees, lianas, saplings, and understory shrubs) were measured in contiguous 2 m^2 blocks along three trails for a total of 250 blocks. Stems smaller than a maximum diameter of 0.5 cm were counted and identified to species when possible. We refer to these data below as evidence for recruitment.

We characterized the plots and strip samples as “protected,” “exposed,” or “intermediate” using both windthrow data and distance from the windward (southeastern) edge of the island. The exposed plot was within 50 m of the south edge and approximately 140 m from the southeastern edge of the island. The protected plot was within 100 m of the edge and approximately one-third up the slope to the crest of the island and 250 m from the southeastern end of the island. The intermediate strip sample was approximately 25 m and only about 4 m in elevation from the southern edge and also approximately 250 m from the southeastern end of the island (see Figure 3).

Windthrow and temperature were estimated in 2001 using a Kestrel® 2000 Pocket Thermo Wind Meter. Average and maximum wind speed (in knots) were collected at two points on the island, observation point A–on the northwestern corner of the exposed plot—and observation point B–the western end of the strip sample, approximately the mid-point on the southeast side of the island (see Figure 3). The wind meter was hand held 2 m above the ground and pointed toward the direction of maximum wind speed as indicated on the read-out. Maximum wind speed (measured as 3-second gusts) as well as average wind speeds and temperature readings were recorded 60 seconds after the meter was activated. Paired samples from points A and B were taken approximately 15 minutes apart.

Data on primate feeding trees were collected in 1991-92 during a 12-month study of the group of nine white-faced sakis (*Pithecia pithecia*) (see methods in Norconk, 1996). Feeding trees totaling 3,570 stems were identified, labeled, and measured (DBH, height, canopy breadth) and ranked by total feeding minutes. We use feeding tree rank as a reflection of dietary preference of the sakis, with the caveat that feeding tree preferences do fluctuate with annual variation in fruit availability (Norconk, unpublished).

3.3. Analysis

We estimated within year (1988-89 and 2001-02) structural variation among vegetation plots using the non-parametric analysis of variance, Kruskal-Wallis test

(SPSS, v. 7.0). The DBH distributions were truncated at 5 cm as the minimum DBH thus the distributions were not normal. DBH differences in each plot were compared between time samples using Mann-Whitney tests for independent samples. Feeding tree species were ranked by total feeding minutes over a 12-month study in 1991-1992 and we used those ranks to correlate feeding trees with stem abundance in the sample plots using Pearson's R correlation. We set α values at 0.05 and all tests were two-tailed.

4. RESULTS

4.1. Wind Data

Northwesterly winds affect predominantly the southeastern portion of the island. Windthrow speed averaged 2.3 knots ($N = 15$) with gusts to 6.6 knots at the southeast end of the island (observation point A). Wind speed was lower at observation point B—1.8 knots ($N = 15$) with gusts to 3.9 knots. Paired samples demonstrated that the windier the conditions, the larger the difference between the two observation points. When maximum wind speed was ≥ 4.0 knots, the difference between the two points averaged 2.4 knots compared with a difference of 0.5 knots when maximum wind readings were <4.0 knots.

4.2. Structural Changes in the Forest

The 1988-89 baseline sample consisted of two plots sampled by Parolin (1992) and one strip sample measured by Parolin and Peetz in 1989 (unpublished). The Kruskal-Wallis test detected significant differences in the average DBH of protected, intermediate, and exposed samples of 1988-89 ($\chi^2 = 9.8$, df = 2, $\rho = 0.007$). No significant differences were found in the 2001-02 samples ($\chi^2 = 2.53$, df = 2, $\rho = 0.28$). The data, as plotted in Figure 4, do not suggest a significant difference either within or between samples, despite the statistically significant result in the 1988-89 data. Nevertheless, we did find significant differences in the between year samples for the exposed and the intermediate plots, but not the protected plot (exposed: $Z = -2.53$, $p = 0.011$; intermediate: $Z = -3.14$, $p = .002$; protected:, $Z = -1.5$, ns). Furthermore, all three measures of central tendency increased in the exposed area in 2001-02 suggesting that losses were more frequent in smaller stems (means compared in Figure 5).

To obtain a better sense of the selective nature of tree loss, we examined the size and frequency of dead trees in the 2001-02 samples (Figure 6). Dead trees were often still standing so that we could measure DBH, but we also measured the maximum diameter of dead trees that had fallen to the ground. Almost three-quarters (73.5%) of the trees in the small category (5.0 to 9.9 cm DBH) were leafless and apparently dead in the exposed plot, compared with a third of the total trees in the intermediate plot and a fifth in the protected plot. Trees ≥ 10 cm DBH represented about 40% of the sample in the exposed plot, of which a third (14) were dead. This compared with 37% of trees in the protected plot measuring ≥ 10 cm DBH with 7% tree loss and 6.4% in the intermediate strip sample. Dead trees now represent a considerable portion of the exposed plot, with the largest trees surviving better than the smallest ones.

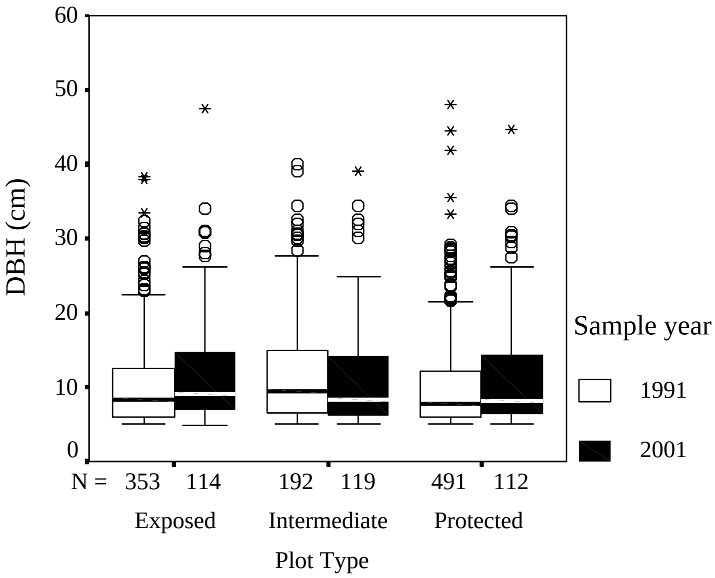

Figure 4. Box plots comparing DBH values measured in the three plots between the two years. The "1991" sample refers to the 1988-89 collection and the "2001" sample refers to the 2001-02 collection. The box plots indicate the median as a heavy line within the boxes, themselves representing the 25th to 75th percentiles of the distributions. Outliers are identified as circles above the largest value (horizontal line) that is not an outlier. Extremes are represented by asterisks.

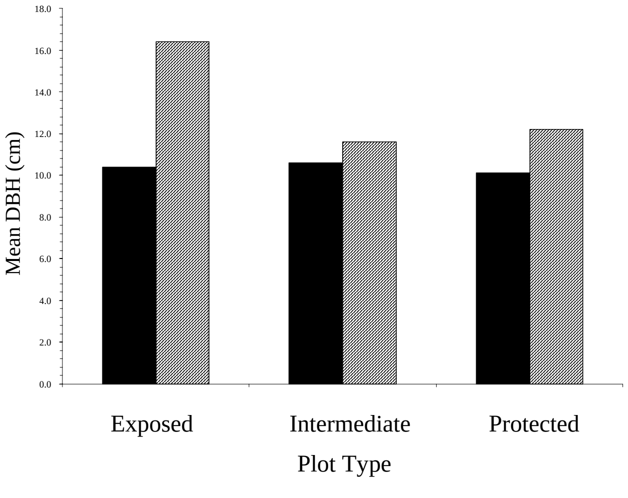

Figure 5. Mean DBH values compared between years. Solid bars are the 1988-89 sample and hatched bars represent data from 2001-02. The average DBH increased from 10.4 ± 6.4 to 16.8 ± 9.8 in the exposed plot; from 10.1 ± 6.2 to 12.2 ± 8.4 in the intermediate plot; and from 9.5 ± 7.2 to 11.2 ± 7.4 in the protected plot.

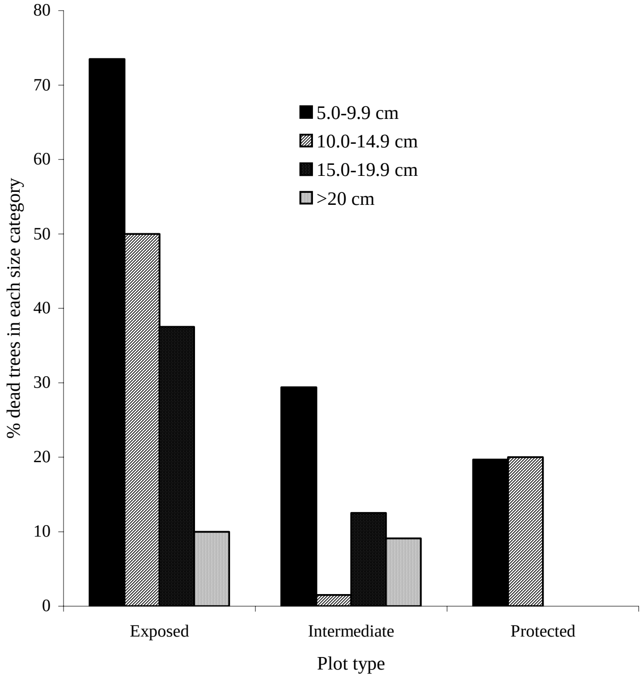

Figure 6. Percentage of dead trees by size category for each of the 2001-02 plots.

The finding that small trees are suffering high losses in the exposed plot was supported by the additional data we collected from the strip samples of 2001. For this sample, we added the category of stems $\leq$0.5 cm (greatest diameter). We tallied these very small stems for each 2 m^2 block of the sample strips. Small stems averaged 1.31 and 3.46 stems/2 m^2 on the exposed and intermediate samples, respectively, and 11.71/2 m^2 in the protected area.

4.3. Plant Species Diversity and Impact on Primate Feeding

We found a total of 31 species in the three 2001-02 plots. Of these, 51.6% (16 species) were found only in one plot, 25.8% (8 species) were found in two plots, and 22.6% (7 species) were found in all three plots. Since these three plots are within a radius of 150 m, more than half the species found only in one plot could be considered to be rare. Of the more common species (i.e., 16 species that were found in at least two plots), the species representation in the intermediate plot was positively correlated with both exposed (r = 0.868, $p < 0.001$) and protected plots (r = 0.573, $p < 0.025$), but not between exposed and protected plots (r = 0.368, ns). The intermediate plot was not only spatially intermediate between the exposed and protected plots, but was also more diverse in species number than either of the other two plots (Figure 7).

We used leaf phenology as an indicator of stem health. None of the species examined here were deciduous, so scores of three or four suggested to us that the tree was doing

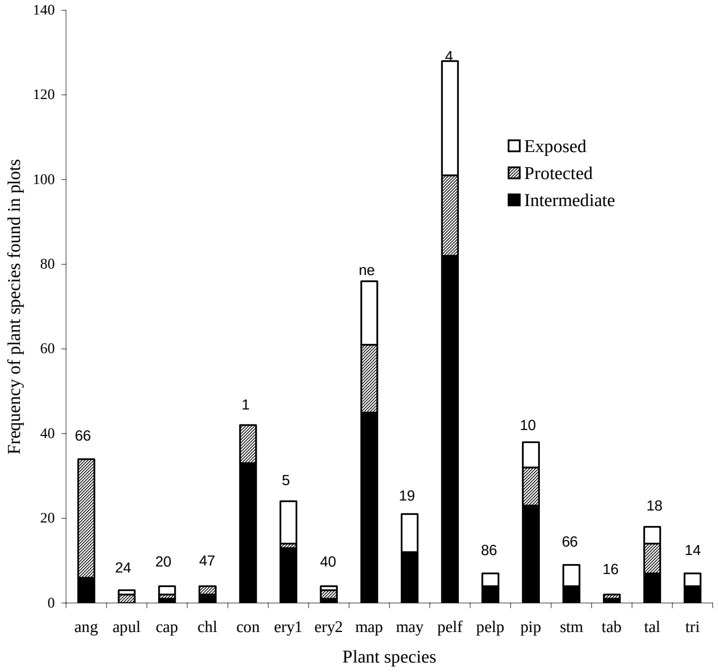

Figure 7. Frequency of feeding tree species in 2001-02 plots and their relative rank (number above the column) in terms of feeding preference by the white-faced sakis. Species are ang = *Angostura trifoliata*, apul = *Apuleia molaris*, cap = *Capparis muco*, chl = *Chrysophylum lucentifolium*, con = *Connarus venezuelanus*, ery1 = *Erythroxylum steyermarkii*, ery2 = *Erythroxylum* sp. 2, map = *Maprounea guianensis*, may = *Maytenus guianensis*, pelf = *Peltogyne floribunda*; pelp = *Peltogyne paniculata*, pip = *Piptadenia leucoxylon*, stm = *Strychnos mitscherlichii*, tab = *Tabebuia serratifolia*, tal = *Talisia retusa*, tri = *Trichilia lepidota*.

well and scores of 1 or 0 indicated that the tree was declining or dead, respectively. The assessment of tree death was somewhat subjective, however. For example, *Erythroxylum steyermarkii* trees had zero scores for all plots. We have not seen *E. steyermarkii* trees with leaves, flowers, or fruit on northern islands in the lake since 1998, and we suspected a population-wide crash for this species (Figure 8). As of 2001, however, new shoots were beginning to regenerate from the bases of many "dead" trees. *E. steyermarkii* aside, there appear to be more stems of low phenology values in the exposed plot than the other two plots. *Maytenus guianensis*, *Strychnos mitcherlichii*, *Maprounea guianensis*, *Piptadenia leucoxylon*, and *Peltogyne floribunda* appeared to be struggling in the exposed plots compared to either the intermediate or protected plots. A few species were doing as well or better in the exposed plot, however. *Apuleia molaris*, *Erythroxylum* sp. 2, *Peltogyne paniculata*, *Talisia retusa*, and *Trichilia lepidota* may be well adapted to dryer conditions and eventually result in a changed flora in that area of the forest.

Comparing the intermediate and protected plots, we noted a number of phenology "reversals" with some species having higher phenology scores in some plots and lower scores in others. Individual variation in this small sample is difficult to account for, but there were not marked differences in scores for same tree species in these two plots (Figure 8).

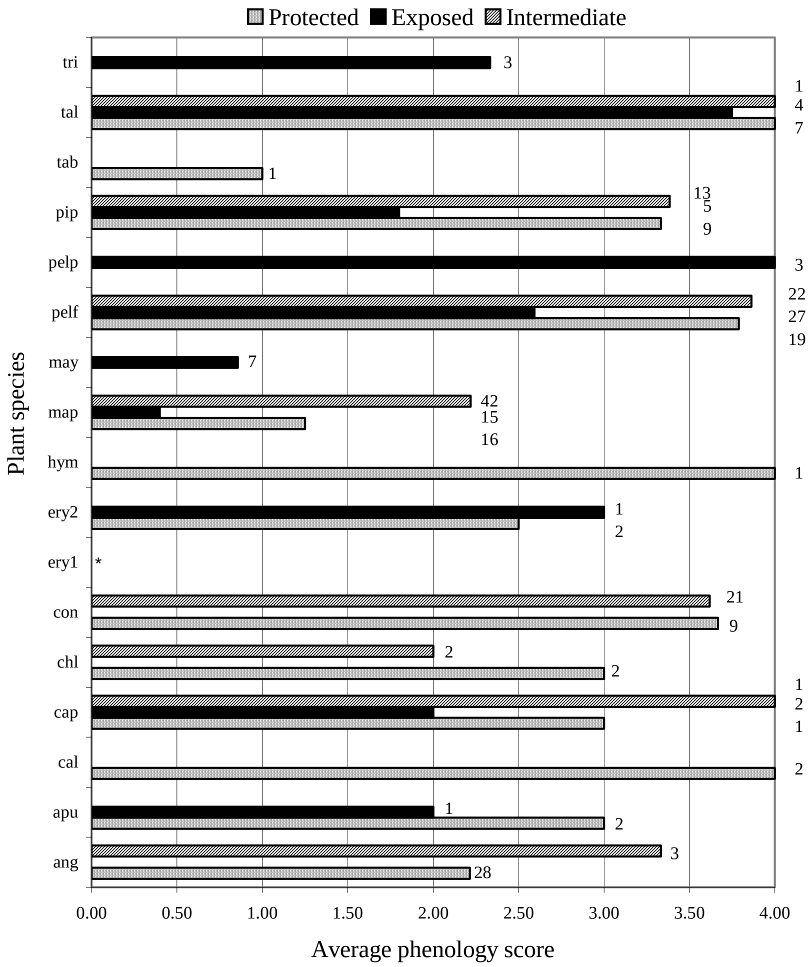

Figure 8. Average phenology scores for stems measured in each of the three sample plots: protected, exposed and intermediate. Scores ranged from 0 (no leaves) to 4 (fully leafed). Plant codes are the same as those used in Figure 7. Sample sizes are given at the end of each bar. * In the case of “eryl” *(Erythroxylum steyermarkii*), there were 10 stems in the exposed plot, one stem in the protected plot, and no stems in the intermediate plot. All eryl stems had a phenology score of zero.

5. DISCUSSION

5.1. Edge Effects on Forest Composition on Isla Redonda

We compared the change in forest structure (using DBH) and species composition in three plots on the windward side of Isla Redonda. The original sample was collected by Parolin (1992) and was compared with samples collected in 2001-02. The average DBH increased in all three forest plots, significantly in the exposed and intermediate plots between the 1988-89 and 2001-02 samples. We interpreted the increase in the mean value to represent a reduction in small stems. That was confirmed when we calculated the stem losses for each plot, with about three-quarters of the small stems ($\leq$5.0 cm DBH) dead (and often still standing) in the exposed plot. Finally, we assessed recruitment in the number of very small (0.5 cm maximum diameter) stems and found the exposed plot to have several magnitudes fewer stems than the protected or intermediate plots. Only at this level of size comparison did we see that the intermediate forest resembled the exposed more than the protected forest.

We anticipated that we would find heavy losses in larger stems as other studies have done and this may have been the case if our plots were closer to the edge. Laurance et al. (1998a, b) and Ferriera and Laurance (1997) found increases in tree mortality within 100 m of fragment edges caused by increased wind turbulence and microclimatic changes. On Isla Redonda, the effect of wave action is apparent at the immediate edge on the south and southeast side of the island, but in recent years engineers at the hydroelectric plant have manipulated the level of the lake by regulating the flow of water through the dam so that we have not seen high lake levels for about four years. While direct erosion has affected the edge of the island, wind and windthrow appear to have had a more pervasive effect on vegetation survival and establishment.

Our interpretation that abiotic factors (wind and dessication) were primary in the habitat changes we observed on this medium-sized island is at odds with a recent study by Terborgh et al. (2001). They compared tree plots on windward and leeward sides of both large and small islands in the southern portion of Lago Guri and found land mass to be the significant variable contributing to stem loss (i.e., all small islands had lower tree densities than large islands). No significant differences in stem density were found between plots on the windward or leeward sides of islands. Our findings may be different since we compared relatively closely spaced plots, all on the windward side of Isla Redonda. The observed differences may be due to differences in the scale of the two studies. All small islands are at higher risk than large islands, but the process of stem loss may be accelerated in areas closest to the edge.

Our findings are consistent with other studies (e.g., Benitez-Malvido, 1998) that indicate that seedling density of mature-phase, shade-tolerant species declines in forest fragments due to reductions in seedling establishment rate and/or increases in seedling mortality. The finding that the 27 individuals of *Peltogyne floribunda* in the exposed plot may be declining in health (based on phenology scores) is of concern since this species represents the predominant cover in that plot. The relative success of other species in this plot may be dependent on shade provided by *P. floribunda*. Alternatively, the loss of some species may provide opportunities for others. We were struck by the number of very small stems of *Connarus venezuelanus* in the exposed plot, relative to the adult stems in that area. If these small stems are successful, it would be good news for the saki monkeys. *C. venezuelanus* has an asynchronous fruit cycle so that fruit was found in fruit traps in 13 out of 15 months of a previous feeding study, in the phenology sample 12 out of 15 months, and in the feeding records every month (Norconk, 1996).

Important plant species for the saki/uakaris (Pitheciins) include Sapotaceae, Chyrsobalanaceae, Lecythidaceae, Euphorbiaceae and Leguminosae (Soini, 1986; Ayres, 1989; Kinzey and Norconk, 1990; Peres, 1993; Boubli, 1999, Stevenson, 2001). Despite the small size of the island, the sakis use a very diverse set of resources. For example, the top five feeding species represented 56.65% of the diet in Lago Guri compared well with 49.85% of the white-faced saki diet in French Guiana (Vié et al., 2001). Nevertheless, some species have emerged as particularly important to Lago Guri's island-bound *Pithecia* sakis. *Connarus venezuelanus* (mentioned above) may be increasing its distribution on the island to include the "exposed" area. In contrast, *Piptadenia leucoxylon* and *Erythroxylum steyermarkii* have both suffered losses in the exposed area. The 2001 phenology scores of large *Piptadenia* in the exposed area averaged 2.67 (N = 16) on a scale of 0 to 4 compared with an average score of 3.35 (N = 20) in the intermediate sample. Selective leaf loss could indicate that individual trees are declining, perhaps from wind and desiccation. *Erythroxylum steyermarkii* suffered heavy losses in what appeared to have been a population-wide collapse and apparent death of all mature *E. steyermarkii* trees on Isla Redonda and other islands in the northern portion of the lake by 1996 (personal observation). However, we are encouraged by viable new growth on a number of apparently dead stems in the year 2000 and fruit appearing on a few stems in 2001. Both *E. steyermarkii* and *P. leucoxylon* were important feeding tree species in the 1991-92 sample, ranking 5th and 10th, respectively.

6. SUMMARY

We compared the forest structure and plant species composition in three areas on the windward side of a medium-sized island in Lago Guri, Venezuela. The early sample (two 25 m^2 plots and a 100-m strip sample) was collected in 1988-89 and demonstrated significant structural variation among the three samples. In 2001-02, we remeasured the trees in the three original samples and added three 100-m-long strip samples. The principle findings were two-fold: we noted a drastic decline in the number of surviving small stems in the range of 5 cm DBH, as well as heavy losses for trees of all sizes in the exposed plot, and a low level of recruitment of very small stems (from 5.0 cm to 0.5 cm maximum diameter). The stem losses appear to be related to proximity to the edge and relatively high levels of windthrow compared with the more protected samples. The picture of plant species diversity, particularly as it relates to feeding trees used by white-faced sakis, is more complex and appears to be changing more slowly than the structural changes. However, if recruitment continues to proceed as indicated by the survivorship of small stems, the exposed area may eventually include a high proportion of *Connarus venezuelanus*, the highest ranking feeding tree for white-faced sakis even though this may be accompanied by an overall loss in dietary diversity as other important resources are lost.

While edge effects will continue to degrade the forest on the south side of the island, demographic changes occurring in the saki group may outpace changes occurring in the vegetation. Approximately 20 years after isolation, it is clear that the foremost pressure on the monkeys is not dietary. The changes in forest composition are proceeding relatively slowly compared to the failure of infants to survive since 1995 (Norconk, unpublished). Infant deaths in combination with a few adult deaths and lack of immigration have seriously impaired replacement. Thus, we feel that the primates are at much higher risk of local extinction due to stochastic events and lack of gene flow than they are of starvation due to changing forest composition.

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