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Biodiversity and Abundance of Lianas along Two Rivers of Varying Levels of Anthropogenic Disturbance, in the Parque Natural Metropolitano, Panamá.

Biodiversidad y Abundancia de Lianas sobre dos Ríos con Diferentes Grados de Perturbación Antropogénico, en el Parque Natural Metropolitano, Panamá.

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EXECUTIVE SUMMARY

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Our internship has been to work with the Parque Natural Metropolitano (PNM), just within the limits of Panamá City. In recent years, especially since the construction of a highway – the Corredor Norte – through the park's eastern border, the PNM has been increasingly concerned with the Río Curundú, which runs parallel to and which was more or less severed from the rest of the park's area by the Corredor Norte. Water quality has been shown to be very degraded and park employees have been concerned about the noticed loss of bird, insect and other faunal biodiversity in the ecosystems adjacent to the river. The reasons for this degradation are associated with increased water flow of rain draining from the Corredor Norte, the development of residential neighbourhoods along the eastern banks of the river and the increased input of urban waste into the river, and due to dredging of the river bottom to reduce flooding of these communities during rainy periods.

The park was suspicious that changes in liana diversity and abundance in the area of the Curundú might be related to the noticed reduced faunal diversity. Lianas are known to contribute to the ecological, structural and taxonomic complexity of tropical forests, and fulfil many ecological functions to tropical fauna. Our study aimed to assess the impact of the degradation of the Río Curundú on adjacent liana populations. To this end, we decided to compare liana populations along the Río Curundú to populations along a smaller, nearby river which was almost wholly undisturbed by human developments.

We sampled ten randomly chosen 10 x 10m quadrats along both rivers, in which we measured the DBH of all lianas above 1cm DBH, the canopy cover and the morphospecies of each liana. We calculated total cross-sectional area, abundance, morphospecies richness, and Simpson's and Shannon's diversity indices, as well as beta-diversity indices.

While we found no statistically significant differences between liana populations of these rivers, morphospecies composition was quite different and there were twice as many morphospecies found on the Curundú as on the Sixto. We suggest that more sampling would have aided the strength of our study. Finally, we offer a number of general recommendations to the PNM, as we believe that the severe and continuing disturbance of the river is undisputable and that any action that can be taken to reduce this would be beneficial to the park.

RESUMEN EJECUTIVO

Para nuestra pasantilla trabajamos con el Parque Natural Metropolitano (PNM), localizada en la ciudad de Panamá. Desde el construcción del Corredor Norte, una autopista que fue construida dentro del parque cerca de su frontera este, el PNM esta interesado en el efecto de este construcción sobre el Río Curundú, que esta paralela a la autopista y separada de la mayoría del Parque. Estudios pasados mostraron que la calidad del agua en el Río Curundú es deteriorada, que se explica por el escurrimiento de los productos químicos sobre la autopista y el alcantarillado de las áreas residenciales que se desarrollaron cerca del río. Además, para la construcción del Corredor hubo que deforestar gran parte del área cerca del río, entonces había más inundaciones causadas por fuertes lluvias porque menos agua penetro en el suelo. Este problema hico que el río fuera dragado.

Desde de la construcción del Corredor Norte, empleados del parque observaron una disminución en la abundancia y de la diversidad de aves, insectos y otros animales en el ecosistemas adyacente al río. Ellos del PNM hicieron la hipótesis que este disminución de diversidad de fauna esta relacionado con cambios en la abundancia y diversidad de lianas en el área del Río Curundú. Las lianas contribuyan a la complejidad ecológica, estructural y taxonómica de los bosques tropicales y rellenan un papel ecológico importante en sus interrelaciones con la fauna. El objetivo de nuestro estudio eran de investigar los impactos de la degradación del Río Curundú sobre las comunidades de lianas adyacente. Para cumplir nuestro objetivo, comparamos las comunidades de lianas cerca del Río Curundú a las comunidad de lianas cerca de un río que esta cerca del PNM y casi sin perturbaciones antropogénicas.

Muestreamos diez quadrats de 10m X 10m sobre cada río, en cuales medimos el diámetro a la altura del pecho (DAP) de cada lianas de mas de 1cm de DAP, la cubierta del dosel y las morpho-especies de cada lianas. Calculamos la área cross-seccional total, la abundancia, la riqueza en morpho-especies, y los indicios de diversidades de Simpson y Shannon.

Mientras que no encontramos diferencias significativas entre los comunidades de lianas entre los dos ríos, la composición de las mospho-especies estaba diferente y el encontramos el doble de morpho-especies en el Río Curundú que en el Río Sixto. Pensamos que mas muestras serian benefíciales y que podrían fuertalisar nuestras resultados. Finalmente, ofrecemos algunas recomendaciones generales para el PNM, como pensamos que, como las perturbaciones del Río Curundú están severas y continuando acciones para mejorar las condiciones del río son necesarias.

INTRODUCTION

Our host institution

The Parque Natural Metropolitano (PNM) originated as a plan concerning land use and conservation in the Panama Canal watershed in 1974. In 1983, the Area Recreativa de Curundú was established in the location of the current PNM. The objectives and goals were similar to the present mandate of the park, especially concerning the prohibition of activities that could affect the integrity of the natural ecosystems. Nonetheless, this prohibition was not extended to the construction of civil services, thus explaining the construction of the several roads that have cut across the park in past years. The PNM was proposed on June 2nd, 1984, and was accepted and established on July 5th, 1985.

The PNM consists of 232 ha of land and is the only natural park in Central America that lies within city limits. A total of 284 species of trees, 45 species of mammals, and 254 species of nesting bird have been observed and recorded in the *PNM*. BirdLife International and the Panama Audubon Society have declared this forested area to be an area of global importance for birds, because of its value to migratory raptors (Wright *et al.*, 2003). It is the Southernmost part of a series of natural parks, including Parque Nacional Camino de Cruces (PNCC), Parque Nacional Soberania, and Monumento Natural Barro Colorado, that protect the natural areas of the Panama Canal watershed and creates a Corredor of protected vegetated area across the isthmus along the East side of the canal (Plan de Manejo, 1999) (see Appendix 2, Figure 9).

The mandate of the park, established as a part of law no. 8, July 5th, 1985 is fivefold:

- To preserve within the city of Panama the equilibrium between the urban and natural areas, especially preventing contamination and improving the health of the environment of Panama City;
- To provide the population of Panama City with access to natural spaces for relaxation and recreation, helping to improve the quality of life;
- To promote the establishment of an area dedicated to natural recreation and interpretation, environmental education, ecological research, as well as culturo-scientific activities and events;
- To protect the ecosystem of the Río Curundú; and
- To conserve the natural resources, the flora and fauna of the area.

Despite these lofty objectives and sustained conservation efforts by park employees and administration, the environmental health of the park has been jeopardized severely over the past decades, most importantly by two large developments: the construction of the Corredor Norte, and the degradation of the watershed and water quality of the Río Curundú.

The Corredor Norte presently runs along the Eastern border of the park, just within the Park's boundaries. Construction began in 1997 after several years of debate about where it would be built, with significant opposition to the chosen site, involving the PNM, NGOs and community groups (Estudio…, 1995).

The degradation of water quality in the Río Curundú has been severe. Residential neighbourhoods line the East shore of the river, extending well beyond Panamá's legal limit of 25m from the river's edge. Many of these neighbourhoods drain sewage directly into the river. Runoff from the Corredor, and roadside garbage dumping also afflict the river. Finally, due to the construction of the Corredor Norte and the proximity of residences, the city of Panama has been required to dredge the river and artificially widen the floodplain to avoid flooding of the adjacent land. This has meant the cutting of many trees that lined the river, and the disturbance of this habitat (Samudio, 1996).

In 2000 and 2002, McGill students researched the water quality in the Río Curundú, and found that many indicators of contamination and degraded water quality worsened with increasing distance from the source, and that the river was substandard for water quality in almost all sites (Itzkovitch et al., 2000; Pappas and Breault, 2002).

Our project began due to concerns of PNM workers who noticed that biodiversity had been lost in the Corredor-affected areas and along the river, including loss in diversity of insects, birds, other animals, and lianas. Park employees wanted a better understanding of the ecological importance of lianas and their role in maintaining animal diversity in the park, and for an assessment of the degree to which lianas has been disturbed in the areas around the Río Curundú and the Corredor, and the effects of this on the ecosystem as a whole. Furthermore, they were interested in the potential of efforts at the reintroduction of biodiversity in the park.

Biology of lianas

Lianas are woody climbers that cannot reach the canopy of the forest without the mechanical support of adjacent plants (Croat, 1978; Putz and Windsor, 1987; Alvira et al., 2004). They can grow to more than 40cm in diameter and to lengths of several hundred meters (Laurance et al., 2001). They can be differentiated from other types of climbers by the fact that they begin life as terrestrial seedlings – as opposed to herbaceous epiphytes and woody hemi-epiphytes, including stranglers, which start life as herbaceous epiphytes and later grow roots to contact the ground. They can also be distinguished from the herbaceous vines, which, like lianas, grow from terrestrial seedlings but which generally possess thinner stems and are not woody or permanently fibrous (Gentry, 1991, Gerwing et al., 2006).

The seedlings of lianas can typically grow up to 30-40cm tall before becoming unstable and needing support, although some species' seedlings can achieve heights of up to 1-2m before needing support (Putz and Holbrook, 1991). Above this height, lianas are dependent on external structures to support their growth. As such, lianas can invest a relatively small amount of resources into structural support compared to trees, allowing lianas to allocate more resources to reproductive and photosynthetic structures, stem and root elongation. Their unique growth form provides them with a very high canopy:stem biomass ratio, resulting in a higher proportionate allocation of biomass to photosynthetic structure relative to most woody plants.

Climbing strategies of lianas are diverse, from branch or stem twining, to clasping tendrils arising from stem, leaves and branches, to hooking with thorns or spines, to adhesive roots (Schnitzer and Bongers, 2002, Dewalt et al., 2000). The relative abundance of each strategy varies as a function of stand age and gap dynamics. Tendril climbers are more abundant in perturbed sites while stem-twining climbers are more competitive in older forests (Dewalt et al., 2000)

The diversity and abundance of lianas is one of the most striking differences between tropical and temperate forests (Gentry, 1991). Similarly to most of the other life forms, the diversity of lianas increases with decreasing latitude, but at a much faster rate. In fact, the proportionate species richness of lianas increases five fold (2 to 10%) between temperate and tropical forests, compared to a less than two fold (12 to 21%) increase for trees and a 1.5 fold (6 to 9%) increase for shrubs. In the temperate forests, only a few genera of lianas can be observed, including *Vitis* spp., *Parthenocissus* spp and *Toxicodendron* spp. Conversely, lianas typically account for about a quarter of the abundance and species richness of neotropical forests (Schnitzer and Bongers, 2002; Gentry, 1991).

To explain the low occurrence of lianas in temperate forests, it has been hypothesized that lianas are more sensitive to embolism induced by freezing than other growth form because of their long and wide vessel elements coupled with relatively narrow, uninsulated stems (Schnitzer, 2005)

Liana abundance is also influenced by several abiotic factors such as total rainfall, seasonality of rainfall, soil fertility. For instance, abundance increases in a gradient from wet to dryer forests. The ability of lianas to invest more in roots systems, allowing access to deeper sources of water, has been proposed to explain this observed pattern of abundance (Schnitzer, 2005)

Lianas are said to be a "major contribution to the taxonomic diversity of the tropical forest" (Gentry, 1991). Indeed, there are at least 133 families that include climbers, such that the evolution of a climbing habit occurred independently a multitude of times (Gentry, 1991).

In neotropical forests there typically are about the same number of lianas that possess a diameter at breast height (DBH) of more than 2.5cm as the number of trees that possess a DBH of more than 10cm (Gentry, 1991). On Barro Colorado island (BCI), Panama, lianas account for more than 45% of all the plant species that achieve 10 meters in height (Laurance et al., 2001). In addition, even though lianas represent less than 10% of the above ground biomass, they produce up to 40% of the leaves present in the tropical forest (Laurance et al., 2001).

Gentry (1991) characterized the role of lianas as "an important structural component of the tropical forest, often literally tying the forest together". Lianas can be considered to exert an important selection pressure in tropical forests, because they compete with trees for sunlight, nutrient and water, and are an important cause of tree death. Lianas have been shown to suppress tree regeneration and increase their mortality (Schnitzer and Bongers, 2002). Furthermore, between 43-50% of the trees over 15cm DBH on BCI support lianas in their crowns, with similar figures occurring in many tropical forests worldwide, and it has been shown that trees with crowns that support lianas typically experience higher mortality than trees with crowns free of lianas. Liana's thus impose a selection pressure towards tree characteristics that avoid the establishment of lianas, such as rapid growth, large leaves, smooth bark and long, branch-free boles (Gentry, 1991; Alvira et al., 2004). Lianas may also play an important role in the cycling of water and nutrients (Gerwing and Vidal, 2002). They have an important effect on the carbon cycle because they can compose up to 40% of the uppermost canopy leaf surface and it was shown that 99% of the light that reaches the canopy of the trees is reflected in the 5 first meters of the canopy (Kitajima, 2003). In addition, they also contribute to the overall diversity of tropical forests by structuring the habitat and facilitating the movement of arboreal animal species, and they constitute an important part of the diet of many primate, bird, and insect species (Gentry, 1991; Gerwing and Vidal, 2002). For example, Gerwing and Vidal (2002) report that approximately 40% of the 700 species of phytophagous beetles that live in the tropical dry forest of Panama are exclusively associated with lianas.

It is clear that lianas play a critical role in all aspects of tropical forest dynamics.

Lianas and disturbances

It has been hypothesized that tree fall gaps are a mechanism for the maintenance of tropical diversity; however, several studies have refuted this hypothesis, showing that, per stem, diversity in gaps was the same as in non-gap area on BCI (Hubell et al. 1999; Browkaw and Busing, 2000). Nevertheless, these studies ignored and excluded lianas in their analysis. Recent studies demonstrated that liana species diversity is maintained by gaps (Schnitzer and Carson, 2001; Schnitzer and Bongers, 2002). Seeing that lianas represent an important portion of the tropical forest diversity, that they are an important instigator of gaps, and that they have higher diversity in gaps, they have been suggested as a mechanism for the maintenance of tropical forest richness (Allen et al., 2005).

Liana abundance and diversity have been shown to be significantly higher in naturally or anthropogenically disturbed than in undisturbed areas (Laurance et al., 2001; Schnitzer and Carson, 2001; Gerwing and Vidal, 2002; Schnitzer and Bongers, 2002; Alvira et al., 2004; Allen et al., 2005). Liana establishment typically requires higher levels of light, such as is found in disturbed areas where the canopy is usually more open. Once established, seedlings can persist in the understorey even under closed canopies (Schnitzer and Bongers, 2002). In addition, lianas are typically thought to have deeper root system, allowing reprieve from competition for water, thus giving lianas the possibility to more fully use available light and raising their competitive advantage in gap (Schnitzer, 2005).

Lianas are described as having four methods of gap colonization, whereas trees have only two; this probably confers lianas a significant competitive advantage and may explain the higher diversity of lianas in gaps than in non-gap areas. Like trees, lianas can colonize gaps via seed dispersal and advance regeneration. However, unlike most other vascular plants, they can also colonize the disturbed area while they are adults by entering laterally from adjacent areas. It was also shown that about 90% of adult lianas that are dragged by falling trees into a gap survive the event and continue to grow (Schnitzer and Carson, 2001; Schnitzer and Bongers, 2002).

Finally, lianas, being a) more successful in gaps, and b) contributing to the formation of gaps in tropical forests by increasing tree mortality, have been described as maintaining their abundance through a positive feedback loop (Wright et al., 2004).

Objectives of our efforts

In keeping with the goals of our host institution, the Parque Natural Metropolitano, to gain understanding of the effects of disturbances to the Río Curundú on the liana populations in the adjacent ecosystems, the goal of our internship project was to investigate the effects of anthropogenic disturbances on the liana populations along this river. To this end, we compared liana populations along the quite-disturbed Río Curundú to populations along the Río Sixto, a nearby river with nearly low detectable anthropogenic disturbance.

The hypothesis that we approached is that liana diversity and abundance vary dependent on anthropogenic disturbance of natural, riverine areas. Based on a review of the primary literature concerning tree-fall gaps, we would expect liana abundance and diversity to be greater in disturbed rather than non-disturbed areas, though this is contrary to the PNM workers' descriptions of our study areas.

For our internship hosts, the Parque Natural Metropolitano, we created several products. The first most important product is the present study on the effect of disturbances along the Curundú River on lianas population. We hope this study will serve as a basic for future investigation on lianas population in the park and more globally on effect of the degradation of the Curundú River. The study includes some recommendations for the management of the park including some proposition on the directions of future studies or maybe other PFSS interns.

To help the park in its educational mission and in response to the concern of some of the park workers, we have created some educational tools. To help the guides gain more knowledge on lianas, we created a list of interesting facts on the ecological importance of lianas in tropical forests. To supplement the list, we created some fact sheets about the most common and easily identifiable lianas species of the park. We hope the two documents will help provide more information to thirsty visitors.

Ours discussions with some workers of the park highlighted that a majority of the visitors are of young age and coming from elementary school. To help educate this public on the ecological importance of lianas, we designed a small and easy game with some guidelines on how to make it informative. Finally, we designed a small 4 pages booklet with easy games and some quick facts on lianas. This booklet can easily be given to children so they can bring it home with them.

METHODS AND MATERIALS

Study sites

Sampling was undertaken during the dry season from February until April along two different rivers, the Río Curundú in Parque Natural Metropolitano (PNM) and an unnamed river in Parque National Camino de Cruces (PNCC). We refer to this unnamed river as the Río Sixto in honour of our PNM guide and friend Sixto Mequizama. Both rivers are located within the limits of Panama City. The Río Curundú runs from its source in PNCC, through PNM, and passes through (and under) urban, commercial and industrial areas of Panama City before reaching the Panama Canal. Overall, the Curundú is approximately 11km long, of which 3km forms the eastern most border of PNM; this border is roughly 3.25km downstream from the river source (see Appendix 2, Figure 10). It should be noted that there are only 100 to 300m of forest separating this 3km river boundary river from the Corredor Norte. Our sample sites were located in the northern half of this 3km portion on the park side of the bank found adjacent to the communities of Las Mercedes, Dos Madres, La Alameda and Villa Soberania (see Appendix 2, Figure 11).

There have been two recent water quality studies done on the Río Curundú by past McGill internships, (Itzkovitch, 2000; Pappas and Breault, 2002). Both of these studies describe high levels of pollution and very low water quality, in physical, chemical and biological terms. These studies attribute such conditions to the direct industrial and urban inputs that are very obviously entering the river. Industrial inputs include waste pipes from a paper recycling plant and a beer plant, while notable urban inputs include sewage drains and visible trash dumping. During our sampling, it was obvious to us from simple visual and aromatic observation that the section of river next to our sites suffered high levels of contamination. The water was a strange translucent blue colour with grayish algal growths covering submerged rocks, there was a very consistent, unpleasant smell and trash was ever-present along the river (see Appendix 2, Figure 15). These observations are extremely similar to those made by Pappas and Breault (2002) for this area. During our sampling, human disturbance was ongoing: there were construction projects occurring upon the banks of the urbanized side of the river, which saw workers taking earth and rocks from the bank on the park side and also dumping left over liquid concrete into the river. A man was also seen walking through the forest and along the river edge and we suspect that he was hunting. Furthermore, the urbanized bank was extensively developed such that we were consistently flanked by homes during our sampling. This development and activity must have occurred within the last four years as Pappas and Breault (2002) described the area as having no houses or people around.

Disturbances related to the construction of the Corredor Norte would include greater seasonal fluctuations in river levels, including higher frequencies of flash flooding because of increased water runoff into the river. The occurrence of flash flooding, and the effects on neighbouring communities, led the city to require that the park dredge the river about 10 years ago, evidence of which was clearly visible along the river and in our sample sites. Specifically, we observed sections on the park side of the bank having a noticeably different bank formation, which we interpreted as an indication of dredging.

Typically dredged banks would have a relatively long and steeply inclined slope emerging from the river, followed by a plateau and then a second small raise in the ground, which formed a high ridge running above the river and also the barrier between the forest edge and the river bank (See Appendix 2, Figure 13). We believe that the steep bank along the Curundú was created through dredging, and the dumping of earth dredged from the river bottom created the associated ridge.

Further evidence of dredging was derived from the vegetation and rubble frequently found in the high ridge. Dredged areas had few – if any – trees growing between the high ridge and the water. Typically, plants were absent from this area and any lianas (i.e. hanging from the odd tree) had been cut from their roots. Large trees were frequently observed along the banks, though many were dead, and we noted many large, mechanically cut branches or trunks, which might have been cut around ten years ago. The only vegetation common along dredged banks was a thick growth of tall grass (*Saccharum spontaneum*, commonly known as paja blanca) growing on the banks, plateau and high ridge areas.

Areas assumed not to have been dredged had very different banks. They did not have the initial steep rising slope, plateau or high ridge; rather, the bank quickly led to the forest edge and there were no layers of tall grass separating the forest from the river edge (See Appendix 2, Figure 14). Trees, bushes and lianas were all present much closer to the river, however, there was still evidence of human-made cutting of trunks and branches and other past human disturbances that could have occurred within the past 10 years. More detailed descriptions of these bank characteristics and disturbances will be provided by the individual site descriptions.

Less is known about the Río Sixto. Its source is found in PNCC and it runs approximately 2.25km before joining up with the Dos Bocas River and continuing on to the Panama Canal. Our sites were within this 2.25km section, which runs through the forested PNCC, before the river enters the residential neighbourhood of Clayton at the river's junction with Río Dos Bocas (see Appendix 2, Figure 12). The Sixto is smaller than the Curundú and there was only a constant flow during heavy rains, otherwise the river existed as scattered pools and streamlets. It was obviously much less polluted than the Curundú, having none of the qualities described above and being much farther from urban or industrial inputs. The only observed sign of disturbance were poacher platforms constructed in trees along the river's edge.

These two rivers fall within an area that is classified as dry tropical forest, and the forests adjacent to the rivers have remained fairly undisturbed until recent years. The PNM occupies 232 hectares and represents the tip of a long line of National Parks lining the eastern side of the Panama Canal and protecting its watershed (see Appendix 2, Figure 9). As it is such an exposed and isolated tip of forest extending into Panama's largest city, it has unsurprisingly been subjected to a high degree of disturbance. Its borders are defined by the roads La Amistad to the North, Route 70 to the South-West and the Río Curundú to the East; furthermore, there are two roads running through the park itself: Juan Pablo II and, as mentioned, the four lane Corredor Norte (see Appendix 2, Figure 10). Urban and industrial neighbourhoods largely surround the park. In spite of all of this, the existing forest has remained intact, mainly thanks the area becoming protected shortly after the U.S.A handed it over to the Panamanian government. During the U.S. occupation, the PNM area was mainly used by the United States military and, while little is known about the military's activities, the forest was by and large preserved. Overall there is little evidence to suggest that any large-scale disturbance, such as deforestation or fire has occurred in either PNM or PNCC for over a century. However, it is important to keep in mind that the forest where we sampled in PNM is an isolated patch between the Curundú and the Corredor Norte and had experienced disturbance through road construction and riverside developments, whereas the area sampled in PNCC appears to have suffer little anthropogenic disturbance. While the PNCC is a much larger park, occupying 4590 hectares and extending far North of the PNM, we sampled quite near to where the two parks meet at Calle La Amistad.

Although we recognised the difference in flow rates of these two rivers and the significance of this confounding factor, we chose to compare the Curundú (our focal river) with the Sixto because it is among the only rivers in the area which we could be assured to be free of human disturbance in the last ten years. Using topographic maps for reference, we consulted with park employees and local Panamanian biologists about the appropriateness of using these rivers for comparison, with agreement that these were among our best options. Furthermore, the Sixto was easily accessed and, due to its proximity to the PNM, can be confidently assumed to be quite similar in forest type and environmental factors.

Quadrat setup

We decided to sample 10 quadrats along forested areas of each river. In order to randomize site selection, we first used topographical maps of the parks (purchased from the Instituto Geografico Nacional "Tommy Guardia" in Panama City), along with field notes from our visits to the rivers, to delimit appropriate areas to sample. Our delimitation criteria was designed to choose forested areas of each river that were unbroken by road crossings and, for the Río Sixto, to choose areas that were not disturbed by human activities and that were far enough from the source that the river flow was maximized. As such, we chose a 750m stretch of the Río Curundú (running North and beginning 200m North of where Vía Brazil crosses over the river), and a 615m stretch of the Río Sixto (beginning 300m upstream from where the Sixto meets Río Dos Bocas). Using Microsoft Excel (2004 for Mac; V.11.2) we randomly generated two sets of numbers corresponding to distances along these delimited stretches of rivers. Because the Río Curundú is only consistently forested along its Western bank, we took these distances to correspond to sites only on the Western bank. For consistency in only sampling one bank of the river, we flipped a coin to decide that distances along the Sixto referred to its Northern bank because the river has a different orientation. These distances along the river were taken to refer to the centre of our 10 x 10m sampling quadrats, such that they extended 5m up- and downstream from this point.

In the field, we arrived at sites by measuring our distance bushwhacked (using a 50m tape measure) from the most accurate reference point available for the first sites: the Vía Brazil bridge on the Curundú, and the junction with Río Dos Bocas on the Sixto; thereafter we measured from the previous site. We took care to follow the river's edge fairly closely, taking care not to cut corners. When we had gone the appropriate distance, we established our quadrats and began sampling.

We established 10 x 10m quadrats at each of the chosen sites. Quadrats were delimited using yellow string and wire corner stakes. We laid one side of each quadrat parallel to the river (extending 5m up- and downstream from the chosen point, as explained above), and extended the quadrat 10m inland from this side using compasses, laying the far side (again parallel to the river) last. Methods for choosing how far from the river to lay the first (parallel to river) side required some flexibility due to the sometimes-extreme differences in riverbank vegetation and topography. On the Curundú, for sites that fell upon dredged areas accompanied by dense stands of palo blanco grass, we laid this side 1m into the forest from the edge of the grass stand, considering this to correspond to the forest edge (palo blanco nearly only grows in pure stands, appearing to almost entirely inhibit the growth of other vegetation). For non-dredged Curundú sites and all Sixto sites, where palo blanco vegetation was absent, we laid this side of the quadrats 1m from what we unanimously decided to be the edge of the forest vegetation.

Sampling

Once the sites had been selected and delimited, liana sampling generally followed guidelines described by Gerwing et al. (2006). To summarize, sites were walked through and, for any liana found, we measured the trunk diameter at breast height (DBH) - roughly 1.3m from where the trunk was rooted to the ground – using vernier callipers. Lianas were defined as climbing plants that produce true wood or have persistent fibrous stems, that germinate on the ground but that lose their ability to support themselves as they grow (Gerwing et al., 2006). All lianas with trunk diameters greater than 10.00mm were enumerated and marked with flagging tape. More detailed information on our liana sampling methods, can be found by referring to Gerwing et al. (2006), however, bear in mind we counted ascending liana stems emerging from interconnected clonal groups as separate individuals, rather than as subseries emerging from the same individual, as recommended by the article. Lianas were identified on site, or were described for later identification, according to a morphospecies system that we established over the length of our sampling. Because of difficulties in accurately identifying lianas to the species level using vegetative features, we identified lianas according to a set of morphospecies: we described individual lianas as extensively as possible, often taking samples of leaves and climbing structures; we then identified each unique type as a morphospecies (numbered ascending from MSpp1). This system allowed us to get a good idea of the diversity within and between sites and rivers. Shortcomings of this system include a potential underestimation of the actual species richness encountered (such as in the event that two species are similar enough that they would be classified as one morphospecies). Our sampling method saw a further shortcoming in our inability to identify a few very tall lianas for which we could not see foliage or climbing structures, despite our attempts to describe identifiable features of bark, trunk and growth form. In this case, we have treated these individuals as unique morphospecies.

After the characteristics of all eligible lianas in the site had been recorded, the abundance and diversity of lianas in each site could be determined. Finally, we used a

Geographic Resource Solution (GRS) Densitometer to measure canopy cover at each corner and at the centre of our site, from which average canopy cover was calculated for each site.

Supplementary sampling was carried out – as suggested by University of Wisconsin liana biologist Stefan Schnitzer (personal communication) – within a 6.125m^2 circular sub-quadrat, created by delineating a 1m-radius circle at the centre of each of our 10 x 10m quadrats. Within this sub-site, all lianas with a DBH greater than 5.00mm were sampled. This was done because there is some debate in the literature as to what minimum DBH is ideal for liana censusing. According to Gerwing et al. (2006) abundance counts should double when minimum DBH values are halved from 1cm to 0.5cm, though the effects of this method change on species richness counts is more ambiguous. This extra procedure was not done to test our hypothesis, but rather to provide a comparison between censusing methods and to shed some light on how they differ, but this data is not presented here.

Finally, field notes were taken about each site, taking care to note signs of human-caused disturbance, any clues as to the ecological histories of the forests, impressions as to environmental or anthropogenic factors affecting the ecology of the sites, as well as generalities and other notes about the sites. A brief description of each site is included in the appendix.

Data analysis

Using DBH measurements, we calculated the cross-sectional area (CSA) of liana trunks at DBH (estimating trunk to be cylindrical) using the following formulae;

$$CSA = \pi r^2$$

This was investigated as a rough estimate of biomass of lianas.

Site data was calculated to include: average site canopy cover, liana abundance, morphospecies richness, Simpson's and Shannon's biodiversity indices and evenness as defied by Simpson's and Shannon Equality. These data were also calculated to give totals for each river.

From the aforementioned morphospecies richness data, we produced taxon-sampling curves to assess the thoroughness of our sampling effort, including curves for each river individually and for both rivers, pooled.

We used our field notes and site descriptions to qualitatively categorize sites on both rivers for additional analysis, including whether or not sites had been dredged, whether or not they occupied a forest light gap, and whether or not there were obvious signs of important human disturbance. Dredging was assessed according to the appearance of the riverbed next to the sites, as well as according to the presence of dumped river-bottom material on the banks of the river (often inside our sites). Light gaps included naturally and anthropogenically caused areas in which there were few or sparse trees above the site, which we noticed was often not reflected in our canopy cover measurements. Human disturbance included dredging as well as other signs of disturbance, such as extensive cutting of branches, trees or lianas. Table 3 (Appendix 1) gives our site categorization and Appendix 3 shows our qualitative site descriptions.

Paired sample t-tests assuming equal variance were used to make comparisons between liana populations on the Ríos Curundú and Sixto. Tested variables include: total cross-sectional area, abundance, morphospecies richness, and Shannon's index. Shannon's index was tested using a modified t-test proposed by Hutcheson (*in* Zar, 1999). The t value is calculated using the following equation;

$$t = \frac{H_1^{'} - H_2^{'}}{s_{H_1^{'} - H_2^{'}}}$$

Were:

$$s_{H_1^{'} - H_2^{'}} = \sqrt{s_{H_1^{'}}^2 + s_{H_2^{'}}^2}$$

The variance is calculated using:

$$s_{h^{'}}^2 = \frac{\sum f_i \log^2 f_i - \left(\sum f_1 \log f_i\right)^2 / n}{n^2}$$

And the degree of freedom with:

$$v = \frac{\left(s_{H_1^{'}}^2 + s_{H_2^{'}}^2\right)^2}{\frac{\left(s_{H_1^{'}}^2\right)^2}{n_1} + \frac{\left(s_{H_2^{'}}^2\right)^2}{n_2}}$$

More t-tests were performed with the different aforementioned categories to test for the impact of different disturbance type on liana communities' parameters.

Sites' species assemblage was also analyzed using the program Biodiversity Probe© (1997, version 2.0). Correspondence analyses were performed and Curtis-Bray Cluster Analysis was drawn to see the degree of differences between the various sites.

Beta diversity was calculated to see species loss and turnover between the two rivers. We used the formula proposed by Ruggiero et al. (1998; *in* Koleff et al., 2003):

$$\beta_{rlb} = \frac{a}{a + c}$$

Whereas component a comprises the total number of species occurring at both rivers and component c includes the total number of species occurring solely at the Curundú river.

Finally, we plotted the canopy cover with CSA, abundance and richness to find the possible existence of correlations between light cover and those parameters.

RESULTS

During our sampling we found a total of 354 individual lianas with a DBH greater or equal to 10.00mm, 188 found at the Curundú river and 166 found at the Río Sixto. A further 27 individuals were found in our central sub-sites with a DBH of 5.00mm or greater, 3 at the Curundú river and 24 at the Río Sixto. Among these individuals 42 morphospecies with DBHs greater or equal to 10.00mm were identified, and with our central sub sites, this total grew to 45 morphospecies. 32 morphospecies were found at the Río Curundú and 22 at the Río Sixto, which includes 5 morphospecies found with a DBH between 5.00mm and 9.99mm.

The total average canopy cover values for each river were very similar, but the Curundú River had a noticeably higher standard deviation (65.8 ±22.11 for the Río Curundú and 68.1 ±16.57 for the Río Sixto). Overall, light cover was found not to have any discernible correlation with liana abundance, diversity or cross-sectional area at DBH (see Appendix 4, Charts 1, 2 and 3, respectively). Both rivers had relatively similar total and standard deviation values for cross sectional areas (63120.917 ±5145.402 and 83511.772 ±7389.642 respectively). Table 1(Appendix 1) provides a summary of our abundance, diversity, biomass and canopy cover for each site at each river.

The t-tests showed no significant differences for liana richness ($P=0.075$), for abundance ($P=0.795$) or cross-sectional area at DBH ($P=0.483$) between the Río Curundú and the Río Sixto sample sites. Table 2 (Appendix 1) summarizes the results of the T-tests. However, in spite of these results, some interesting trends did emerge when comparing the data from Ríos Curundú and Sixto. There was markedly higher total species richness at the Río Curundú, with a two fold difference between both rivers, but this was not coupled with a higher abundance (Figure 4, Appendix 2).

T-tests were also performed to verify the impact of dredging, light gap and human induced disturbances on abundance, diversity and cross-sectional area at DBH. Table 3 (Appendix 1) summarize the various categorization used to perform the test. The 9 test performed showed no significant results (see Table 4, Appendix 1 for results).

The Simpson index showed much higher alpha diversity values for the Río Curundú over the Sixto (11.63 ±1.71 vs. 4.00 ±1.40 respectively). Shannon Wiener indices also gave higher value of alpha diversity for the Río Curundú (2.86 ±0.77 vs 1.87 ±0.57) but a Hutcheson (1970) t-test (as described by Zar, 1999) showed no significant difference between the 2 rivers ($0.5>P>0.2$). Evenness, as indicated by these two indices, was also greater for the Río Curundú (0.364 ±0.318 and 0.825 ±0.403 for Simpson and Shannon Wiener respectively) compared to the Río Sixto (0.235 ±0.312 and 0.661 ±0.386 for each index respectively).

A simple beta diversity analysis showed that there was a high degree of dissimilarity in liana diversity between river sites. The B(rlb) equation gave a value of 0.1875, which indicates that there is little continuity of species between sites, or a high degree of loss because it is close to zero (Koleff et al., 2003). The percentage of liana morphospecies specific to each river and those found at both shows a higher diversity at the Curundú and a low similarity between rivers (Figure 5, Appendix 2).

Correspondence analyses show that there is a strong segregation between Curundú and Sixto liana community composition (Figure 6, Appendix 2 and Table 6, Appendix 1 for coordinates). This is further supported by cluster diagrams showing the percent similarity between sites (Figure 7, Appendix 2). Notice how for both figures there is a general trend associating Curundú and Sixto sites separate from each other, and while the correspondence analysis displays a wide variation among the individual river sites, the cluster diagram shows greatest similarity among Sixto sites (see Table 5, Appendix 1 for percent similarity values).

Lastly, the taxon sampling curves indicated that our sampling effort was insufficient and suggests we did not find all of the morphospecies that exist at each river (Figure 8, Appendix 2). The curve incorporating all sites implies that we were not far from sampling all possible morphospecies at each river as indicated by the planing of the slope, but this is not as true for each river. The Río Curundú curve has a much steeper slope than the Río Sixto curve, suggesting that more morphospecies remain to be found at this river, while the sampling effort at the Río Sixto appears much more sufficient.

DISCUSSION

Our results indicate that there are no significant differences in liana communities between the two rivers, which disagrees with our hypothesis that predicted significant differences in liana community parameters between severely disturbed and predominantly undisturbed riparian forest environments. Cross sectional area and abundance values are directly related to each other, and had similar values for each river, so it was not surprising they showed no significant differences between the two. However, these findings contradict previous studies that suggested liana abundance is significantly higher in naturally or anthropogenically disturbed areas than in undisturbed areas (Laurance et al., 2001; Schnitzer and Bongers, 2002; Alvira et al., 2004; Allen et al., 2005).

The contradictory results observed in our study may be related to the nature of disturbance along the Río Curundú. Laurance et al. (2001) and Schnitzer and Bongers (2002) studied the impact of natural tree fall gaps on liana regeneration, Allen et al. (2005) analyzed recovery of liana communities following an hurricane and Alvira et al. (2004) studied the impact of logging on liana communities. The disturbances observed along the Río Curundú were related either to past dredging or to the activities of the surrounding communities, which included direct industrial, and sewage inputs, construction, as well as high volumes of trash. Dredging related disturbances, such as the use of heavy machinery and the displacement of earth, would have likely caused increased liana mortality, through increased stress, or physical damage. Indeed, at some sampling sites, a lot of dead lianas were observed, many of which had been obviously cut by people. Such a disturbance of the Río Curundú could have affected the abundance of lianas, but not necessarily their diversity. Gerwing et al. (2002) and Alvira et al. (2004) found that cutting liana stems before logging reduced the density of climbing lianas by between 55% and 69%, whereas when lianas were not cleared and left on the ground, around 81% grew back to the canopy. In these studies, diversity did not appear to be significantly affected. Therefore, this may explain why we witnessed a higher overall diversity at the Río Curundú but not abundance as compared to the Río Sixto (Fig). Unfortunately we cannot evaluate the effects of community related disturbances in this study, nor speculate their effects because no relevant studies were found.

In terms of diversity, our results showed strong trends toward greater liana diversity at the Río Curundú. Looking at total species richness and the Simpson and Shannon Wiener indices, they all show much higher diversity values for the Río Curundú (Table 1, Appendix 1). Both indices also show higher evenness for the Río Curundú suggesting a more even distribution of species. However, it is possible the higher evenness may be linked with higher diversity. For this reason, it was unanticipated that our t-tests would show no significant differences between rivers.

The absence of significant results in diversity may be attributable to the tendency of t-tests to include the overlap of the same morphospecies occurring between sites at each river. Total values, on the other hand describe overall species richness and exclude these overlaps occurring between sites. Insufficiencies in our sampling effort could have also contributed to our insignificant results. A low number of sample sites for each river provide a very rough distribution of liana species, making it less probable that large differences in diversity and composition are realistic representations of each river community. This said, comparing our data describing total diversity values, our site observations, and our taxon sampling curves for each river, we would expect that with more sample sites, statistical analyses would show a significant difference in diversity between rivers.

Many trends in our results suggest a greater diversity of lianas at the Río Curundú over the Río Sixto, and there are also trends suggesting large differences in liana community composition between each river. To begin, the rivers revealed very different environments, and even the individual sites at each river exhibited clear qualitative variation in their plant community composition and disturbance levels. Site by site variation was particularly strong along the Río Curundú where sites ranged across a wide gradient of disturbance levels and biotic characteristics (see Appendix 3). In contrast, the environment along the Río Sixto was much more uniform and undisturbed, only one gap site was sampled and biotic variation was much less distinct. Based on these qualitative site differences, theories by Schnitzer and Carson (2001) and Schnitzer and Bongers (2002), as well as basic niche theory, the Río Curundú should produce a wider diversity of liana species given its greater habitat heterogeneity, and higher light gap frequency - assuming that they are not adversely affected by other disturbances.

The difference in degree of site by site environmental variation observed between rivers and the theoretical effect this should have on liana community composition are supported by our Cluster diagrams and associated data (Figure 6, Appendix 2 and Table 5, Appendix 1). The percent similarity between Río Curundú sites is generally lower than the similarity between Sixto sites which suggests a more uniform liana distribution and composition and hence, environment. Our correspondence analysis also suggests that the sites from the two rivers do not correspond with each other in liana species distribution or composition, rather that they tend to correspond to sites of the same river (Figure 5, Appendix 2). It is interesting to note that they also tend to form small, distinct groupings of about three sites and that these groupings can poorly correspond to other groupings from the same river. Perhaps this means there are certain environmental parameters which have especially strong determining factor in liana species composition?

Trends in beta diversity also support both higher liana diversity at the Río Curundú, and different liana community composition between the Ríos Curundú and Sixtos. The extremely low continuity between rivers is surprising given their proximity and similarity in forest type. This therefore implies significant environmental differences between each site, which are not only excluding certain liana species from each site, but also diversifying the liana community at the Río Curundú. If this is true, then it would also imply that a strong niche effect is determining species distribution at the river Curundú, where the environmental variety favours more specialized liana species that wouldn't grow under more natural conditions.

The fact that no correlation was found between canopy cover and abundance, species richness or biomass is very strange considering how studies by Schnitzer and Bongers (2002) have shown strong relationships between light levels and liana properties. We suspect the major factor affecting our results is the GRS Densitometer used to calculate canopy cover. Although the creators of the instrument boast it to be an effective and efficient quantitative measurer of canopy cover, we found it to be highly impractical for quantitative analysis. It had absolutely no comparative or numerical standards for measurement, the only instruments it provided was a couple of leveling devices ensuring it was positioned properly during use. Otherwise, the naked eye was left to evaluate the canopy cover presented by the Densitometer’s viewfinder. Such a determination of canopy cover likely has a source of error as large as 25%, and furthermore, fails to take into account of light penetrating from areas outside of the canopy directly above from where measurements were taken. Originally it was hoped we could use measurements taken from both the Densitometer and a Luxometer, however, we were unable to obtain the latter instrument. It is highly recommended that future studies seeking accurate, qualitative information of canopy cover, or lower level light measures do not rely on Densitometer measurements, which are suitable only for qualitative purposes.

With the results of our study, the diminution of diversity of animals and insects observer by the PNM workers cannot be attributed to change in liana populations. Abundance is not significantly lower than along the Río Sixto in the Parque Camino De Cruces so diversity of animals and insects should not lower. Moreover the trend toward higher diversity observed along the Río Curundú should in fact reflect higher abundance of animals and insects. Indeed, diversification of species of lianas should offer more ecological niche for diversified and specialized animals, birds and insects. However, the ecological importance of lianas has not been widely studied in tropical forests with few existing papers in the available literature. Therefore we cannot precisely address the dynamics between lianas and animals communities.

In addition, in the case of the PNM, no base studies on lianas population have been realized in the past. All the available information was a list of climbing plants frequently encountered in the park in the management plan of the PNM. The list contained only about 15 species of lianas and obviously lacked many we encountered during our study. The lack of previous information prevented us from analyzing how lianas populations have changed through time and we cannot confirm the claims of the park workers. We hope our study will be useful for future studies concerning lianas dynamics in the PNM. However, we did observe abundant dead trees, lianas and other plants on many of our sampled site due to anthropogenic and natural disturbances. It suggests a changing environment where abundance and/or richness of species could have been higher in the past.

This being said, park employees have observed a decline in diversity while our study does not show that this diminution could be attributed to lianas population therefore some other factors might be causing this decline. The environment along the Río Curundú is highly unstable and shows a lot of anthropogenic perturbations. Previous studies showed that the water of the river is highly polluted (Itzkovitch et al., 2000; Pappas and Breault, 2002), the Corredor Norte has been recently build an mitigation measure were poorly applied, sewage and garbage is constantly dropped in the river, some poachers are seldom encountered in the forest along the river and recent housing development has led to collection of earth, rock and dumping of construction material on the park side of the river. All these factors surely have contributed to the decline in animal abundance and diversity observed along the river. In addition, the edge effect and fragmentation of the forest engendered by the construction of the Corredor and household development is probably leading to a gradual change in the biological composition of the forest species. Fragmentation of tropical forests leading to the creation of edge has been shown to have deleterious impacts on bird communities (Barlow et al., 2004) and on biodiversity in general (Jha et al., 2003). Contrary to those observations, lianas diversity appear to be positively affected by forest edge (Laurance et al., 2001) explaining why we found high diversity while park workers have observed a decline in the abundance of some animal species.

RECOMMENDATIONS TO THE PARQUE NATURAL METROPOLITANO

We feel that addressing the issue of the Río Curundú is essential for the PNM. It is apparent that a great deal of anthropogenic disturbance continues to occur at the Río Curundú, through urban development and high urban and industrial waste inputs. As past studies investigating the water quality of the river have shown, these disturbances are degrading the river's environment. Our study also suggests that habitats adjacent to the river have been affected by these disturbances and are experiencing higher degrees of physical and biological variation than witnessed at an undisturbed river. While the nature of these effects is not entirely understood, and while we did not see any statistically significant consequences of these disturbances on the liana, or any other biotic communities, we believe that the habitats adjacent to the river are being degraded. As a result of this degradation, we anticipate that without any diminishment in the scale or frequency of these disturbances, the biological integrity of the river habitats will not be preserved.

The frightening state of the Curundú, as is established by previous studies and especially by personal observation, has serious implications for surrounding environments. It is probable that the river and associated ecosystems will, or already have, become saturated with harmful contaminants and other chemicals, such as nitrogen, that have the potential to disrupt biological processes. Such extreme levels of these compounds in the river may result in the contamination of ground waters or water tables connected to the river. The problem with this situation is two fold: not only does ground water cover a wider area, and is therefore accessed by many more organisms including plant, animal and human communities; but in order for contaminants to be removed and the natural ground water quality to be restored, it takes many times longer than that of river water. Therefore, serious contamination of groundwater could lead to extremely long-term degradation of environments surrounding the Río Curundú.

If at all possible, it is highly encouraged that studies that investigate the environment and ecology of the Río Curundú continue. The production of historical databases and continuous investigation of the area would allow the park to better witness and understand the nature of any changes occurring in that area. Particularly, it would help them to recognize direct links between the consequences of these changes and their sources; specifically how any changes may be related to human activities. It is recommended for future projects similar to ours that the characteristics of a biological indicator species or a widely studied organism with a reasonable amount of background information be evaluated. A noteworthy limitation to our project was a lack of liana related texts, previous scientific investigations, and information regarding liana ecology.

Furthermore, it is recommended that in addition to closely monitoring the environment and biota of this area, PNM should monitor community activities and continue towards community integration. For example, the park should try and be aware of developments in the area, such as residential development on the river's edge, or the development of industries that could influence the river via waste inputs. If at all possible, these developments should be reserved from creating unnecessary damage and contamination to the river, and developers should be encouraged to seek alternative waste management techniques.

In order to be able to reach and impact local residents on these issues, it is recommended that the PNM seek the cooperation of governing bodies, especially municipal representatives, as well as the community itself. The government must contribute significantly towards educating the community in regards to better waste management, awareness of the park's importance, the poor conditions of the river and how their actions affect the river and the park. In addition to this, the government must accept the responsibility of enforcing regulations that help to ensure that residents and industries conduct themselves in an environmentally sensitive manner.

A final recommendation for the park is that further development on park land should be absolutely disallowed allowed. It is possible that with the development of the Corredor Norte, the parkland isolated between this road and the Río Curundú will become more vulnerable to future development, and hence a reduction of the park size, and the service it serves. Since this area has become isolated from the bulk of the park, and is also being degraded by the environmental effects of the road, its ecosystem health may degrade. What's more, as an isolated patch, it is easier to perceive it as a "useless" part of the park, and there is greater potential for developers to argue that the land would be more useful if it were developed for residential or other use. Municipal planners and governing bodies need to appreciate that projects such as the Corredor Norte, which segregate parts of a parkland, have the potential to endanger more than just the land occupied by the development, having strong and sometimes convoluted impacts on adjacent areas and ecosystems.

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REFERENCES

Allen, B.P., Sharitz, R.R. and P.C. Goebel (2005). Twelve years post-hurricane liana dynamics in an old-growth southeastern floodplain forest. *Forest Ecology and Management,* **218,** pp. 259-269.

Alvira, D., Putz, F.E., and T.S. Fredericksen (2004). Liana loads and post-logging liana densities after liana cutting in lowland forest in Bolivia. *Forest Ecology and Management*, **190**, pp. 73-86.

Barlow, J., Peres, C.A., Enriques, L.M.P., Stoufer P.C. and Wunderle J.M. (2004). The response of understorey birds to forest fragmentation, logging and wildfire: An Amazonian synthesis. *Biological Conservation***, 128**, pp.182-192

Brokaw, N. and R.T. Busing (2000). Niche versus chance and tree diversity in forest gaps. *Trends in Ecology and Evolution*, **15**, pp. 183-188.

Croat, T.B. (1978). *Flora of Barro Colorado Island,* Stanford University Press, Stanford, California.

Gentry, A.H. (1991). The distribution and evolution of climbing plants. *In The Biology of Vines* (Putz, F.E. and H.A. Mooney, eds), pp. 3-49, Cambridge University Press.

Estudio de Impacto Ambiental del Corredor Norte (Fase 1). Panamá. 1995.

Gerwing, J.J., and E. Vidal (2002). Changes in liana abundance and species diversity eight years after liana cutting and logging in an Eastern Amazonian Forest. *Conservation Biology,* **16**, pp. 544-548.

Gerwing, J.J., Schnitzer, S.A., Burnham, R.J., Bonger, F., Chave, J., DeWalt, S.J., Ewango, C.E.N., Foster, R. Kenfact, D., Martinez-Ramos, M., Parren, M., Parthasarathy, N., Perez-Salicrup, Putz, F.E., and D.W.Thomas (2006). Censusing Lianas. *Biotropica,* **38** (2), pp. 1-6.

Hubbell, S.P., Foster, R.B., O'Brien, S.T., Harms, K.E., Condit, R., Welchsler, B., Wright, S.J. and S. Loo de Lao (1999). Light-gap disturbances, recruitment limitation, and tree diversity in a Neotropical forest. *Science*, **283**, pp. 554-557.

Itzkovitch, M., Josephs, N., and Smith, S. *An assessment of the water quality of the* Río Curundú. McGill University, Panama Field Study Semester, 2000.

Jha, C.A., Goparaju, L., Tripathi, A., Gharai, B., Raghubanshi, A.S. and Singh, J.S. (2003). Forest fragmentation and its impact on species diversity: an analysis using remote sensing and GIS. *Biodiversity and Conservation*, **14**, pp. 1681–1698,

Kitajima, K. (2003). Carbon Uptake: the canopy microclimate and plant growth, *In Studying forest canopies from above: the international canopy crane network,* (Basset, Y., Horlyck, V., and S.J. Wright, eds), pp.142-143, Smithsonian Tropical research Institute and UNEP.

Koleff, P., Gaston, K.J. and Lennon, J.J. (2003). Measuring beta diversity for presence-absence data. *Journal of Animal Ecology*, **72**, pp. 367-382

Laurance, W.F., Perez-Salicrup, D., Dalamonica, P., Fearnside, P.M., D'Angelo, S., Jerozolinski, A., Pohl, L., and T.E. Lovejoy (2001). Rain forest fragmentation and the structure of Amazonian communities. *Ecology,* **82**, pp. 105-116.

Pappas, S. and Breault A.C. *Rapid water quality assessment of the Rió Curundú. McGill University*, Panama Field Study Semester, 2002

Plan de Manejo del Parque Natural Metropolitano. Ciudad de Panamá, Panamá. 1999.

Putz, F.E., and D.M. Windsor (1987). Liana Phenology on Barro Colorado Island, Panama. *Biotropica,* **19,** pp. 334-341.

Putz, F.E, and N.M. Holbrook (1991). Biomechanical studies of vines. *In The Biology of Vines* (Putz, F.E. and H.A. Mooney, eds), pp. 73-97, Cambridge University Press.

Samudio, J.C. and Samudio, R. 1996. Análisis, Evaluación y Discusión del Plan de Acción y Manejo Ambiental (PAMA) del Proyecto Corredor Norte – Componente Fauna Silvestre.

Schnitzer, S.A. and W.P. Carson (2001).Treefall gaps and the maintenance of species diversity in a tropical forest. *Ecology,* **82**, pp. 913-919.

Schnitzer, S.A., and F. Bongers (2002). The ecology of lianas and their role in the forests. *TRENDS in Ecology and Evolution,* **17**, pp. 223-230.

Snichtzer (2005). A mechanistic explanation for global patterns of lianas abundance and distribution. *The American Naturalist*, **166** (2), pp. 262-276

Schnitzer, S.A. 2006. Personal communication with authors, at STRI, Panama City, Panama.

Wright, S.J., Calderon, O., Hernandez, A., and S. Paton (2004). Are lianas increasing in abundance in tropical forests? A 17-year record from Panama. *Ecology*, **85**, pp. 484-489.

Wright, S.J., Horlyck, V. and Y. Basset (2003). Tropical Canopy Biology Program, Republic of Panama: Institutional Background, *In Studying forest canopies from above: the international canopy crane network,* (Basset, Y., Horlyck, V., and S.J. Wright, eds), pp.137-140, Smithsonian Tropical research Institute and UNEP.

Zar, J.H. (1999) *Biostatistical Analysis* (fourth edition), Upper Saddle River, New Jersey: Prentice-Hall

Appendix 1: Data tables

Table 1. Summary of average percent canopy cover and measured characteristics of liana populations for each of our sites. Note that average percent canopy cover was not measured at site S3 and was thus not included in our analyses of canopy cover.

		Avg canopy cover (%)	Cross-sect. area (mm^2)	Abundance	Species richness	Simpson's index	Simpson's equality	Shannon's index	Shannon's equality
Río Sixto	S1	91	8047.497	11	3	2.051	0.6836158	0.860	0.783
	S2	36	8074.507	43	4	1.271	0.3176976	0.470	0.339
	S3		15375.382	19	4	3.438	0.8595238	1.297	0.936
	S4	72	4804.081	24	2	1.385	0.6923077	0.451	0.650
	S5	80	2405.121	5	3	2.778	0.9259259	1.055	0.960
	S6	63	2689.491	16	1	1.000	1	0.000	0.000
	S7	52	2817.913	11	3	2.469	0.8231293	0.995	0.906
	S8	74	14330.220	26	3	1.170	0.3898501	0.325	0.295
	S9	65	4576.703	11	7	4.840	0.6914286	1.768	0.908
	S10	80	0.000	0	0	0.000	0	0.000	0.000
	Total	68.1	63120.917	166	17	4.003	0.235465	1.873	0.661
	StDev	16.568	5145.402	12.249	1.886	1.396	0.3120524	0.574	0.386
Río Curundú	C1	78	11941.742	31	8	4.124	0.516	1.696	0.816
	C2	53	0.000	0	0	0.000	0.000	0.000	0.000
	C3	94	3099.796	13	5	4.333	0.867	1.525	0.947
	C4	68	19898.676	28	7	3.664	0.523	1.597	0.821
	C5	78	15696.909	50	9	2.080	0.231	1.232	0.561
	C6	78	176.008	1	1	1.000	1.000	0.000	0.000
	C7	82	7442.614	19	6	4.149	0.692	1.566	0.874
	C8	68	302.951	1	1	1.000	1.000	0.000	0.000
	C9	24	16182.983	16	9	4.923	0.547	1.895	0.862
	C10	35	8770.092	29	6	3.433	0.572	1.400	0.781
	Total	65.8	83511.772	188	32	11.634	0.364	2.860	0.825
	StDev	22.107	7389.642	16.123	3.393	1.712	0.318	0.772	0.403
All sites	Total	66.9	146632.689	354	42	8.831	0.210	2.115	0.566
	StDev	19.177	6285.016	13.982	1.927	1.579	0.308	0.689	0.384

Table 2. Paired sample t-tests where $\alpha = 0{,}05$.

	Cross-sect. area (mm^2)	Abundance	Species richness	Shannon's index
Mean (Curundú)	2994.786	18.8	5.2	1.873
Mean (Sixto)	2666.494	16.6	3	2.860
Mean difference	328.292	2.2	2.2	2.115
StDev	3940.897	25.944	3.458	0.689
df	0.263	9	2.012	12.43
t	9	0.268	9	0.6592
p	**0.798**	**0.795**	**0.075**	**0.5>P>0.2**

Table 3. Qualitative categorization of sites (derived from site descriptions, Appendix 3).

		Dredging	Light gap	Human disturbance
Río Sixto	S1	0	0	0
	S2	0	1	0
	S3	0	0	0
	S4	0	0	0
	S5	0	0	0
	S6	0	0	0
	S7	0	0	0
	S8	0	0	0
	S9	0	0	0
	S10	0	0	0
Río Curundú	C1	1	0	1
	C2	1	1	1
	C3	0	0	0
	C4	0	0	0
	C5	1	0	1
	C6	1	0	1
	C7	0	0	1
	C8	1	1	1
	C9	1	1	1
	C10	0	1	1

Table 4. Paired sample t-tests results with different site categorization with an α level of 0,05

P Values	Cross-sect. area (mm^2)	Abundance	Species richness
Dredging vs Undistrubed	0.984263	0.852554	0.683293
Human disturbance vs Undisturbed	0.899189	0.877584	0.331305
Light Gap vs Undisturbed	0.803989	0.988596	0.943217

Table 5. Distances and degree of similarity between the various sites for used for the Bray-Curtis analysis. Sites starting with C are along the Curundú and those starting with S along the Sixto. A value of 100 mean total dissimilarity.

Sites	C1	C3	C4	C5	C6	C7	C8	C9	C10	S1	S2	S3	S4	S5	S6	S7	S8	S9
C1	*	100	93.22	85.19	93.75	68.00	100	78.72	100	100	91.89	100	85.45	94.44	100	85.71	100	95.24
C3	*	*	95.12	90.48	100	81.25	100	93.10	85.71	100	96.43	100	100	100	100	91.67	100	100
C4	*	*	*	89.74	100	91.49	100	86.36	100	100	94.37	100	92.31	100	90.91	89.74	100	100
C5	*	*	*	*	96.08	85.51	100	100	100	100	20.43	100	43.24	96.36	51.52	96.72	100	96.72
C6	*	*	*	*	*	90	100	100	100	100	95.45	100	100	100	100	100	100	100
C7	*	*	*	*	*	*	100	82.86	66.67	100	87.10	100	100	100	100	100	100	100
C8	*	*	*	*	*	*	*	100	100	100	100	100	100	100	100	100	100	100
C9	*	*	*	*	*	*	*	*	100	100	100	100	100	100	100	100	100	100
C10	*	*	*	*	*	*	*	*	*	100	97.22	100	100	100	100	100	96.36	95
S1	*	*	*	*	*	*	*	*	*	*	100	33.33	100	100	100	100	100	100
S2	*	*	*	*	*	*	*	*	*	*	*	100	40.30	100	45.76	100	100	100
S3	*	*	*	*	*	*	*	*	*	*	*	*	100	100	100	100	82.22	93.33
S4	*	*	*	*	*	*	*	*	*	*	*	*	*	93.10	20	82.86	100	94.29
S5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	100	62.5	93.55	37.5
S6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	100	100	100
S7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	94.59	54.55
S8	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	89.19
S9	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 6. Coordinates of the various sites in the correspondance analysis

Correspondance	Axis 1	Axis 2
C1	0.465	0.288
C3	0.454	0.932
C4	0.483	-0.192
C5	0.542	-0.837
C6	0.498	0.198
C7	0.434	1.285
C8	0.000	0.000
C9	0.510	0.867
C10	0.284	2.401
S1	-2.681	-0.638
S2	0.550	-0.948
S3	-2.508	-0.424
S4	0.511	-0.964
S5	-0.209	0.229
S6	0.558	-1.113
S7	-0.047	0.110
S8	-1.841	0.303
S9	-0.418	0.427

APPENDIX 2: FIGURES

Figure 1. Correlations between sites' average percent canopy cover and the total cross-sectional area of liana trunks at DBH (as an estimate of biomass), for sites along the Río Curundú, the Río Sixto, and for a pooling of sites along both rivers. Site S3 was not included in this analysis (see Table 1).

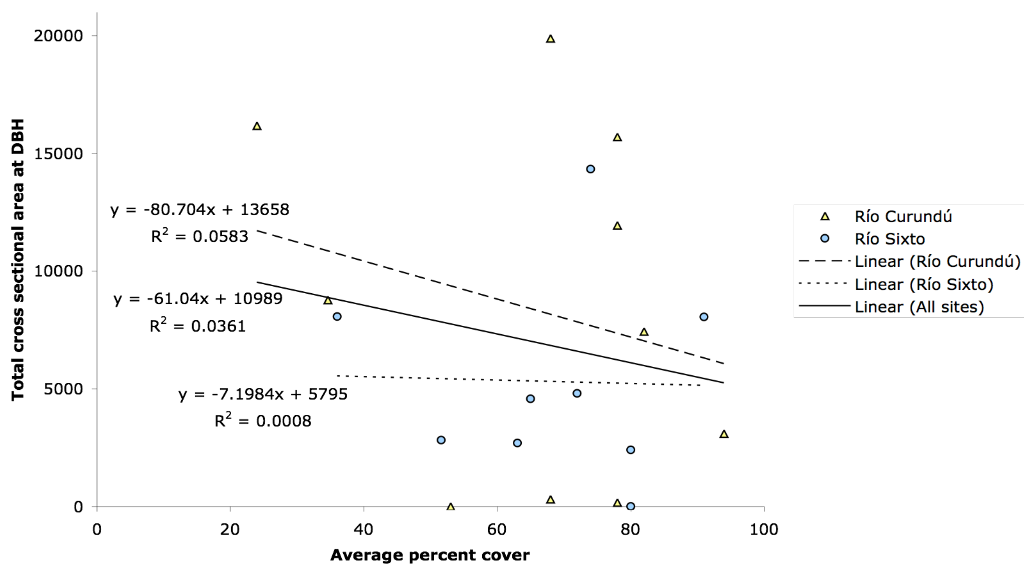


Figure 2. Correlations between sites' average percent canopy cover and liana abundance, for sites along the Río Curundú, the Río Sixto, and for a pooling of sites along both rivers. Site S3 was not included in this analysis (see Table 1).

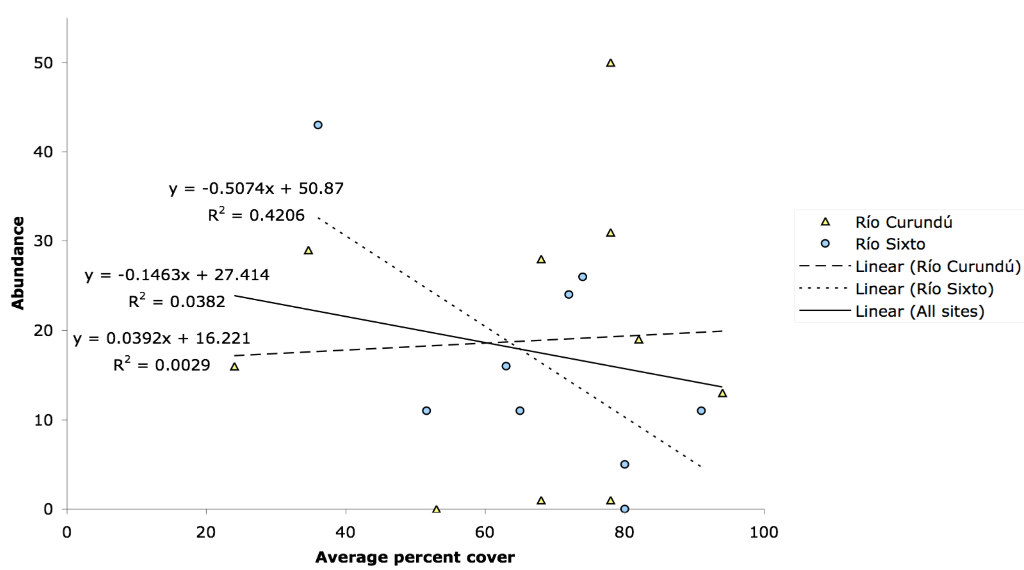


Figure 3. Correlations between sites' average percent canopy cover and liana morphospecies richness, for sites along the Río Curundú, the Río Sixto, and for a pooling of sites along both rivers. Site S3 was not included in this analysis (see Table 1).

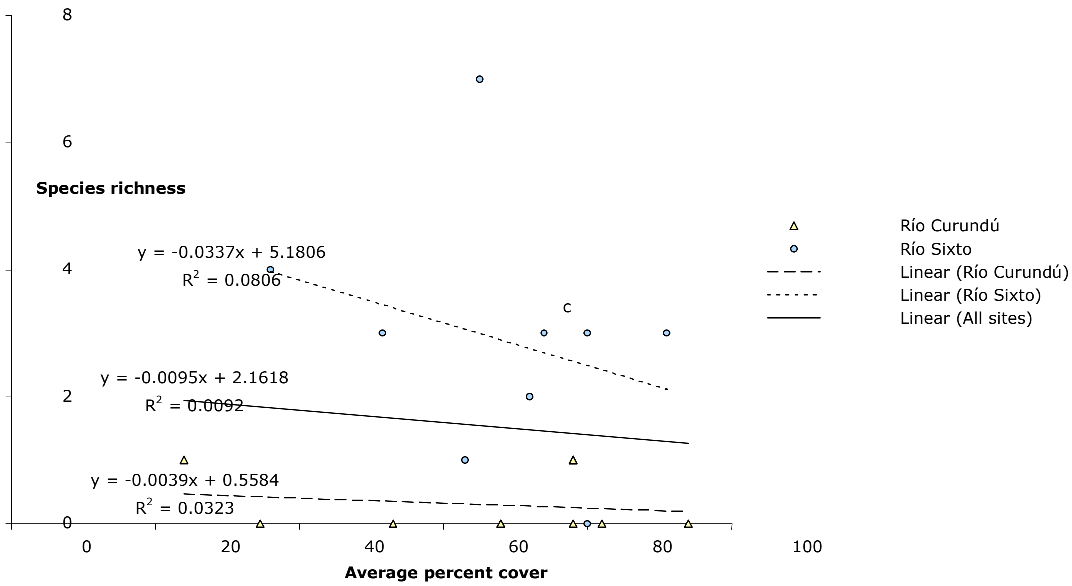


Figure 4. Histogram of total species richness and abundance for sites along each river.

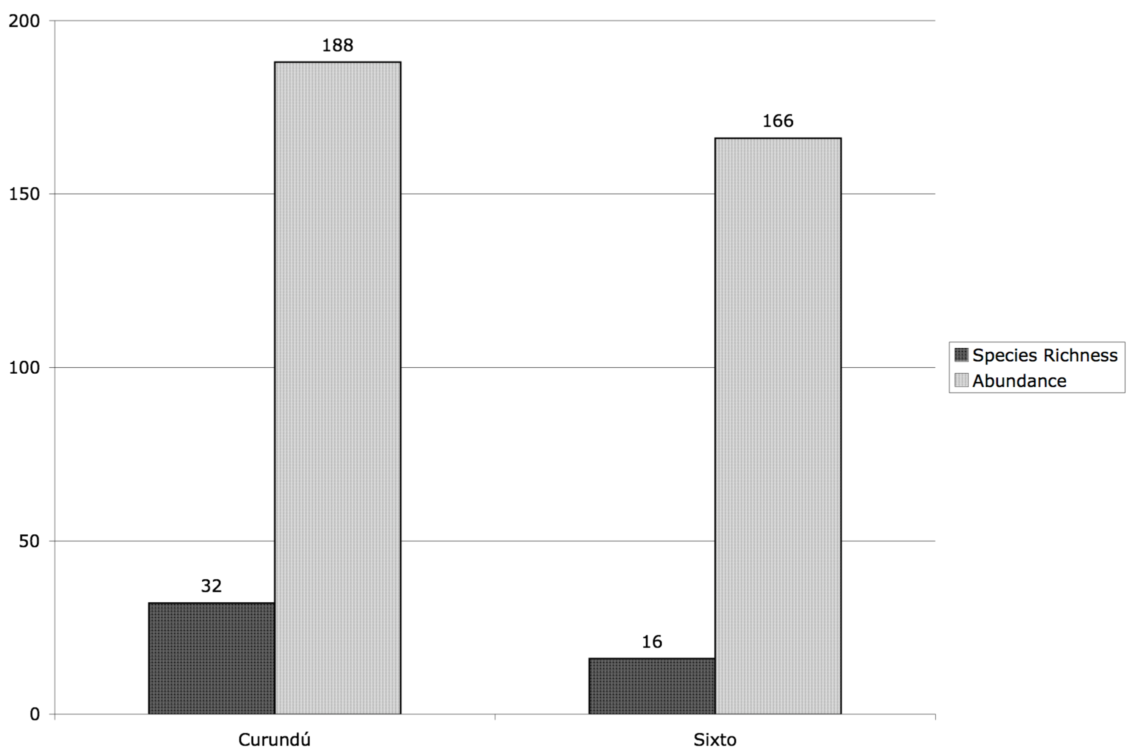


Figure 5. Percent distribution of morphospecies between rivers.

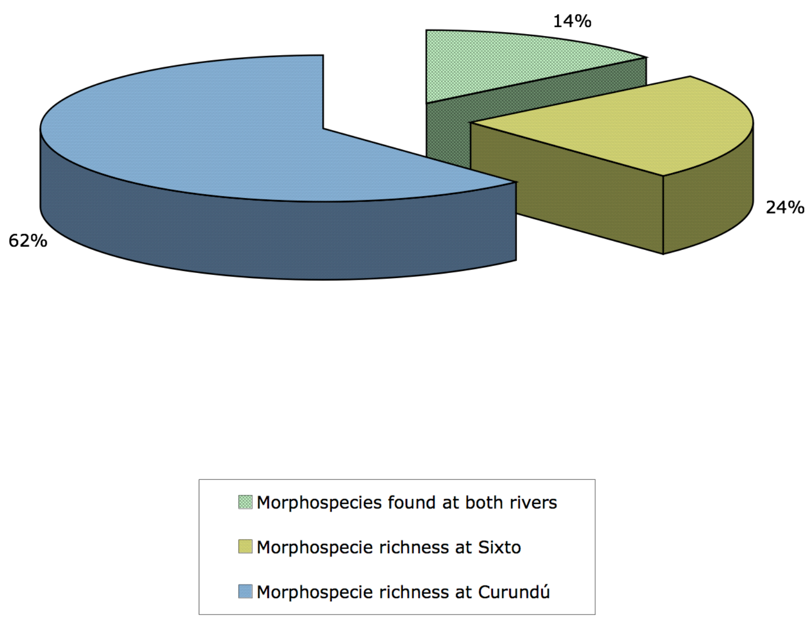


Figure 6. Correspondence analyses showing segregation between Curundú and Sixto liana community composition.

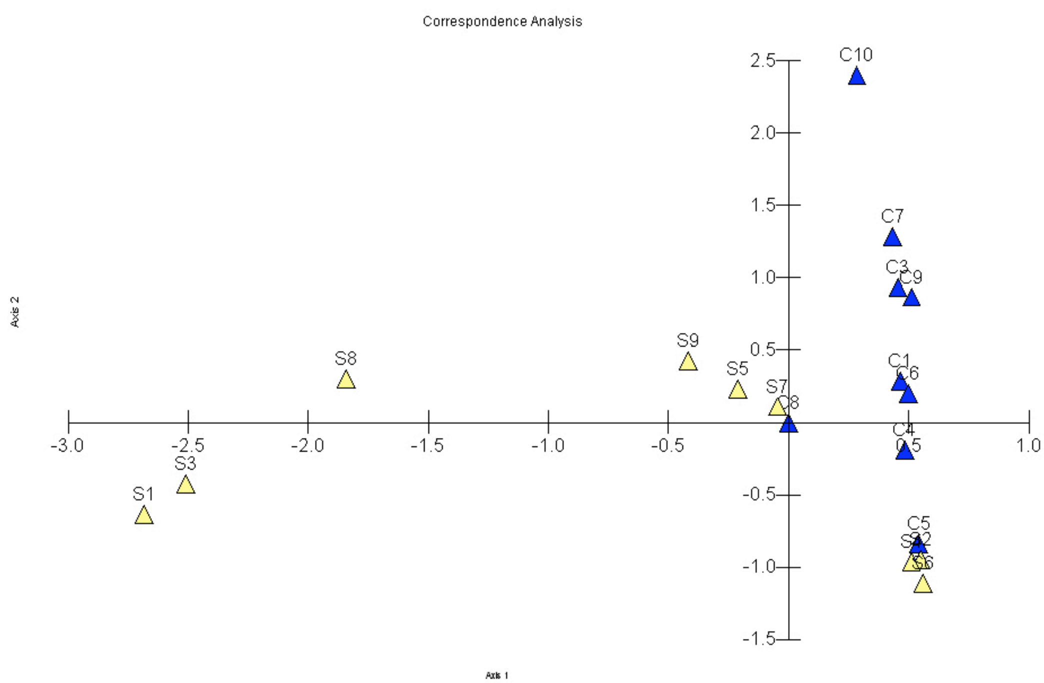


Figure 7. Bray-Curtis cluster analysis diagrams showing the percent similarity between sites.

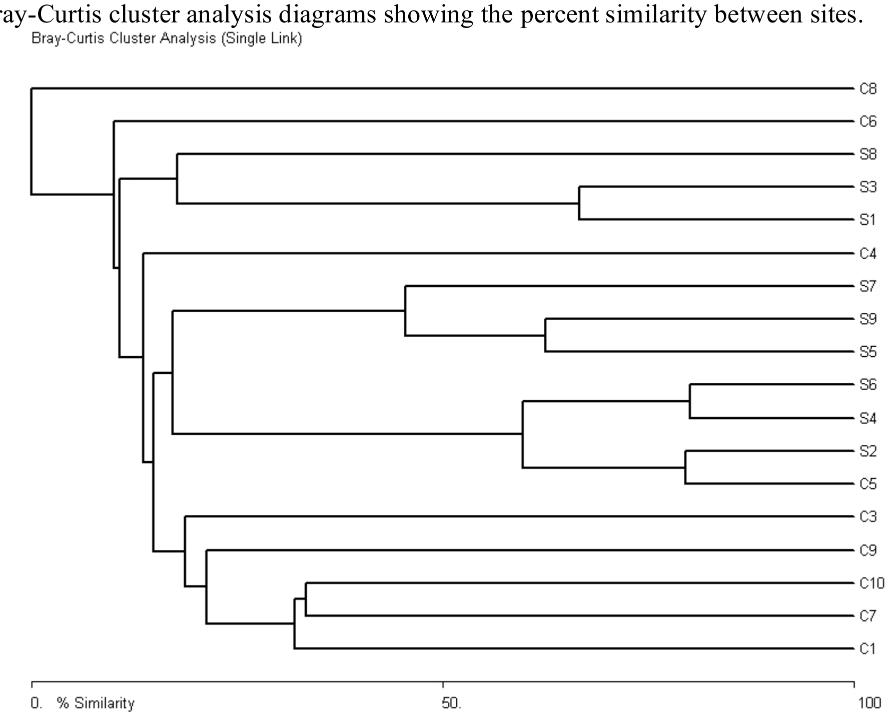


Figure 8. Taxon sampling curves.

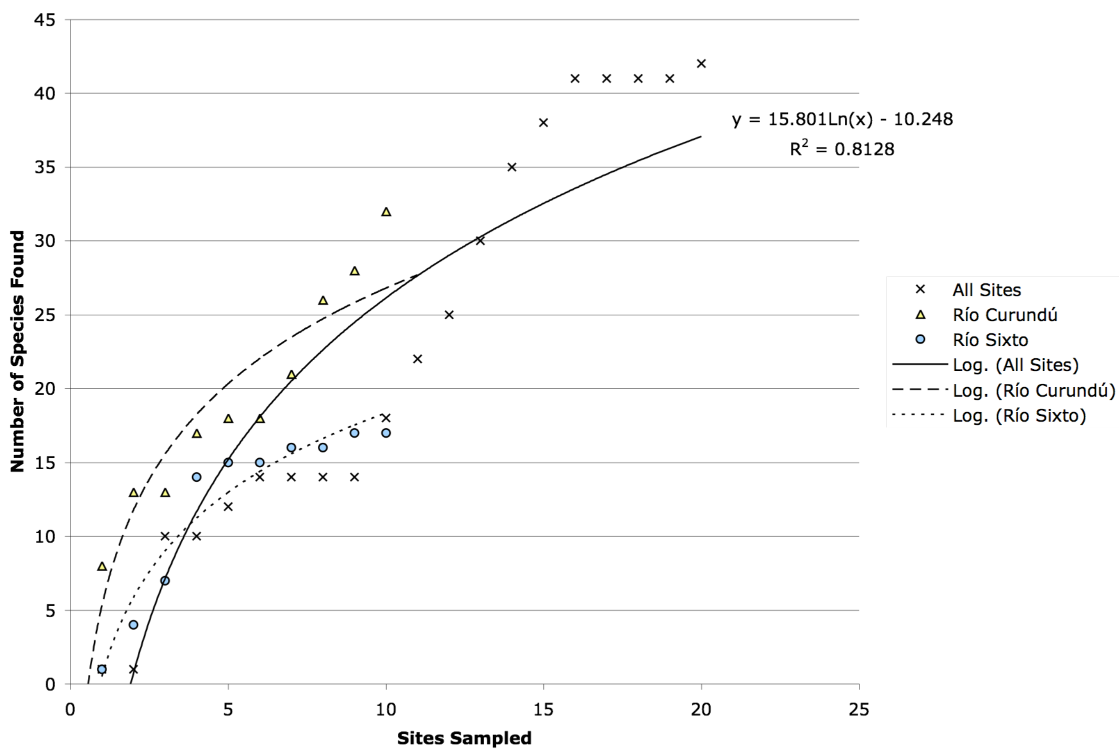


Figure 9. Protected areas of the Panama Canal watershed.

Figure 10. Map of study area, including Parque Natural Metropolitano (outlined in red), Río Curundú and Río Sixto sites (outlined in blue; see Figures 2 and 3 for close-ups of these rivers, respectively).

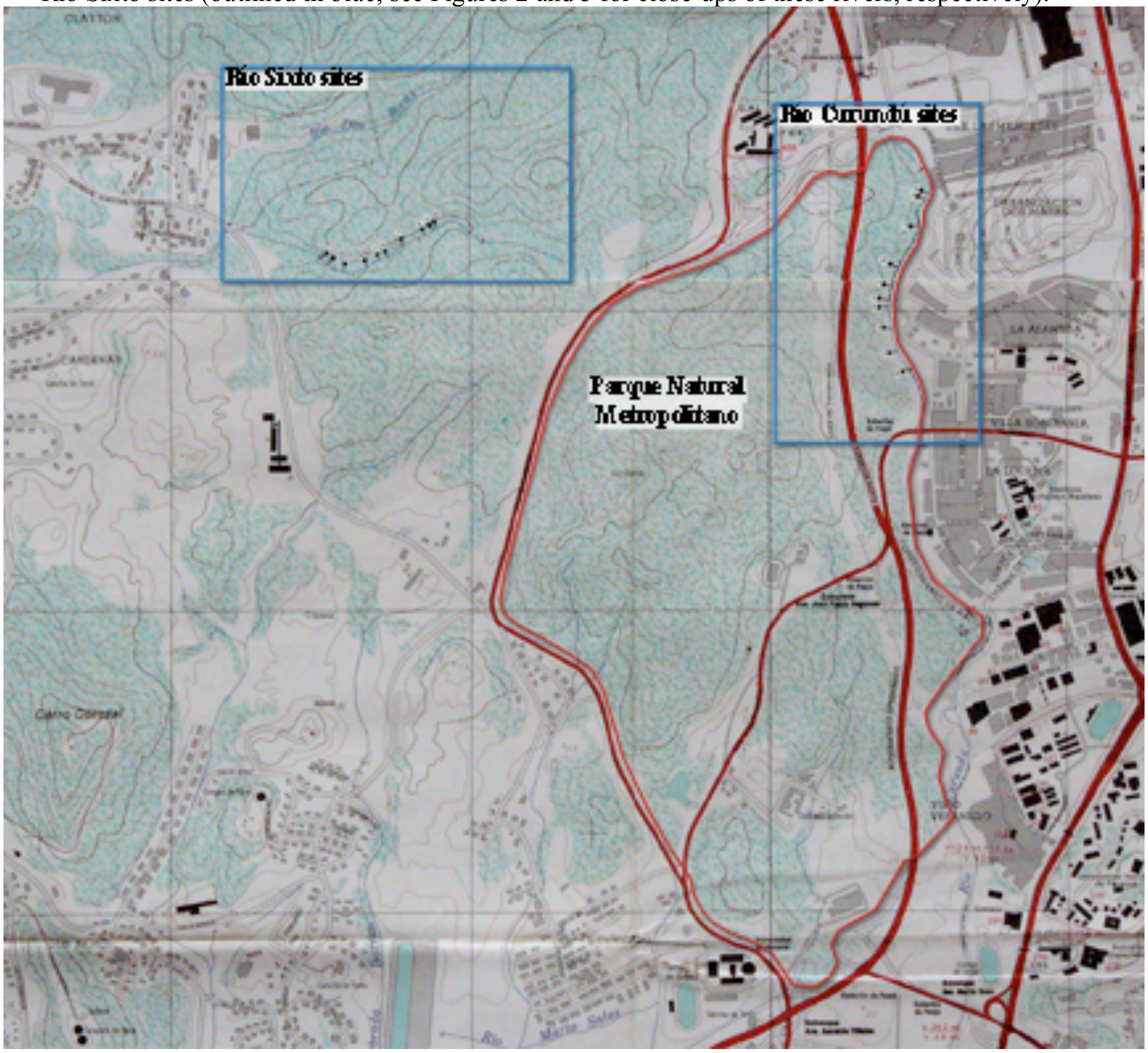


Figure 11. Study area and location of quadrats along the Río Curundú.

Figure 12. Study area and location of quadrats along the Río Sixto.

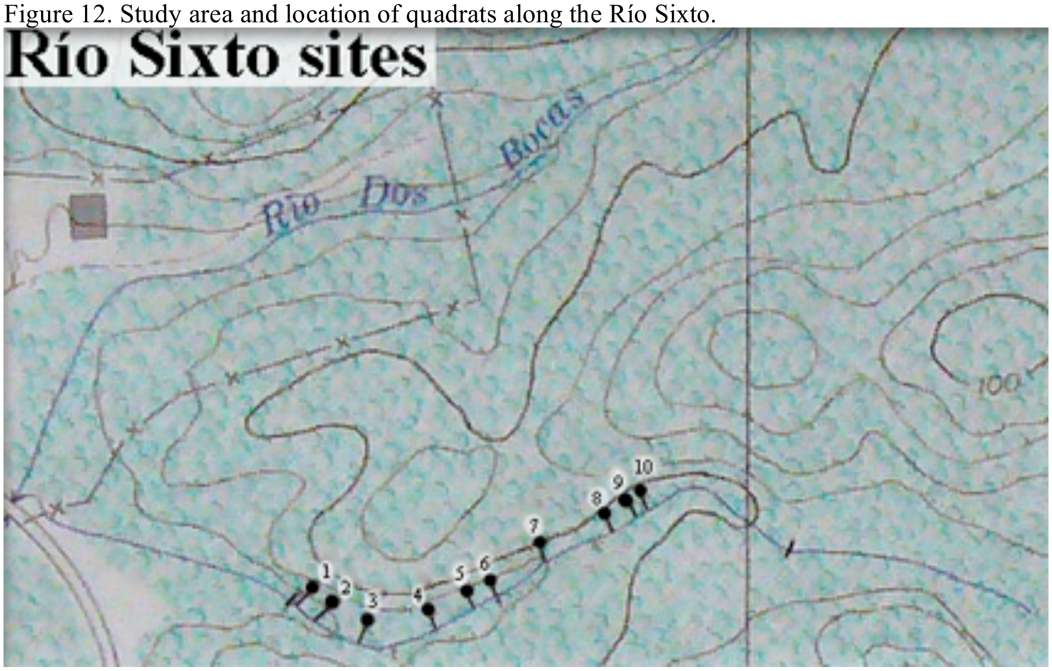


Figure 13. Dredged river bank figure. The color yellow represents fields of *S. spontaneum* growing on the clear and elevated riverbank. The color black represents the location of our quadrates. Notice the small bump representing dropped sediments.

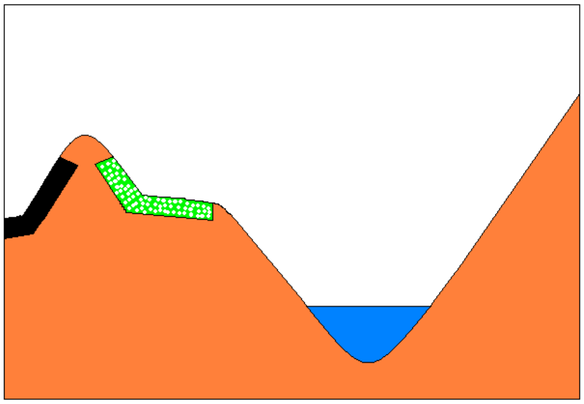


Figure 14. Un-dredged river bank figure. The color black represents the location of our quadrates 1 m away from the forest edge.

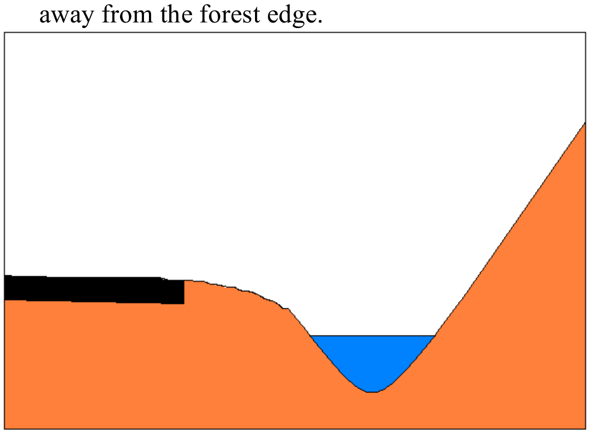


Figure 15. Pollution and unsavoury colour of the Río Curundú, near site C 7.

Appendix 3: Description of Sites

Río Curundú site C 1

280m from Vía Brazil. Sampled 9h30, March 9, 2006.

There were thick patches of bamboo growing in this site; however, the innermost area (that deepest in the forest) had several large trees growing and many saplings. This area had also been dredged and had a high ridge on its bank with a grass layer.

Río Curundú site C 2

360m from Vía Brazil. Sampled 12h00, March 9, 2006.

This site had less grass growing around it, but it had very obviously been dredged and the ground was extremely rocky. Instead of the grass layer, there was a low-lying vegetation layer on top of the high ridge, dominated by heliconias. There was a large dead, uprooted tree stump surrounded by these plants and vines. There were some trees adjacent to the plot providing cover, but inside there were only a few trees, mostly spiny palms, and a dead looking *Indio desnudo*. There were many large, dead lianas scattered about the ground of the site, and none were found alive.

Río Curundú site C 3

840m from Vía Brazil. Sampled 10h00, March 23, 2006.

This site had an abundance of spiny palms. There are a lot of dead branches on the ground, possibly dumped by resident because no evidence of tree fall was noticed. There are about 3 major trees, with their branches and leaves covering the plot. Some bamboos are present. A house was being built on the other side of the river. Cement and/or paint is being dumped into the river, a clear lack of consideration about the environmental impacts; this despite the homeowner's expressed pride in the natural beauty of the park and the construction worker's threats to call the police if we were seen hunting ñeque.

Río Curundú site C 4

857m from Vía Brazil. Sampled 10h00, March 23, 2006

What appear to be residential sewage outlets flow into Curundú directly across from this site. Site seems to have a high density of lianas, and some very large lianas, but understorey is relatively clean. No obvious signs of disturbance, though there is garbage on the banks. Some lianas were found cut (by machetes).

Río Curundú site C 5

463m from Vía Brazil. Sampled 10h30, March 7, 2006.

This site appeared to have been dredged, but no dumping had occurred along the bank, neither was there tall grass lining the bank. Furthermore, the dredging seems to stop about 25m upstream. Here a slight change in our site delineation methods occurred because of the forest edge was changing with the changes in bank form. In the site, ferns form the ground layer, bamboo is less present and liana density is higher.

Río Curundú site C 6

440m from Vía Brazil. Sampled 15h45, March 9, 2006.

Another dredged site, which had concrete mixed in with the dirt that made up the banks. This bank was the highest and steepest of them all and a little stream joined the Curundú just downstream of our site (flowing along the downstream side of our quadrat). A lot of bamboo was present with some tall, thin pioneer trees.

Río Curundú site C 7

746m from Vía Brazil. Sampled 13h30, March 22, 2006.

The site is densely vegetated. Ferns, bamboos and shrub compose most of the understorey vegetation. Accumulation of garbage appears to be a major disturbance. No dredging is observed. Sampling started from the high water mark of the river. A field of tall herbs occupies the other side of the river. No houses are seen.

About 6 big trees in the quadrate and most have kept their leaves. Rattans are observed on the site.

Río Curundú site C 8

513m from Vía Brazil. Sampled 13h30, March 17, 2006.

A very strange site, many dry leaves on the forest floor, such as membrillo, but very low tree abundance. There were several large trees outside the site providing some canopy cover, but the few trees inside the site were completely engulfed in bamboo. Bamboo essentially covered most of the site. Any lianas present were also dead and hard to pick out of all the tangled bamboo thickets. It seems as if this site had been completely cleared out at some point in time. It also represents the upper limit of the dredging.

Río Curundú site C 9

208m from Vía Brazil. Sampled 12h30, February 24, 2006.

This site was a large tree fall gap that probably occurred quite recently. Most of the site area was covered by a thick mat of underbrush - mostly lianas and other vines - entwined around a large fallen tree trunk and the large portion of it that was still standing. There was an extreme density of liana stems, which had obviously been using the fallen tree for support. There were large bits of rusted metal strewn about the site and signs that humans had cut the brush. This section of the river had been dredged and the earth piled on the bank and a large grass thicket was present on the bank.

Río Curundú site C 10

580m from Vía Brazil. Sampled 10h15, March 22, 2006.

Opposite what I assume to be a residential sewage drainage pipe: very smelly. River doesn't appear to have been dredged here: rocky river-bottom and no sign of cutting to the riverbanks.

Early regeneration forest, though bamboo is absent. Trees are thin and fairly dense. Sparse canopy, many leaves on ground. Fairly high liana density, but many are dead or leafless.

Río Sixto site S 1

304m from Río Dos Bocas. Sampled 9h30, March 24, 2006.

Site with many ferns. Decaying matter cover the ground. 2 big palm occupy most of the space. The quadrate is surrounded by some big trees that keep their leaves. On the side of the river, 2 big trees have lianas climbing in them but the lianas' are outside the quadrate.

Río Sixto site S 2

339m from Río Dos Bocas. Sampled 10h00, March 24, 2006.

Gap site, one giant clump of bamboo and other general jungleness. Very high liana density but very low diversity, being almost entirely dominated by shrubby lianas that frequently reroot and are low lying mixed in with the bamboo and often too small to record. The only large tree on the site is dead and covered with lianas, but the rest of the site has little that the lianas have found to clamber up on.

Río Sixto site S 3

395m from Río Dos Bocas. Sampled 10h30, March 25, 2006.

This quadrat was changed to a slightly trapezoid shape because it fell upon the inside of a tight riverbend.

Site has 2 large palms, 3 large trees. Ground has much organic matter (maybe deposited during wet season; appears to be a floodplain), ferns and shrubs. Fairly dense vegetation but not much bamboo.

Río Sixto site S 4

481m from Río Dos Bocas. Sampled 10h00, March 31, 2006.

High riverbank. Still much bamboo. Few trees in site, but there are trees present adjacent to site. Same liana as from last site, small and forms a shrub when nothing to immediately latch onto, again many too small to record.

Poacher's "nest" in a tree on the riverbank.

Río Sixto site S 5

525m from Río Dos Bocas. Sampled 11h25, March 31, 2006.

Densely vegetated site. At one corner there is a big tree with roots that spread throughout the quadrat. Quadrat has many spiny palms and another smaller palm tree. The site is elevated compared to the river.

Part of the site hosts a small tree-fall gap where bamboo grows. A small landslide next to the river, within the edge of the quadrate, left a depression filled with dead branch and leaf litter.

Río Sixto site S 6

553m from Río Dos Bocas. Sampled 12h00, March 31, 2006.

High (maybe 2m) riverbank. Many spiny palm trees present and many of MSpp 25 lianas where palm trees are not so dense or where they are absent. Nonetheless, most of these were too small to measure.

Río Sixto site S 7

609m from Río Dos Bocas. Sampled 13h45, March 31, 2006.

Site characterized by an abundance of bamboos signifying a recent disturbance.

Big tree in the center and other all around the quadrat with branches covering the quadrate. The site is situated in a curve of the river.

Río Sixto site S 8

707m from Río Dos Bocas. Sampled 14h00, March 31, 2006.

Seems to have relatively few lianas, except for one corner, which has various lianas present in a large, dense cluster around a large tree. No obvious disturbances.

Río Sixto site S 9

737m from Río Dos Bocas. Sampled 13h00, April 1, 2006.

Site elevated above the river. One big tree borders the river, spreading its roots throughout the quadrat (protecting a nest of leaf cutter ants). Small palms and some bamboo occupy the rest of the quadrat. Vegetation is relatively thick.

Río Sixto site S 10

750m from Río Dos Bocas. Sampled 14h00, April 1, 2006.

No lianas large enough to record. A few big palms, a giant bamboo stand, and one largish tree are the only things in the site with a very clear understorey.

APPENDIX 4: CHRONOGRAM

Date	Description of the activity	Place*
January		
10	Meeting with *PNM* administration to plan the internship.	*PNM*
19-20, 26-27	Information collection and literature review.	*PNM*/STRI/Clayton
February		
2	Information collection and literature review	*PNM*/STRI/Clayton
3	Visit of the investigation site.	*PNM*
6	Meeting with Stefan A. Schnitzer	STRI
7	Preparation of the work plan & Map collection	Clayton/*IGNTG*
8-9	Preparation of the work plan	Clayton
10	Presentation of the work plan to the Park and discussion	*PNM*
16-17	Preparation of the field material and trial site	*PNM*
23-24	Sampling at Rio Curundú	*PNM*
March		
2-3	Carnaval Week	*PNM*
9-10	Sampling at Rio Curundú, data entry	*PNM*/Clayton
16-17	Sampling at Rio Curundú, data entry, species identification	*PNM*/Clayton
20-25	Sampling at Rio Curundú and Rio Sixto, data entry and species identification	*PNM*/*PNCC*/Clayton
30-1	Sampling at Rio Sixto, data entry and species identification	*PNCC*/Clayton
April		
13-15	Data entry, morphospecies identification, statistical analysis.	Clayton
17-23	Elaboration of the product for the *PNM*, statistical analysis, redaction of final report and preparation for symposium.	Clayton
24	Symposium	STRI

* Index to abbreviations: *PNM*= *Parque Natural Metropolitano*; *PNCC*= *Parque Nacional Camino de Cruces*; STRI= Smithsonian Tropical Research Institute; *IGNTG*= *Instituto Geográfico Nacional* "Tommy Guardia."

Total number of days spent in the field:
13 days X 4 persons = 52 person-days

Total number of days spent in the Ciudad de Saber, working on the project:
20 days X 4 persons = 80 person-days

APPENDIX 5: FACT SHEETS ABOUT LIANAS

¿Qué es una liana?

What is a liana?

- Una planta trepadora leñosa que no puede subir en el dosel sin el soporte mecánico de plantas adyacentes.

  Woody climbers that cannot reach the canopy of the forest without the mechanical support of adjacent plants.

¿Cómo diferenciar las lianas de otras plantas trepadoras?

How to differentiate a liana from other climbing plants?

- La lianas empiezan sus vidas como arbolillos terrestres.

  Lianas begin life as terrestrial seedlings

- Las lianas son leñosas o son fibrosas permanentemente.

  Lianas are woody or permanently fibrous

Características generales sobre las lianas

General facts about lianas

- Las lianas pueden crecer hasta 40 cm de diámetro y hasta longitudes de varios cientos de metros.

  Lianas can grow to more than 40cm in diameter and to length of several hundred meters.

- Usualmente las lianas componen cerca de un cuarto de la abundancia y riqueza de especies del bosque Central Americano.

  Lianas typically account for about a quarter of the abundance and species richness of neotropical forests.

- Cerca de 43-50% de los árboles grandes del bosque tropical sirven de soporte a las lianas.

  About 43-50% of the larger trees of tropical forests have their crown infested by lianas.

- Aunque lianas componen menos de 10% de la masa biológica arriba del suelo, ellas producen hasta 40% de las hojas de los bosques tropicales.

  Even though lianas represent less than 10% of the above ground biomass, they produce up to 40% of the leaves present in the tropical forest.

¿Cómo las lianas crecen hasta la cima de los árboles?

How do lianas climb to the canopy?

- Las lianas pueden crecer hasta una altura de 30-40 cm antes de necesitar un soporte externo.

  Lianas can grow up to 30-40 cm tall before needing external support.

Estrategias para subir

Climbing strategies

- Se rodea alrededor del tronco y de las ramas.

  Branch or stem twining

- Las tendrilas que crecen del tronco, de las hojas y de las ramas.

  Clasping tendrils arising from stem, leaves and branches.

- Se sostienen con espinas.

  Hooking with thorns or spines.

- Raíces adhesivas.

  Adhesive roots

Importancia ecológica de las lianas

Ecological importance of lianas

- Las lianas suprimen la regeneración de los árboles y aumentan sus mortalidades.

  Lianas suppress tree regeneration and increase their mortality

- Las lianas ejercen una presión de selección importante en los bosques tropicales porque compiten con los árboles para la luz del sol, los nutrientes, el agua y son una causa importante de mortalidad.

Lianas exert an important selection pressure in tropical forests because they compete with trees for sunlight, nutrient and water, and are an important cause of tree death.

- Las lianas juegan una función importante en la circulación del agua y de los nutrientes.

  Lianas also play an important role in the cycling of water and nutrients

- Las lianas sirven de hábitat a las especies animales.

  Lianas serve as habitat for animal species

- Las lianas ayudan al movimiento de especies arbóreas.

  Lianas facilitate de movement of arboreal species

- Las diferentes partes de las lianas son un componente de la dieta de especies de primates, aves e insectos.

  Lianas' parts are a component of the diet of primate, bird and insect species

Uncaria Tomentosa

Otros Nombres / Other Names: Bejuco de Agua.

Familia / Family: *Rubiaceae*

Distribución en Panamá: Se encuentra en los bosques tropicales húmedos de la Zona del Canal (la costa Atlántica), Bocas del Toro, Panamá, y Darién.

Distribution in Panama: Found in tropical moist forests of the Canal Zone (Atlantic slope), Bocas del Toro, Panamá, and Darién

Características particulares:

Particular traits:

- Corteza agrietada profundamente, gruesa, marrón oscuro.
  Thick deeply fissured, coarse, dark brown bark
- La corteza en el interior es naranja.
  Inner bark is somewhat orange.
- El tronco más joven es cuadrado.
  Younger stem square
- La parte baja de la hoja es pubescente.
  Lower surface of the blade is pubescent
- Las hojas son elípticas con sus márgenes enteras.
  Elliptic leaves with entire margin
- Produce un fruto bivalvo y oblongo que es dispersado por el viento.
  Produce a bivalve, oblong fruit wind dispersed

Información interesante:

Facts:

- La corteza, las raíces y las hojas tienen utilización terapéutica. Contienen alcaloides y esteroides vegetales que sirven de inmunoestimulante, antiinflamatoria, antirradicales libres, antiviral, desintoxicante y afrodisíaca para los varones
  The bark, roots and leaves have medicinal uses. They contain alkaloids and vegetal steroids that serve as imunostimulant, anti-inflammatory, anti free radicals, antiviral, desintoxicant and aphrodisiac to men.

- Sirve para ayudar curar el cáncer, SIDA, otros virus, problemas gástricos, prevenir problemas de circulación y ataca cardiaca.

  Serve to help cure cancer, AIDS and other viruses, gastric problems and help prevent circulatory problems and heart attack

- Cuando es cortada, es posible tomar el agua que sale del tronco.

  When cut, it is possible to drink water flowing out of the stem.

Paullinia pinnata

Otros Nombres / Other Names: Bejuco de Costilla (rib vine)

Familia / Family: *Sapindaceae*

Distribución en Panamá: Se encuentra En los bosques tropicales húmedos de la Zona del Canal, Bocas del toro, San Blas, Panamá, y Darién.

Distribution in Panama: Found in tropical moist forest in the Canal Zone, Bocas del Torro, San Blas, Panamá, and Darién

Características particulares:

Particular traits:

- Las hojas son compuestas con un pecíolo alado.
  Leaves are compound with a winged petiole.
- Las frutas son capsulas.
  Fruits are capsule.
- El tronco joven está segmentado en 6 partes con espinas y cuando está más viejo está segmentado en 3 partes
  Stem 6-ribbed with spines when young and 3-ribbed without spines when older.

Información interesante:

Facts:

- Llamada “Bejuco de Costilla” porque el tronco joven esta estriado en ángulo con espinas.
  Called “Bejuco de Costilla” (rib vine) because of the green young stem angularly striated with spines.
- Pueden alcanzar una altura de 10 m y de 12 cm o más de circunferencia del tronco.
  May reach 10 m high and 12 cm or more of stem circumference.
- Las semillas son venenosas.
  Seeds are poisonous

- Partes de las lianas están utilizadas en la producción de remedios homeopáticos.
  Parts are used in the production of homeopathic medicine

Esta especie puede ser confundida fácilmente con otro miembro de la familia Sapindaceae *que se encuentra en el Parque Natural Metropolitano*:

This species is easily confused with another member of the Sapindaceae *found in the Parque Natural Metropolitano :*

Serjania cornigera

Distribución en Panamá: Se encuentra en los bosques tropicales húmedos de la Zona del Canal, Colon, y Darién.

Distribution in Panama: Found in tropical moist forests of the Canal Zone, Colon and Darien.

Características distintivas:

Distinguishing features

- El tronco está segmentado en 5 partes.
  Stem 5 ribbed
- Las hojas son biterneta, compuestas, y el pecíolo no esta alado.
  Leaves biternate, compound, and unwinged
- Floración al inicio de la estación seca.
  Flowering at beginning of dry season
- El fruto es una sámara que es dispersada por el viento.
  The fruit is a samara (wind dispersed)

Strychnos panamensis

Otros Nombres / Other Names: Carjura, fruta de murciélago

Familia / Family: *Loganiaceae*

Distribución en Panamá: Se encuentra en los bosques tropicales húmedos de la Zona del Canal, Chiriquí, Coclé, Panamá and Darién. También en bosques secos tropicales de Isla Taboga.

Distribution in Panama: Found in tropical moist forest of the Canal Zone, Chiriqui, Coclé, Panamá and Darién. Also in Tropical dry forest of Panama.

Características particulares:

Particular traits:

- Las hojas tienen 3 nervaduras.
  The leaves are 3-veined
- Tendrilas leñosas y pubescentes.
  Tendrils short-coiled, pubescent and woody
- Las semillas están dispersadas por los mamíferos.
  The seed dispersed by mammals
- Comúnmente cerca de las riveras y menos frecuente en el bosque.
  Common along shores and somewhat less abundant in forest.

Escalera de Mono (Bauhinia spp, Entada ssp.)

Monkey ladder

Familia / Family : Legumaceae

Otros Nombres / Other Names: Sea Heart

Distribución en Panamá: Se encuentra en los bosques tropicales húmedos de la Zona del Canal, Colón, San Blas, Veraguas, Panamá y Darién. También en bosques premontano de Coclé.

Distribution in Panama: Found in tropical moist forest in the Canal zone, Colon, San Blas, Veraguas, Panamá and Darien and from premontane forest in Coclé.

Características particulares:

Particular traits:

- Se rodea alrededor del tronco y de las ramas
  Twining
- El tronco más viejo esta delgado y regularmente doblado.
  Older stem flattened and regularly folded
- Producen semillas en forma de corazón que flotan sobre las corrientes oceánicas del mundo y que pueden sobrevivir hasta algunos años.
  Produce heart-shaped seeds that ride the ocean current of the world and can survive up to several years

Información interesante:

Facts:

- Crecen muy rápidamente, más de 30 m en 18 meses.
  Grow very fast – more than 30 m in 18 months
- Tienen la vaina más grande de todas las leguminosas.
  Longest bean pod of any legumes
- Proveen a monos, lagartos, serpientes, y perezosos de un puente en las alturas que conecta los árboles.

Provide monkeys, lizard, snakes and sloths with a high bridge that connects the trees together

- Las semillas han servido de cajas de tabaco y de cerillas en Noruega y de instrumento de música en otras partes del mundo.

  The seeds have been used as deluxe snuff or matches boxes in Norway and of musical seed shaker in other part of the world.

- Características medicinales: alivia la inflamación, enfermedades del riñón, constipación, mordeduras de serpientes y pueden servir para contracepción o como un afrodisíaco.

  Medicinal characteristics: relieve inflammation, kidney diseases, constipation, snake bites and can be used for contraception, and as an aphrodisiac.

- En Noruega, se usa como un te amargo que alivia los dolores durante el parto.

  In Norway a bitter tea was made from the seeds to relieve the pains during child birth

- Las partes de las raíces y del tronco pueden ser maceradas en el agua para producir un líquido usado como un jabón o shampoo.

  When parts of the roots and the stems are macerated into water it produces a liquid that can be used as soap and shampoo.

- En Inglaterra las semillas se usaban para hacer anillos y encantos para los marineros que embarcaban en un largo viaje porque se creía que si las semillas sobrevivían el viaje a través del océano, quizás protegerían a su dueño durante el viaje.

  In England the seeds are used to make rings and good luck charm for sailors embarking for a long journey because it was believe that if the seed could survive the travel across the sea, perhaps it could protect his owner during his trip.

Doliocarpus sp.

Familia / Family : *Dilliniaceae*

Distribución en Panamá: Se encuentra en los bosques tropicales húmedos de la Zona del Canal y Darién. También en los bosques pre montaño de Colón y Darién.

Distribution in Panama: Found in tropical moist forest in the Canal Zone, Darién and from premontane forest in Colón and Darién.

Características particulares:

Particuliar traits:

- Lianas leñosas con tallos gruesos usualmente mayores de 30 cm de circunferencia

  Woody liana with circumference growing up to around 30 cm.

- Hojas simples, no ásperas al tacto, alternas, dentadas o enteras, glabras o con pubescencia

  Simple leaves, alternate, non-asperous to the touch, entire or serated margin, glabrous or pubescent.

- Dos especias de *Doliocarpus* se encuentran en el Parque Natural Metropolitano: *D. Major* caracterizado por hojas elíptica y *D. Olivaceus* reconozca por su fruta dehisento.

  Two species of Doliocarpus are commonly found in the Parque Natural Metropolitano: *D. Major* characterized by elliptic leaves and *D. Olivaceus* recognized by its dehiscent fruits.

APPENDIX 7: GUIDELINES FOR THE EDUCATIONAL GAME

ACTIVIDAD PARA REALIZAR CON UN GRUPO DE NIÑOS SOBRE LAS LIANAS.

Material: no es necesario material.

Tiempo: Alrededor de 5 a 10 minutos cada sesión, dependiente del nombre de niños.

Organización: Todos los niños deben estar cercas uno de los otros y en un circulo
***si el grupo es muy grande deben hacer 2 o 3 equipos diferentes.

Desarrollo de la sesión

1- Para crecer las lianas necesitan un suporte externo (explicar los diferentes estrategias para subir en los árboles).
   Los niños deben tomar las manos de dos niños diferentes que no sean sus vecinos en el círculo.

2- El tronco de las lianas es muy flexible y permite subirse en la altura. También algunas veces, bajan cerca del suelo y hacen otras raíces para cosechar más nutrientes y agua del suelo.
   Sin separarse los niños deben tratar de desenredar sus manos. Al momento de dar la instrucción de alto, se le preguntará a los niños como se sienten (las lianas son más flexibles que los humanos!!!!). Además, cuando un niño debe deslizarse a nivel del suelo para cambiar de posición, se le debe explicar que las lianas pueden bajar y tener muchas raíces.

3- El resultado es siempre el mismo: un circulo o dos círculos entrelazados.

APPENDIX 8: EDUCATIONAL BOOKLET

Page 1:

¡Descubran las Lianas!

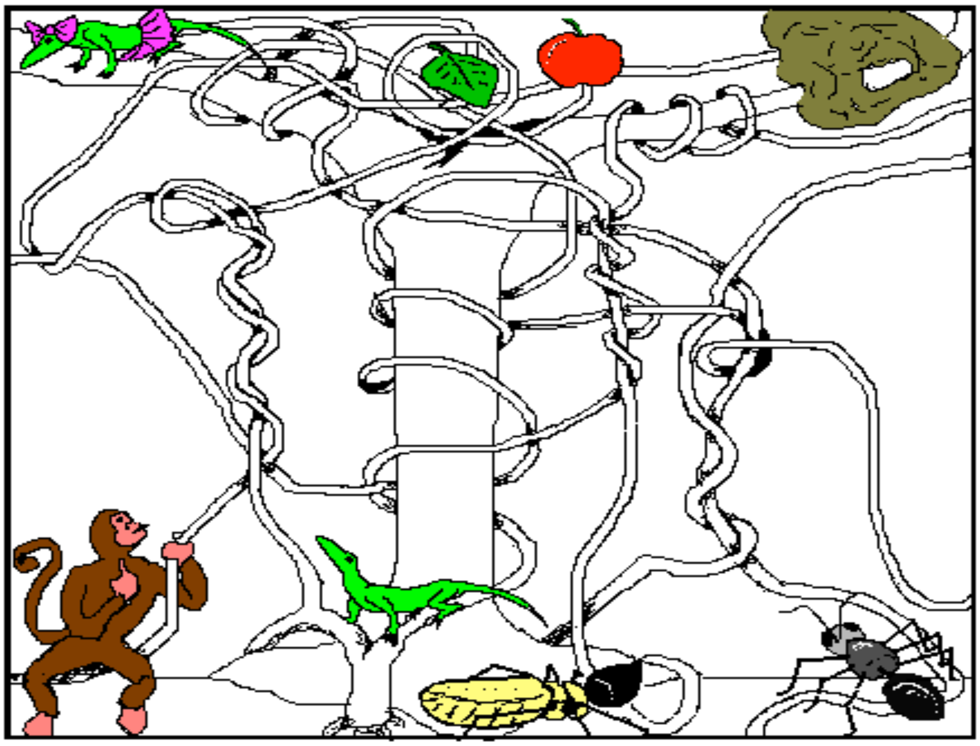
¿Qué son lianas?

Una planta trepadora con madera que no puede subir a la cima de los árboles sin el soporte de otras plantas y empieza su vida en el suelo.

¡Nadie me había dicho que las lianas tenían RAICES!

La Importancia de las Lianas en los Bosques Tropicales

Ayudan al mono a buscar su comida, a la termita a ir a su nido, al lagarto a encontrar a la lagarta, y a la hormiga a cosechar una hoja.



Importancia de las lianas para los animales

Sirven de hábitat a las especies animales como las termitas.

Ayudan al movimiento de especies que viven en los árboles como los monos.

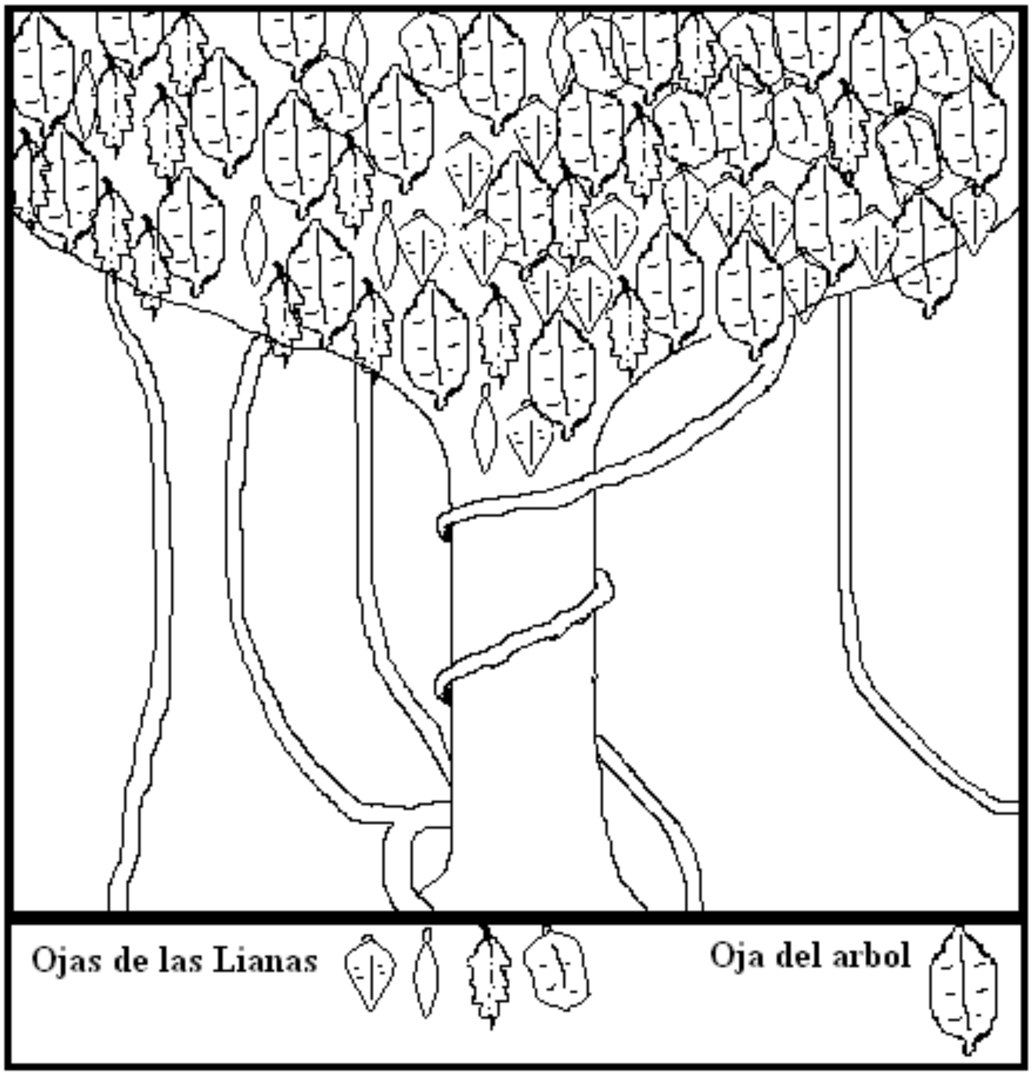
Las diferentes partes de las lianas son una componente de la dieta de especies de primates, aves e insectos.

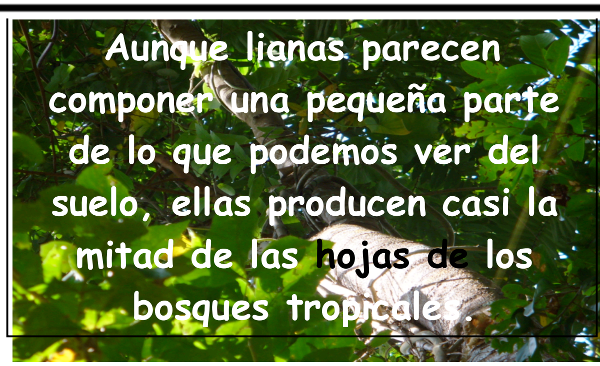
¿Saben Qué?

En los Bosques Tropicales, las lianas representen cerca de 25% de las especies vegetales presentes.

Page 3

Coloreen los diferentes tipos de hojas de diferentes colores: Hojas de lianas en verde y el del árbol en amarillo.





¡Protegen la Natura y su Ambiente!

Las lianas son frágiles, como el ambiente. Para protegerlas y que todos pueden disfrutar del ambiente, debemos cuidar de la natura.

Aquí están algunos gestos que podrían hacer para mejora la cualidad de su ambiente:

Botar las basuras en los botes.

Reducir su consumo de papel, plástico y vidrio.

Reutilizar los contenidos de plásticos o de vidrio.

Reutilizar las bolsas de plásticos.

Parque Natural Metropolitano

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