

September 1999

Vegetative fragmentation within two microhabitats along an altitudinal gradient in the Monteverde cloud forest, Costa Rica

Emily Leamy

Follow this and additional works at: https://digitalcommons.usf.edu/tropical_ecology

Recommended Citation

Leamy, Emily, "Vegetative fragmentation within two microhabitats along an altitudinal gradient in the Monteverde cloud forest, Costa Rica" (1999). *Tropical Ecology and Conservation [Monteverde Institute]*. 679.

https://digitalcommons.usf.edu/tropical_ecology/679

This Book is brought to you for free and open access by the Monteverde Institute at Digital Commons @ University of South Florida. It has been accepted for inclusion in Tropical Ecology and Conservation [Monteverde Institute] by an authorized administrator of Digital Commons @ University of South Florida. For more information, please contact digitalcommons@usf.edu.

Vegetative Fragmentation Within Two Microhabitats Along an Altitudinal Gradient in the Monteverde Cloud Forest, Costa Rica

Emily Leamy

Department of Biology, James Madison University

ABSTRACT

Reproduction by vegetative fragments of cloud forest plants was studied at Monteverde, Costa Rica. The relative frequency of reproduction via seeds and plant fragments was quantified on trail edges and in forest understories, along an elevational and east-west gradient encompassing the Continental Divide. The proportion of young plants that originated from fragments in the understory increased with elevation and on the east-facing slope. A similar trend was found along the trail edge, with the highest proportion of fragments at the Continental Divide. The diversity and composition of plants that reproduce via fragmentation was compared among three sites (west-facing, Continental Divide, and east-facing). No significant species diversity overlap was found using the Sorenson quantitative index, and a modified t-test showed no significant differences in diversity between each of these three sites. Occurrence of fragmentation is related to levels of wind, moisture, sunlight, nutrients, density of the understory, terrain, and decomposition rates of specific sites and elevations.

RESUMEN

Se estudio la reproducción por partes vegetativas de la planta (fragmentas) en el Bosque Nuboso de Monteverde, Costa Rica. Se cuantifico la frecuencia relativa de reproducción para las semillas y fragmentos de plantas en los bordes de senderos y en el sotobosque, a lo largo de un gradiente de elevación en la División Continental. La proporción de plantas jóvenes que se originaron de fragmentos en el sotobosque aumento con la elevación y en la area este. Una tendencia similar se encontro a lo largo del sendero, con la proporción mas alta de fragmentos en la División Continental. La diversidad y composición de plantas que se reproducción vía fragmentos fue comparada entre tres sitios (Lado Oeste, División Continental, y Lado Este). No se encontro diferencia significativa entre la diversidad de especies entre los tres sitios ($p < 0.05$). El índice de Sorenson fue utilizado para ver similitudes y no se encontro diferencia tampoco ($p < 0.05$). La ocurrencia de fragmentos es relacionado con los niveles de viento, humedad, luz, niveles de nutrientes, densidad del sotobosque, terreno, y el grado de descomposición de los sitios específicos y elevaciones.

INTRODUCTION

The ability of Plants to regenerate from vegetative fragments is reportedly rare taxonomically and biogeographically. Fragmentation (rooting and establishment from vegetative fragments severed from parent plants) is observed in only a handful of temperate willows (*Salix spp.*) and some aquatic and shoreline plants broken from storms and water (Kinsman 1990). Fragmentation of tropical wet forest trees is reportedly rare, but may be a common method of regeneration and multiplication of understory plants in tropical wet forests (Kinsman 1990). Cloud forests provide favorable conditions for fragmentation to occur, with frequent disturbances and ample moisture in the air and soil. Various disturbances such as wind, tree falls, broken limbs, and falling lianas and epiphytes can damage understory forest plants (Kinsman 1990). Consequently, vegetative reproduction may be an important mode of survival for understory plants in areas with high disturbance (Gartner 1989), where the cost of breakage in a population is offset by the regeneration of fragments.

There have been a few studies performed on fragmentation in tropical wet forests. The ability of 22 species of neotropical montane forest shrubs to regenerate from fragments was studied over a five year period in the Monteverde Cloud Forest Preserve, Costa Rica, and it was found that 14 of these species persisted through all five years of the study (Kinsman 1990). Gartner documented the extent of stem breakage, frequency of vegetative reproduction, and ability to regrow from pinned branches for 16 species of Piper (Piperaceae). It was found that the majority of individuals sampled had at least one broken branch, more than 40 percent of the sampled plants originated vegetatively, and most of the pinned branches survived and produced adventitious roots within approximately three weeks (1989). The frequency of vegetative propagation in *Poikilacanthus macranthus* was studied along an altitudinal gradient in the Monteverde cloud forest, Costa Rica, and it was observed that the great majority of individuals sampled originated from fragments as opposed to seeds (Bush 1993).

This study was designated to inventory young plants in two types of microhabitats, understory and trail edge, along an altitudinal and east-west gradient in the Monteverde cloud forest, to determine whether they originated from seeds or fragments, and to identify these plants taxonomically. The relative frequency of fragmentation is expected to increase with elevation due to windier conditions at higher elevations. These conditions could cause more frequent breakage, and combined with the presence of higher amounts of moisture in the air and soil could facilitate fragmentation. Trail edge sites are expected to have a higher amount of fragmentation than understory sites of the same elevation due to higher disturbances along trails because of additional traffic. It is also expected that there will be a higher richness of species able to regenerate by fragmentation in areas with higher disturbance. This is because they are better adapted to living in areas conducive to fragmentation when compared to non-fragmenting species, which would be at a disadvantage in harsher conditions where they would be prone to frequent breakage.

MATERIALS AND METHODS

The occurrence of fragmentation was investigated in the cloud forest at La Estación Biológica in Monteverde, Costa Rica from October 21 to November 18, 1999. The Monteverde cloud forest is mainly aseasonal and evergreen, receiving approximately 3m of rainfall annually. Wind-borne mists and cloud cover are brought in from the Atlantic to the east-facing slopes during the dry season, contributing to the consistent input of moisture year round (Haber et al. 1996). The Atlantic side of the cloud forest has two more months of wet season than that of the Pacific side, and receives two times the annual rainfall. Trade winds blow year round, and are the strongest along the continental divide. The cloud forest on the Pacific slope, beginning around 1500m, consists of dense forest with tall straight trees having a canopy of 20-35m, and is classified as a lower montane wet forest life zone according to the Holdridge classification. At higher peaks and on the upper Atlantic slope, the cloud forest canopy is lower (15-20m) and more broken due to exposure to the strong north east trade winds and seasonal wind storms. This area is known as the elfin forest, and is classified as lower montane rain forest by Holdridge. The uneven canopy and many treefalls here provide sufficient light for a dense understory layer (Haber 1996).

Four separate elevations along the mountain within the cloud forest were selected for this study. Two were on the Pacific slope at approximately 1540m (Pac.) and 1760m (Pac), another was on the ridge of the continental divide in the elfin forest at 1810m (Ridge), and one was on the Atlantic slope in the elfin forest at 1790m (Alt.). Within these elevational bands, sampling was conducted separately on the trail edge and at least two meters off the trail in the forest understory, for a total of eight sites sampled. Understory sites within each elevation were chosen based upon the presence of seedlings, full overhead canopy coverage, and no evidence of recent treefalls within the collection area. Trail edge sites were selected for the same criteria as well as having similar amounts of use, as seen in the condition of the trails.

Within each site, young plants ($n= 156-216$) greater than 3 cm in height were collected and identified as having originated from seed or fragment. Seedlings from fragments can be identified by a characteristic L-shape or by the presence of a callous ring at the root/stem junction, which is absent in sexually produced plants (Kinsman 1990). Seedlings were then sorted into different morphospecies, and representatives were either pressed or freshly refrigerated for taxonomic identification.

To analyze the ratio of plants originating from seeds or fragments collected in each site of elevation, a one-sample chi-squared test for goodness of fit against a random input of seeds and fragments was used. The ratio of plants originating from seeds to fragments between elevations for the same microhabitat, as well as between microhabitats of the same elevation, was analyzed in a 2x2 contingency table with a chi-squared test. The Sorenson quantitative index for diversity, $CN = 2jN / aN + bN$, was used to test similarity of species composition of the families and species of fragments collected and identified from trail sites of 1760 Pac, 1810 Ridge, and 1790 Atl. In elevation (Magurran 1988). A modified t-test, $t = (H'_1 - H'_2) / s (H'_1 - H'_2)$, was also used

to test differences between two diversity indices of the total species diversity observed at the aforementioned sites (Zar 1984).

RESULTS

A total of 1434 plants from the eight sites were collected and their origins (seed or fragment) identified (Table 1). A one-sample chi-squared test for the ratio of plants originating from seeds to fragments in each site of each elevation revealed that these ratios were significantly different from random (50: 50) in all sites but the trail edge habitats at 1790 Atl. and 1810 Ridge (Table 2). Chi-squared values of the contingency tables for the ratio plants originating of seeds to fragments of the same habitat but different elevations were significant for all 12 tests (Table 3). Chi-squared values of the contingency tables for the ratio plants originating from seeds to fragments of the same elevation but different habitat were significant for all four comparisons (Table 4). There were strong trends seen in the proportion of collected plants originating from seeds or fragments for the trail edge and understory habitats along an altitudinal gradient, indicating that an increase in the proportion of fragments may be related to an increase in elevation, with the greatest proportion of fragments at trail sites at 1810 Ridge (Figure 1) and understory sites at 1790 Atl. (Figure 2).

Of the total number of plants collected, 62% were identified (63% of those originating from seeds and 59% of those from fragments) to species or family (see Appendix 1 and 2). Different numbers and proportions of plants from the eight sites were identified, due to conditions of certain plants and techniques of preservation, as well as time constraints. Because of this, the diversity of the three sites (trail edge habitats at 1760 Pac., 1810 Ridge, and 1790 Atl. Elevations) having the greatest amount of plants from fragments identified were used in statistical analyses for species diversity. The Sorenson quantitative index for diversity of family-level taxa revealed that the trail sites at 1810 Ridge and 1790 Atl. Had the highest level of family overlap, while the trail sites at 1760 Pac. and 1790 Atl. showed the least amount of overlap (Table 5). At the species-level, the Sorenson quantitative index showed a similar trend of overlapping as that in the family-level, but sites (Table 6). The modified t-test showed that there was a significant difference in the diversity indices between all pairwise comparisons of sites (Table 7).

DISCUSSION

Many factors need to be considered in order to understand the differences in the occurrence of fragmentation at various elevations and different habitats in the cloud forest. First, the conditions that affect the input, removal, and germination of seeds and fragments must be recognized. The germination and establishment of both seeds and fragments depend upon nutrient availability, moisture levels, and sunlight. Input of seeds is related to disperser actions, the season and fruiting time periods of angiosperms, as well as their relative density. Fragment input is related to disturbances, such as wind and treefalls. Branches and other plant parts get broken off due to wind, and then have the

capacity to become established on the forest floor. The removal of seeds can be due to various factors, such as dispersers, predators, water, and the slope of the terrain, while fragment removal is mainly due to rotting before the fragment can become fully established.

The establishment of fragments at different elevations should be affected by multiple factors. Wind is greatest at the highest elevations and on the Atlantic side, due to the year round blowing of trade winds from the Atlantic Ocean (Haber et al. 1996). This creates a much higher disturbance level at these elevations and orientation, resulting in a greater input of fragments than at lower, more protected elevations on the Pacific slope. Moisture levels are also significantly greater at higher elevations, specifically in the elfin forest (Mullen 1997), where the leaf litter dries out only a few days a year (Haber et al. 1996). Ample moisture in the elfin forest provides a much more conducive environment for fragmentation than at lower elevations. Sunlight levels should also be greater at higher elevations, due to the more open canopy in the elfin forest (Haber et al. 1996). Further, there is higher nutrient availability in the elfin forest, because the silty clay-loam soil type found there is better for holding water and nutrients than types found at lower elevations (Robinson 1997; but see Mullen 1997 who did not detect this difference). The density of understory is significantly greater in the elfin forest than at lower elevations in the cloud forest (Mullen 1997), because the uneven canopy and many treefalls allow more light to reach the lower layer of plants (Haber et al. 1996). The terrain at lower elevations is steeper than that of the flat ridge area of the continental divide, which may have a greater impact on the establishment, input, and removal of seeds and fragments at lower elevations, but this has not been measured in the cloud forest. Finally, there is a greater potential for rotting of fragments before establishment at the higher, wetter elevations of the elfin forest, since this area may exhibit higher decomposition rates due to greater moisture and fungi density.

The occurrence of fragmentation in the cloud forest increases as expected, with elevation in both trail edge and understory habitats. Further, the proportion of fragment originated plants continued to increase on the Atlantic slope for the understory sites. This supports the prediction that as disturbance and moisture increases with elevation, so does vegetative fragmentation. The trend of fragmentation increase for trail sites was slightly different than that of the understory, but still exhibited an increase in fragmentation relative to elevational increase. The highest amount of fragmentation for trail sites was in the elfin forest along the continental divide, as opposed to the elfin forest on the Atlantic slope for the understory sites.

Factors that contribute to fragmentation along an altitudinal gradient may be responsible for the differences in the increased fragmentation on trail edges. Wind may be higher along trails if the canopy is more open. Moisture levels are expected to be of a more consistent volume in the understory than on the trail. The trail would be expected to have higher and inconsistent volumes of water due to a river-effect, which is when high volumes of water wash down sloped terrain. This often occurs on trails because they are already carved out of the terrain. However, because trails may receive higher levels of sunlight with a more open canopy than the understory, this may cause moisture to dry out

faster on trail edges than in the understory. The terrain of trail edges commonly contains mini canyon-like areas formed by the higher volumes of water flowing through or across the area, which should make trails less conducive for plant establishment. Understory habitats should exhibit higher decomposition levels than that of trail edges of the same elevation, because of higher and more consistent levels of moisture, greater amount of leaf litter, and less sunlight, which together promotes rotting of fragments before they can become established. Nutrient levels are lower at trail edges than in the understory due to greater traffic, which causes soil compaction as well as top soil loss (Holmes 1997). Lastly, the density of understory plants is lower along trail edges and increases as one move off the trail into the understory, due to a decrease in traffic-related disturbances (Holmes 1997).

It was predicted that trail edge sites would show a higher relative abundance of fragmentation than in the understory sites of the same elevation, but this was not observed for all four elevations. The proportion of plants originating from fragments collected at 1540 Pac, and 1810 Ridge sites was higher for trail edge sites than understory sites, but not for the 1760 Pac, and 1790 Atl. Sites. However, the proportions of fragments collected at the 1540 Pac, and 1810 Ridge sites along the trail and in the understory were nearly equal, whereas the trail and understory sites at 1760 Pac, and 1790 Pac, and 1790 Atl. Differed greatly. This may suggest that at the 1760m sites on the Pacific slope, which would have a lower level of disturbance and moisture than the higher elfin forest elevations, the understory may provide a more favorable environment for fragment establishment than the trail edge. This could possibly be due to higher moisture, nutrients, and density of understory plants, despite having a higher rotting potential, lower sunlight levels, and less wind. Similarly, it is possible that at the 1790m Atlantic slope sites, the understory may contain more moisture, nutrients, and density of understory plants, along with having the greatest disturbance level at this elevation. This would provide better conditions for fragmentation than at the trail edge site of the same elevation. Further, the Atlantic slope trails are used much less frequently than those of the Pacific slope and continental divide in the cloud forest at La Estación Biológica, which may contribute to the relatively low values of fragmentation in the trail site compared with the understory site of that area. This is because trails with greater usage should have a higher disturbance level than trails used less frequently.

The relative abundance of fragments and seedlings differ significantly between all sites, suggesting that fragmentation rates vary on small geographic scales. Predictions of higher levels of fragmentation at certain locations can be supported by the careful examination of the factors that contribute to fragmentation. In areas with greater conditions for fragmentation, such as the elfin forest along the ridge and on the upper Atlantic slope, it should be expected that there would be a wider variety of species that exhibit fragmentation, because they are better adapted to living in high moisture and high disturbance-level environments. These species may still exist at lower elevations where disturbance and moisture is lower. However, at these elevations they may not be able to successfully fragment and establish, either due to a lack of disturbance to create fragment input or due to moisture levels too low to provide adequate conditions for growth.

Species richness within each site proved to be more difficult to inventory than originally expected due to difficulties associated with identifying young plants. Comparisons between three trail edge sites of different elevations (1760 Pac., 1810 Ridge, and 1790 Atl.) revealed that there were significant differences in species diversity between these sites. However, in ranking species richness of these sites, it can be seen that species richness increased with disturbance levels, being lowest at 1760m and highest at 1790m on the Atlantic slope, which has the greatest level of disturbance of elevations studied (Table 6). A relative measurement of overlap in species composition between these sites showed that the greatest overlap occurred between the ridge and Atlantic slope trail sites (Sorenson index, Table 5). The higher amount of overlapping in the two elfin forest sites may be due to similar tree and/or understory composition as well as similar conditions found at these elevations.

A similar study with multiple collections per habitat and elevation would provide a basis for a more powerful statistical comparison. Additionally, it would be interesting to examine the occurrence of fragmentation at additional elevations on the Atlantic slope to see how these data relate to data from this study. A quantification of the input of fragments and seeds to the study sites could allow for a more accurate estimation of the expected values of this ratio. Therefore, if the amount of fragments and seeds added to an area differs from the proportion of seedlings and fragments found, this could suggest additional reasons for the occurrence of fragmentation at different sites. An inventory of understory species diversity of plants within the collection sites would yield information about what species may be contributing to the input of seeds and fragments to the area. In a longer study, greater numbers of plants could be identified for better analyses of species richness and diversity among different sites. If species diversity could be determined, it would be interesting to compare those species that were observed to produce fragments and in what proportion they were produced relative to seeds.

ACKNOWLEDGEMENTS

I would like to thank the entire CIEE staff—Alan Masters, Mauricio Garcia, Andy Rodstrom, Eben Broadbent, Justin Calabrese, and especially Karen Masters, for all of your help with everything that went into this project and life in general. Your support, knowledge, and friendships are much appreciated. Thank you Bill Haber and Willow Zuchowski for your tremendous help in plant identification, and Amey Libman for your helpful revisions. Thanks to the Estación Biológica staff for the use of everything, especially the forest. Thanks to my Tico and Gringo families for all the support, and thanks to all my friends for being so entertaining and cheerful throughout this experience.

LITERATURE CITED

- Bush, S.P. 1993. Vegetative Reproduction Via Fragmentation in *Poikilacanthus Macranthus*. CIEE. Summer.
- Gartner, B.L. 1989. Breakage and Regrowth of Piper Species in Rain Forest Understory. *Biotropica* 21 (4): 303-307.
- Haber, W. A., W. Zuchowski, and E. Bello. 1996. An Introduction to Cloud Forest Trees: Monteverde, Costa Rica.

- Holmes, T. 1997. Impact of Two Trail Types on the Herb Layer at the Santa Elena Reserve. CIEE Spring.
- Kinsman, S. 1990. Regeneration by Fragmentation in Tropical Montane Forest Shrubs. American Journal of Botany 77(12): 1626-1633.
- Magurran, A.E. 1988. Ecological Diversity and its Measurement. Princeton, NJ. Princeton University Press.
- Mullen, T. 1997. Factors Affecting the Understory Plants of the Monteverde Elfin Forest: A Bottom-up Approach. CIEE Fall.
- Robinson, M. 1997. Root Mat Location in the Soil Horizon of Premontane Wet and Lower Montane Rail Forests. CIEE Spring.
- Zar, J.H. 1984. Biostatistical Analysis, Second Edition. Englewood Cliffs, NJ. Prentice-Hall, Inc.

Table 1: Number of plants originating from seeds or fragments collected at trail edge and understory sites along an altitudinal gradient

Elevation	TRAIL EDGE			UNDERSTORY		
	# Seeds	# Fragments	Total	# Seeds	# Fragments	Total
1540m Pacific	188	22	210	199	11	210
1760m Pacific	164	27	191	97	53	150
1810m Ridge	72	107	179	75	86	161
1790m Atlantic	83	93	176	38	119	157
Total	507	249	756	409	269	678

Table 2: One-sample chi-squared test values for the ratio of plants originating from seeds or fragments collected at each site, *p < 0.05

Habitat	Chi-squared value per elevation			
	1540m	1760m	1810m	1790m
Trail X ²	131.20 *	98.30 *	6.84 *	0.56
Understory X ²	168.30 *	12.90 *	0.75	41.79 *

Table 3: Chi-squared test values of 2 x 2 contingency table for the ratio of plants originating from seeds or fragments of the same habitat (trail edge and understory) in different elevations, * p < 0.05

Habitat	Chi-square values of pairwise elevation comparison					
	1540 vs 1760m	1540 vs 1810m	1540 vs 1790m	1760 vs 1810m	1760 vs 1790m	1810 vs 1790m
Trail	153.8 *	234.8 *	204.8 *	351.3 *	307.8 *	183.3 *
Understory	289.1 *	405.6 *	574.8 *	175.9 *	255.2 *	193.9 *

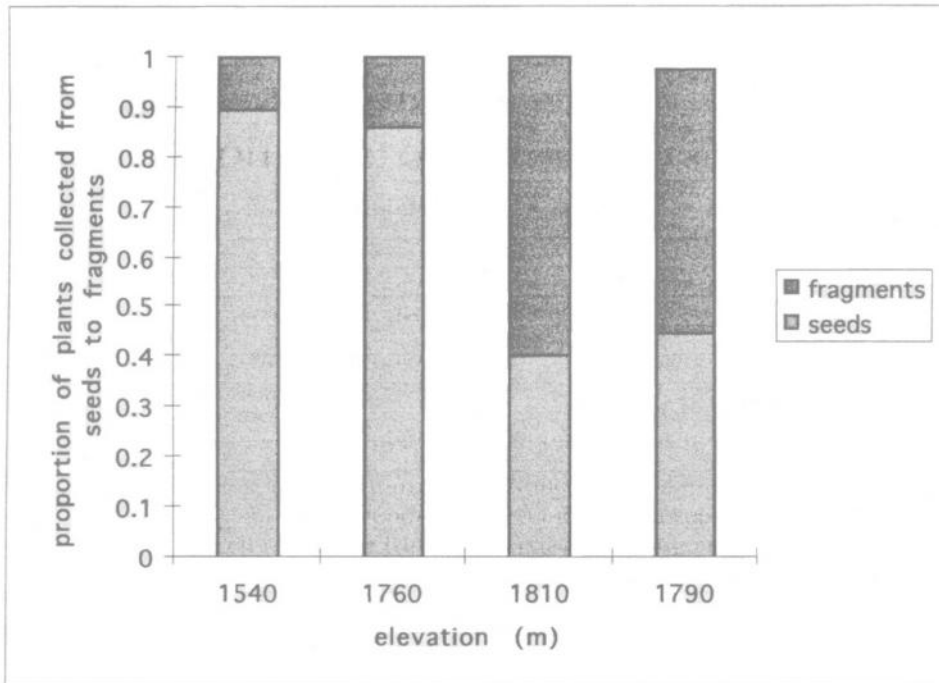


Figure 1: Proportion of plants originating from seeds or fragments collected at trail edge sites along an altitudinal gradient

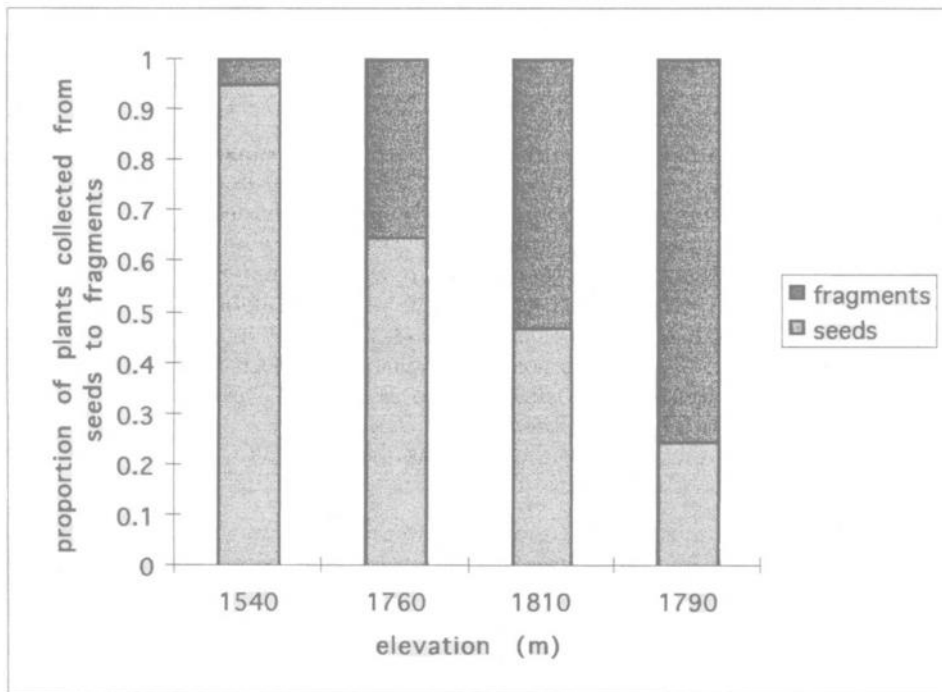


Figure 2: Proportion of plants originating from seeds or fragments collected at understory sites along an altitudinal gradient

Table 4: Chi-squared test values of 2 x 2 contingency table for the ratio of plants originating from seeds or fragments of the same elevation in different habitats (trail edge and understory), * $p < 0.05$

	Chi-squared values per elevation			
Habitat	1540m	1760m	1810m	1790m
Trail vs. Understory	217.6 *	212.4 *	172.8 *	204.1 *

Table 5: Values of Sorenson quantitative indices (CN) for the comparison of fragmented plants collected in trail edge habitats of 1760 Pac., 1810 Ridge, and 1790 Alt. elevations at family- and species-levels (species-level also includes those plants only identifiable to family level)

	Sorenson quantitative index values of pairwise elevation comparison		
CN	1760 vs 1810m	1760 vs 1790m	1810 vs 1790m
Family-level	0.458	0.149	0.527
Species level	0.229	0.116	0.240

Table 6: H' values of modified t-tests for differences between diversity indices of the total species diversity of fragmented plants collected in trail edge habitats of 1760 Pac., 1810 Ridge, and 1790 Atl. Elevations

	H' values of trail edge elevation		
value	1760m	1810m	1790m
H'	0.7186	1.0062	1.1547

Table 7: Values of modified t-test for differences between diversity indices of the total species diversity of fragmented plants collected in trail edge habitats of 1760 Pac., 1810 Ridge, and 1790 Atl. Elevations, * $p < 0.05$

Value	1760 vs 1810m	1760 vs 1790m	1810 vs 1790m
t	3.302 *	5.053 *	2.619 *

APPENDIX 1: Taxa and the number of plants identified as originating from seeds; *represents taxa which are shared with that of plants collected from fragments

FAMILY	GENUS SPECIES	number
Acanthaceae *	<i>Various</i>	10
Acanthaceae *	<i>Poikilacanthus Macranthus</i>	3
Aquifoliaceae	<i>Ilex sp.</i>	1
Araceae *	<i>Various</i>	5
Araceae	<i>Anthurium sp.</i>	2
Araceae *	<i>Monstera spp.</i>	27
Araceae *	<i>Syngonium spp.</i>	9
Arecaceae	<i>Various</i>	84
Arecaceae	<i>Prestoea sp.</i>	1
Begoniaceae *	<i>Begonia cooperi</i>	1
Begoniaceae *	<i>Begonia involucrata</i>	3
Caprifoliaceae	<i>Viburnum sp.</i>	57
Celestraceae	<i>Euonymus sp.</i>	3
Chloranthaceae	<i>Hedyosmum sp.</i>	1
Cyperaceae	<i>Uncinia hamata</i>	1
Dioscoreaceae	<i>Dioscorea sp.</i>	1
Euphorbiaceae	<i>Hyeronima oblonga</i>	1
Flacourtiaceae	<i>Casearia tacanensis</i>	1
Flacourtiaceae	<i>Casearia sp.</i>	11
Gesneriaceae *	<i>Besleria princeps</i>	5
Gesneriaceae *	<i>Monopyle maxonii</i>	5
Heliconiaceae	<i>Heliconia monteverdensis</i>	2
Lauraceae	<i>Beilschmiedia brenesii</i>	1
Malpighiaceae	<i>Malpighia albiflora</i>	3
Malvaceae	<i>Hampea sp.</i>	15
Malvaceae	<i>Malvaviscus palmanus</i>	1
Melastomataceae *	<i>Various</i>	54
Menispermaceae	<i>Abuta panamensis</i>	1
Moraceae	<i>Pseudolmedia sp.</i>	1
Moraceae	<i>Pseudolmedia mollis</i>	21
Moraceae	<i>Sorocea trophoides</i>	32
Myrsinaceae	<i>Ardisia sp.</i>	3
Myrtaceae	<i>Eugenia sp.</i>	2
Myrtaceae	<i>Myrcia splendens</i>	6
Orchidaceae	<i>Sp. 1</i>	1
Orchidaceae	<i>Cranichis sp.</i>	1
Piperaceae *	<i>Various</i>	2
Piperaceae *	<i>Peperomia hernandiifolia</i>	2
Piperaceae *	<i>Peperomia spp.</i>	3
Piperaceae	<i>Piper auritum</i>	1
Piperaceae	<i>Piper near auritum</i>	3
Piperaceae *	<i>Piper aequale</i>	6
Piperaceae	<i>Piper glabrescens</i>	1
Piperaceae *	<i>Piper spp.</i>	1
Piperaceae *	<i>Piper urifillum</i>	2

Poaceae*	<i>Ichnanthus sp.</i>	11
Rubiaceae	<i>Coussarea Austin-smithii</i>	6
Rubiaceae	<i>Faramea multiflora</i>	1
Rubiaceae	<i>Guettarda poasana</i>	2
Rubiaceae	<i>Hoffmania congesta</i>	1
Rubiaceae *	<i>Palicourea albocaerulea</i>	9
Rubiaceae*	<i>Psychotria aubletiana</i>	7
Rubiaceae*	<i>Rondeletia</i>	3
Rubiaceae*	<i>Various</i>	3
Sabiaceae	<i>Meliosma glabrata</i>	7
Sapindaceae	<i>Paullinia costaricensis</i>	3
Simaroubaceae	<i>Picramnia teapensis</i>	5
Smilacaceae*	<i>Smilax sp.</i>	2
Smilacaceae*	<i>Smilax spinosa</i>	14
Solanaceae	<i>Sp. 1</i>	1
Solanaceae	<i>Cestrum sp.</i>	1
Solanaceae	<i>Solanum ramonense</i>	3
Staphyleaceae	<i>Turpinia sp.</i>	1
Styracaceae	<i>Styrax sp.</i>	1
Urticaceae*	<i>Pilea pittieri</i>	2
Urticaceae*	<i>Pilea ptericlada</i>	2
Total = 34 families	66 species (<i>various species counted as 1</i>)	581 seeds

APPENDIX 2: Taxa and the number of plants identified as originating from fragments

FAMILY	GENUS SPECIES	Number
Acanthaceae*	Various	32
Acanthaceae	<i>Dicliptera iopus</i>	1
Acanthaceae*	<i>Poikilacanthus macranthus</i>	1
Acanthaceae	<i>Pseuderanthemum sp.</i>	1
Acanthaceae	<i>Razisea sp.</i>	11
Araceae*	Various	1
Araceae*	<i>Mostera spp.</i>	54
Araceae	<i>Philodendron</i>	14
Araceae	<i>Philodendron aurantiifolium</i>	3
Araceae*	<i>Syngonium spp.</i>	8
Asclepiadaceae	<i>Sp. I</i>	1
Begoniaceae*	<i>Begonia cooperi</i>	1
Begoniaceae*	<i>Begonia involucrata</i>	2
Campanulaceae	<i>Centropogon costaricae</i>	15
Campanulaceae	<i>Sp. 1</i>	6
Campanulaceae	<i>Sp. 2</i>	4
Celestraceae	<i>Euonymus costaricensis</i>	1
Celestraceae	<i>Gymnosporia haberiana</i>	1
Commelinaceae	<i>Sp. 1</i>	1
Commelinaceae	<i>Tradescantia zanonina</i>	2
Gesneriaceae*	<i>Besleria princeps</i>	35

Gesneriaceae*	Monopyle maxonii	3
Melastomataceae*	Various	2
Melastomataceae	Clidemia globuliflora	2
Monimiaceae	Siparuna tonduziana	1
Orchidaceae	Erythrodes sp.	1
Piperaceae*	Various	12
Piperaceae*	Peperomia hernandiifolia	22
Piperaceae*	Peperomia spp.	16
Piperaceae*	Piper aequale	3
Piperaceae	Piper carpinteranum	2
Piperaceae*	Piper spp.	9
Piperaceae*	Piper urifillum	1
Poaceae	Sp. 1	1
Poaceae*	Ichnanthus sp.	2
Rubiaceae*	Palicourea albocaerulea	1
Rubiaceae	Psychotria steyermarkii	3
Rubiaceae	Psychotria uliginosa	2
Rubiaceae*	Psychotria aubletiana	12
Rubiaceae	Psychotria parvifolia	1
Rubiaceae*	Rondeletia	1
Rubiaceae*	Various	3
Smilacaceae*	Smilax sp.	1
Smilacaceae*	Smilax spinosa	1
Solanaceae	Witheringia coccoloboides	1
Solanaceae	Witheringia maculata	2
Urticaceae*	Pilea pittieri	2
Urticaceae*	Pilea ptericlada	1
Vitaceae	Cissus martiniana	1
Total = 18 families	49 (various species counted as 1)	304 fragments