

September 2002

The effect of varying forest disturbance on fruit and seed diversity, and black-faced solitaire (*Myadestes melanops*) abundance

Danielle Leah Wood

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

Recommended Citation

Wood, Danielle Leah, "The effect of varying forest disturbance on fruit and seed diversity, and black-faced solitaire (*Myadestes melanops*) abundance" (2002). *Tropical Ecology Collection (Monteverde Institute)*. 236.

https://digitalcommons.usf.edu/tropical_ecology/236

This Text 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 Collection (Monteverde Institute) by an authorized administrator of Digital Commons @ University of South Florida. For more information, please contact scholarcommons@usf.edu.

The Effect of Varying Forest Disturbance on Fruit and Seed Diversity, and Black-faced Solitaire (*Myadestes melanops*) Abundance

Danielle Leah Wood

Department of Rural Sociology and Institute of Environmental Studies, University of Wisconsin-Madison

ABSTRACT

The amount of intact forest being destroyed and degraded increases every day. An important question is how do varying degrees of forest disturbance not only affect fruiting plants, but their dispersal as well. This study suggests that disturbance has a negative effect on fruiting plant diversity and abundance, seed rain diversity and abundance, and abundance of the very important cloud forest disperser, the Black-faced Solitaire. Inventories of understory fruiting plants and seed rain were conducted in varying levels of disturbance in the lower montane wet forest life zone (Holdridge 1967) of Monteverde, Costa Rica. Study sites included primary forest, secondary forest, forest gaps, forest strip, and pasture. Black-faced Solitaire calls were recorded in each site. Primary forest had the highest diversity of fruits and seeds compared to all the other sites. Black-faced Solitaires were found to be common in the intact forest, but absent in the forest strip and pasture. Disturbance was found to affect fruit and seed abundance and diversity, as well as Black-faced Solitaire abundance.

RESUMEN

La cantidad de bosque intacto que ha sido destruido y degradado aumenta cada día. Una pregunta importante es como los diferentes niveles de alteración afectan las plantas con frutas y sus semillas, así como su dispersión. Estos estudios sugieren que una alteración tiene un efecto negativo en la diversidad y abundancia de las plantas con frutas, la lluvia de semillas y la abundancia de un dispersor de semillas muy importante en el bosque nuboso, el Jilguero. Los inventarios de las plantas con frutas de sotobosque, la lluvia de semilla y de Jilgueros fueron conducidos a varios niveles de alteración en la zona de vida del bosque húmedo tropical montano bajo (Holdridge 1967) de Monteverde, Costa Rica. Los sitios de estudio incluyeron el bosque primario, bosque secundario, claros en el bosque, una franja de bosque y un pastizal. Los cantos de los Jilgueros se registraron en cada sitio. El bosque primero tuvo la diversidad más alta de frutas y semillas comparado con todos los otros sitios. Los Jilgueros fueron más comunes en el bosque primario, pero completamente ausente en la franja de bosque y en el pastizal. Se encontró que los diferentes niveles de alteraciones afectaron la abundancia, diversidad de frutas y semillas y la abundancia de Jilgueros.

INTRODUCTION

As land is transformed for development and agriculture, the amount of forests being degraded increases. The biodiversity of Costa Rica is important because it lies in the Mesoamerican hotspot which ranges from southern Mexico to western Panama. Although Costa Rica accounts for a mere 0.15% of the global land area, it harbors 8% of

all described vascular plant species and 10.1% of all described non-fish vertebrate species (Mittermeier et al. 1998). With such a high number of species to land area, the alteration of this land could have a devastating effect on worldwide biodiversity.

Costa Rica is home to approximately 840 bird species and of these, 60% of the land dwelling birds depend, at least partly, on large areas of intact forest (Stiles and Skutch 1989). In the lower montane wet forest of Monteverde there are 265 recorded bird species (Young and McDonald 2000). Of these, the Black-faced Solitaire (*Myadestes melanops*, Turdidae) is one of the major seed dispersers. It is known to disperse 51 species of seeds, second to the 95 species by the Emerald Toucanet (*Aulacorhynchus prasinus*, Ramphastidae) (Murray 2000a). Some small frugivores are thought to be more important than large-seed dispersers because of their abundance and broad diets (Murray et al. 2000) and “the loss of these species could have profound effects on the biodiversity of Monteverde” (Murray 2000a). The Black-faced Solitaire is commonly found in protected areas, but not in disturbed ones (Stiles and Skutch 1989). Both migrant and resident birds show declines in abundance after a disturbance. Rappole and Morton (1985) have found a negative correlation between suitable habitat size and the abundance of individuals able to survive. As well, Island Biogeography Theory asserts that large areas can support higher numbers of individuals and species (MacArthur and Wilson 1967). How do different levels of forest disturbance affect not only fruiting plants and seeds, but the vital Black-faced Solitaire as well? This study strives to relate disturbance levels with fruiting plant abundance and diversity, and Black-faced Solitaire abundance.

METHODS

Study Sites

Data were collected in the lower montane wet forest of Estación Biológica Monteverde, Monteverde, Puntarenas, Costa Rica from April 17 until May 7, 2002 (Holdridge 1967). Study sites included primary forest, secondary forest, forest gaps, a strip of forest, and pasture. Primary forest (elevation 1575 – 1595m) included trees highly varied in diameter with a relatively tall canopy and relatively open understory. Secondary forest (elevation 1545- 1575m) was dominated by *Conostegia oerstediana* (Melastomataceae) (53% basal area) and had trees with a relatively smaller overall diameter, thicker understory, and open canopy compared to primary forest. Secondary forest was pasture 30-35 years ago and has since been left to regenerate (M. Garcia – C 2002, personal communication). Five treefall gaps (elevation 1510-1580m) were used within the intact forest. The areas of the gaps were 63.11m², 371.98m², 56.62m², 319.50m², and 110.83m² ranging in age from six months to four years (M. Garcia –C2002, personal communication). The strip of forest (elevation 1520 – 1530m) was 25m wide and exhibited edge characteristics throughout. Compared to the intact forest, there were higher light, temperature, and wind levels. The pasture (elevation 1510-1520m) was open with sparse vegetation and dominated by *Cynodon nlemfuensis* (Poaceae). The pasture has been cut back for at least 50 years (M. Garcia – C 2002, personal communication).

Fruit Inventory

In addition to using artificial fruit, naturally occurring understory fruiting plants were identified at each site. Plants were keyed out to species by W. Haber and the numbers of individual plants of each species were recorded, as well as the number of fruits per individual. All fruiting shrubs and treelets in the five treefall gaps were recorded. In the remaining four sites, three transects 25 x 2m were measured and a census was taken of all understory plants. Data gathered on understory fruiting plants in each site were analyzed using Shannon-Weiner diversity index (Zar 1984). A similarity index was used to compare fruiting species found in each site. The evenness of each site was also calculated.

Seed Rain Inventory

Seeds were collected in each site using seed traps. The traps, made of green nylon material, were cut into 0.5 x 0.5 meter squares. Nylon cord was tied to each corner of the fabric and then tied to trees 0.5 – 1 meter off the ground to prevent small mammals from removing seeds from the traps. A rock was placed in the center of each trap to reduce the number of seeds lost to wind. Three traps were placed at least 20 m apart from one another in each site. Traps were collected twice, dried, and seeds removed for identification. The majority of seeds were identified to genus or family by M. García – C. The seed rain was analyzed using Shannon-Weiner diversity index (Zar 1984). Sites were compared to one another using a similarity index, and evenness of seeds collected in each site was also computed.

Clay Fruits

Nontoxic, water resistant, odorless, red clay fruits between one and two centimeters were used to measure bird activity in each site in the same manner as Alves – Costa and Lopez (2001). Fifteen clay balls were attached to five trees in each of the five sites using a metal hook. Small treelets at least ten meters apart, without prior fruits or flowers were selected and clay fruits were placed one to two meters high in areas without foliage. Fruits were checked four times within each study period and pecks were recorded and clay smoothed over.

Black-faced Solitaire Calls

The frequency of Black-faced Solitaire calls were recorded in each site during the afternoon. The number of individual calls heard were recorded during three ten-minute intervals for each site. This was done five times, for a total of two and a half hours of listening in each site. A call was defined as the sound heard from an individual bird from a specific direction. When another individual from another direction, or multiple individuals from one direction were heard, they were recorded. Calls were analyzed using a one-way ANOVA.

RESULTS

Fruit Inventory

All fruits found in the sites are bird dispersed (Haber 2000). The five gap sites had the most species of understory fruiting plants, the most individual fruits, and the most individual plants (figure 9). Primary forest had the second most abundant amount of species, but a low number of individual fruits and the same amount of individual plants as the secondary forest (figure 7). Secondary forest had the second most abundant amount of individual fruits, but only a moderate amount of species (figure 8). The forest strip had few species, but had more individual fruits than the primary forest and not many individual plants (figure 10). Lastly, the pasture only contained one plant with one fruit on it.

There was a significant difference in fruits between each site, found using Shannon-Weiner diversity index (table 1). Using a similarity index, it was found that the primary forest and gap were the most similar, while the pasture did not have any fruiting plants in common with any other site and neither did the primary forest and the strip of forest.

Using a Shannon-Weiner diversity index it was found that primary forest had the highest diversity (table 3). The gaps had the second highest diversity, next was the secondary forest, and the forest strip. The pasture was not analyzed due to the presence of only one plant with one fruit. The primary forest had the highest evenness while the forest strip was second (table 3). The evenness of the secondary forest and forest gap were very close to one another. Again, because there was only one fruiting plant in the pasture, it had the lowest evenness.

Seed Rain Inventory

Primary forest had the most abundant genera of seeds and many individual seeds present (figure 1), but forest gap, which was similar in number of genera it contained, had a larger abundance of seeds (figure 3). Secondary forest and forest strip both had the same amount of genera, but the secondary forest had more seeds than the strip (figures 2 & 4).

Each site was compared to one another using the Shannon-Weiner diversity index, there were two cases in which there was not a significant difference between sites (table 2). This occurred when comparing the strip and secondary forest and the strip and pasture. The rest of the sites were significantly different. Using a similarity index, genera were the most similar in secondary-gap, gap-strip, and strip-pasture. The secondary forest and pasture were the least similar.

Using the Shannon-Weiner diversity index, once again the primary forest had the highest diversity (table 4). Interestingly the pasture had the next highest diversity, followed by the forest strip, the secondary forest, and the forest gaps. In contrast to the evenness of fruits (table 3), the pasture had the highest evenness of seeds (table 4). Interestingly the pasture had the next highest diversity, followed by the forest strip, the secondary forest, and the forest gaps. In contrast to the evenness of fruits (table 3), the pasture had the highest evenness of seeds (table 4). The primary forest was next, followed by the forest strip, the secondary forest, and the forest gap.

Clay Fruits

Eighteen of the 375 clay fruits throughout the sites were visited by birds (0.05%). Majority of the pecks occurred in secondary forest with 7 of 75 fruits showing peck marks (0.09%). Primary forest was next with 4 of 75 fruits pecked (0.05%). Forest strip and treefall gaps both had 3 of 75 pecked (0.04%). The pasture only had 1 of 75 fruits pecked (0.01%). Of the 18 total clay balls pecked, 16 were representative of small bird pecks and two were representative of large bird pecks according to Alves-Costa and Lopez (2001). One large peck occurred in the forest strip and the other was in the pasture.

Black-faced Solitaire Calls

Information gathered on Black-faced Solitaire calls illustrates there is a significant difference between the strip and pasture compared to the other three sites. No calls were recorded in the strip or pasture. Data for the other three sites were analyzed using a one way ANOVA (figure 11). No significant differences was found between the three sites where Black-faced Solitaires were present. The greatest mean number of calls was recorded in the primary forest followed by the secondary forest and the gap.

DISCUSSION

Fruit Inventory

Human disturbance and fruit diversity were found to be negatively correlated (table 3). The primary forest had the highest diversity of fruits, followed by forest gaps, secondary forest, forest strip, and pasture. Except for the pasture, the strip had the lowest diversity of fruits when compared to the other sites. This could be due to the fact that seeds make it there, but they just do not have optimal light, temperature, and moisture for germination. This could also explain why there was only one plant with one fruit present in the pasture, but it had the second highest diversity of seeds. This shows that just because a seed can make it to an area, it will not necessarily germinate and survive.

The highest similarities in fruiting plants occurred in the intact forest (table 1). In each case, when the strip was compared with another site, the similarity index was low. There were no similarities between the pasture and every other site because only one species was found in the pasture. The primary forest and strip also had no similarities in fruiting plants. The primary forest and gap had the highest similarity for fruiting plants and also had the highest levels of fruiting plant diversity. These two sites have experienced the least amount of human-caused disturbance. Though the gaps are highly disturbed, they are so naturally, and the forest depends on them for its high diversity. Almost all tropical forest trees are in some way dependent on gaps (Denslow 1987).

Seed Inventory

The highest diversity of seeds was found to be in the primary forest (table 4). There was not a significant difference between the secondary forest and the strip, or the strip and the pasture (table 2). Though there was not a significant difference in seeds found in the

secondary forest and strip, there were no similar fruits found in each area. This could be due to the forest edge conditions in the strip that could make it a sub-optimal location for the seeds to successfully germinate and grow. Because the forest strip and pasture are located adjacent to each other, it is not surprising that there was not a significant difference in seeds between the two. Out of the four seed genera found in the pasture, two, *Koanophyllon* (Asteraceae) and *Neomirandia* (Asteraceae) are wind dispersed (Haber 2000). The forest strip also contained *Neomirandia* seeds. The close proximity could have made it very easy for these seeds to disperse between the two sites.

Clay Fruits

In addition, clay fruits were not a good representation of bird abundance considering so few were actually visited. In prior experiments 43% of clay fruits were pecked, but fruits were attached using cord (Alves-Costa and Lopes 2001). Low numbers found in this study could be a result of the metal hook attachment. In the future, if clay fruits are used, preliminary tests should be conducted to find an optimal medium of attachment.

Black-faced Solitaire Calls

Given that they are the second most important bird disperser in Monteverde (Murray 2000a), the higher abundance of Black-faced Solitaires in the intact forest sites (especially in the primary forest) could be linked to the high fruit and seed diversity in these areas. Because the highest diversities and abundances of fruits were found in the intact forest, Black-faced Solitaires have more fruits to choose from in these three sites. They usually only disperse seeds within 50-60 meters of parent trees (Murray et al. 2000) and are not usually found in degraded areas, but are common in protected ones (Stiles and Skutch 1989). These facts lead to a possible reason for why Black-faced Solitaires were absent in the pasture and forest strip. The Black-faced Solitaire also increases the potential for a parent plant's offspring to survive by 16-36 fold (Murray et al. 2000). Their absence from the forest strip and pasture may explain the low abundance and diversity found in these areas.

Concluding Remarks

Though overall generalizations can be made regarding findings from fruit and seed inventories, *Psychotria* (Rubiaceae) was the only genus found in both the seed and fruit inventories. This may be because sampling was not conducted at the optimal time of year. Peaks in fruit production occur from late June through December with fruits being most numerous during the second half of the wet season (Koptur et al. 1988). It should also be noted that fruiting peaks of mature fruit might differ for each site. Plants take varying amounts of time to develop fruits after their flowers are pollinated, and peak fruiting times are less marked than peak flowering times (Koptur et al. 1988).

Studies show that forest habitat alteration causes decreases in the abundance and diversity of forest-dwelling birds (Rappole and Morton 1985). Although most "true forest species" visit secondary growth areas, these birds return to primary forest and edge to breed, and probably could not survive in secondary growth permanently (Stotz et al. 1996). Small, less prominent birds, such as the Black-faced Solitaire, may be

keystone mutualists for the massive amount of biodiversity in Monteverde (Murray 2000a). It has been suggested that plants have lower overall reproductive success when Black-faced Solitaires are absent (Murray 2000a). Because they are not usually found in disturbed areas (Stiles and Skutch 1989), Black-faced Solitaires may be at risk if forests continue to be degraded. So, not only is the forest plant diversity at risk from degradation, but the very disturbance that causes lower fruit diversity could cause lower dispersal, leading to even lower diversity. Further studies and conservation efforts need to continue to focus on the implications of habitat alteration on biodiversity. Until alternatives to forest destruction can be found, forests, and all the species within and around them are at risk.

ACKNOWLEDGEMENTS

Muchas gracias to my advisor, Mauricio García-C, for helping me design my project, identify seeds, and the coffee talk. Thank you Estación Biológica Monteverde for allowing me to study in such an awe inspiring environment. I never would have been able to identify all the plant species without the help of Bill Haber and Willow Zuchowski. Thank you Will Wieder for the flow of knowledge and the giggles. The beguiling late night computer room kept me entertained and answered all my stupid questions. I am grateful to Alan and Karen Masters for always pushing us along and providing such an amazing opportunity. Lastly, thank you to R. Andrew Rodstrom because he did a few things for me, but mostly for his love of Regae.

LITERATURE CITED

- Alves-Costa, C.P. and A. V. Lopes. 2001. Using Artificial Fruits to Evaluate Fruit Selection by Birds in the Field. *Biotropica* 33(4): 713-717.
- Denslow, J.S. 1987. Tropical Rainforest Gaps and Tree Species Diversity. *Ann. Rev. Ecol. Syst.* 18: 431-451.
- Haber, W.A. 2000. Appendix 1: Vascular Plants of Monteverde. In: Monteverde: Ecology and Conservation of a Tropical Cloud Forest. Nadkarni, N.M. and N.T. Wheelwright, eds. Oxford University Press. New York. Pp. 457-518.
- Holdridge, L.R. 1967. Life Zone Ecology. San José, Costa Rica. Tropical Science Center.
- Koptur, S., W. A. Haber, G. W. Frankie, and H.G. Baker. 1988. Phenological Studies of Shrub and Treelet Species in Tropical Cloud Forests in Costa Rica. *Journal of Tropical Ecology* (4) 323-346.
- Mac Arthur, R.H. and E.O. Wilson. 1967. The Theory of Island Biogeography. Chapter 3: Further Explanations of the Area-Diversity Pattern. Princeton University Press. Princeton. Pp. 19-25.
- Mittermeier, R.A., N. Myers and J.B. Thomsen. 1998. Biodiversity Hotspots and Major Tropical Wilderness Areas: Approaches to Setting Conservation Priorities. *Conservation Biology* 12: 516-520.
- Murray, K.G. 2000a. The Importance of Different Bird Species as Seed Dispersers. In: Monteverde: Ecology and Conservation of a Tropical Cloud Forest. Nadkarni, N.M. and N.T. Wheelwright, eds. Oxford University Press. New York. Pp. 294-302.
- Murray, K.G. 2000b. Fruiting Phenologies of Pioneer Plants: Constraints Imposed by Flowering Phenology, Disturbance Regime, and Disperser Migration Patterns. In: Monteverde: Ecology and Conservation of a Tropical Cloud Forest. Nadkarni, N.M. and N.T. Wheelwright, eds. Oxford University Press. New York. Pp. 283-286.

- Murray, K.G., S. Kinsman, and J.L. Bronstein 2000. Chapter 8: Plant-Animal Interactions. In: Monteverde: Ecology and Conservation of a Tropical Cloud Forest. Nadkarni, N.M. and N.T. Wheelwright, eds. Oxford University Press. New York. Pp. 245-302.
- Rappole, J.H., and E. S. Morton. 1985. Effects of Habitat Alteration on a Tropical Avian Forest Community. In: Neotropical Ornithology. Buckley, P.A., M.S. Foster, E.S. Morton, R.S. Ridgely, and F. G. Buckley, eds. Allen Press Inc. Lawrence, Kansas. Pp. 1013-1021.
- Stiles, A. G. and A. F. Skutch. 1989. Birds of Costa Rica. Cornell University Press. New York.
- Stotz, D.F., J. W. Fitzpatrick, T.A. Parker III, and D.K. Moskovitz. 1996. Neotropical Birds: Ecology and Conservation. Chapter 2: Neotropical Vegetation Types as Avian Habitats. The University of Chicago Press. Chicago, Illinois. Pp. 11-26.
- Vitousek, P.M, H.A. Mooney, J. Lubchenco, and J.M. Melillo. 1997. Human Domination of Earth's Ecosystems. *Science* 277: 494-499.
- Wheelwright, N.I., W.H. Haber, K.G. Murray, and C. Guindon. 1984. Tropical Fruit Eating Birds and their Food Plants: A Survey of a Costa Rican Lower Montane Forest. *Biotropica* 16 (3): 173-192.
- Young, B.E. and D.B. McDonald. 2000. Chapter 6: Birds. In: Monteverde: Ecology and Conservation of a Tropical Cloud Forest. Nadkarni, N.M. and N.T. Wheelwright, eds. Oxford University Press. New York. Pp. 283-286.
- Zar, J. H. 1984. Biostatistical Analysis. Prentice-Hall Inc. Englewood Cliffs, New Jersey.

TABLE 1. Paired t-test for diversity index (Shannon-Weiner) and Similarity Index for fruits comparing sites with varying levels of disturbance.

Site Comparisons	P-Value	S Index
Primary vs Secondary	p < 0.001	0.158
Primary vs Gap	p < 0.001	0.24
Primary vs Strip	p < 0.001	0
Primary vs Pasture	p < 0.001	0
Secondary vs Gap	p < 0.001	0.136
Secondary vs Strip	p < 0.001	0.083
Secondary vs Pasture	p < 0.001	0
Gap vs Strip	p < 0.001	0.111
Gap vs Pasture	p < 0.001	0
Strip vs Pasture	p < 0.001	0

TABLE 2. Paired t-test for diversity index (Shannon-Weiner) and Similarity Index for seeds comparing sites with varying levels of disturbance.

Site Comparisons	P-Value	S Index
Primary vs Secondary	p < 0.001	0.2
Primary vs Gap	p < 0.001	0.214
Primary vs Strip	p < 0.001	0.15
Primary vs Pasture	p < 0.001	0.158
Secondary vs Gap	0.005 > 0.002	0.222
Secondary vs Strip	0.20 > p > 0.10	0.2
Secondary vs Pasture	p < 0.001	0.111
Gap vs Strip	p < 0.001	0.222
Gap vs Pasture	p < 0.001	0.118
Strip vs Pasture	0.50 > p > 0.20	0.222

TABLE 3. Diversity (Shannon-Weiner Diversity Index) and evenness ($E = H'/\ln S$) of understory fruiting plants in varying levels of disturbance.

Site	H'	# spp	evenness
Primary Forest	0.915955007	11	0.38198291
Secondary Forest	0.592637954	8	0.28499861
Forest Gap	0.751913157	14	0.28491733
Forest Strip	0.441282797	4	0.31831825
Pasture	n/a	1	0

TABLE 4. Diversity (Shannon-Weiner Diversity Index) and evenness ($E = H'/\ln S$) of seeds in varying levels of disturbance.

Site	H'	#spp	Evenness
Primary Forest	0.87157769	15	0.32184695
Secondary Forest	0.322105141	5	0.20013518
Forest Gap	0.10838942	13	0.04225792
Forest Strip	0.453135591	5	0.28154897
Pasture	0.546363368	4	0.39411786

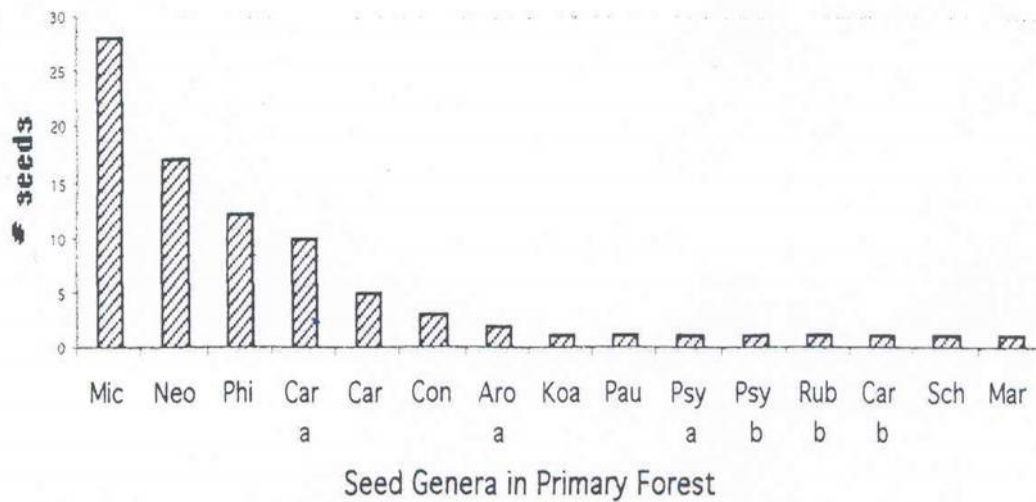


FIGURE 1. Relation of seed abundance in primary forest (Mic=*Miconia*, Neo=*Neomirandia*, Phi=*Philodendron*, Car a=*Carendishia a*, Car=*Carendishia*, Con=*Conostegia*, Aro a=*Araceae a*, Koa=*Koanophyllon*, Pau=*Paulina*, Psy a=*Psychotria a*, Psy b=*Psychotria b*, Rub b=*Rubiaceae b*, Car=*Carendishia b*, Sch=*Schefflera*, Mar=*Marcgravia*.)

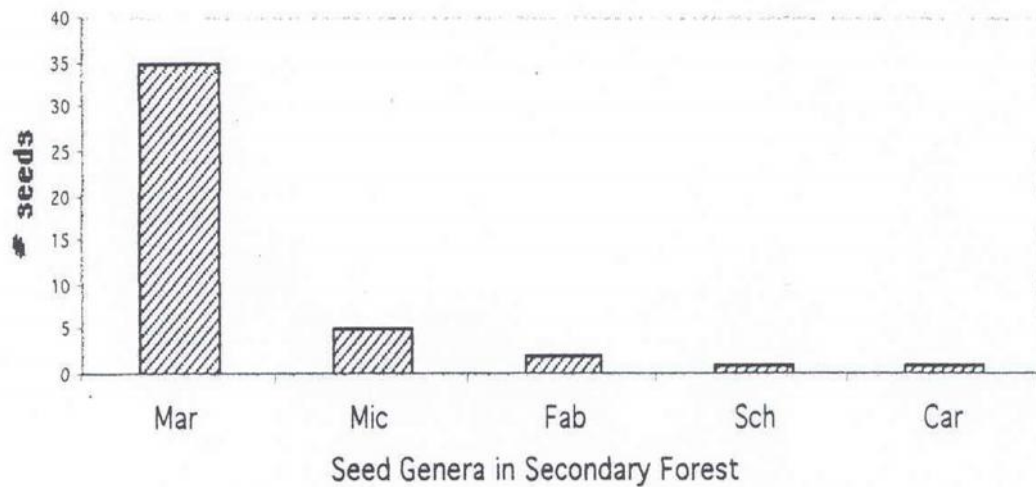


FIGURE 2. Relation of seed abundance in secondary forest (Mar=*Marcgravia*, Mic=*Miconia*, Fab=*Fabaceae*, Sch=*Schefflera*, Car=*Carendishia*).

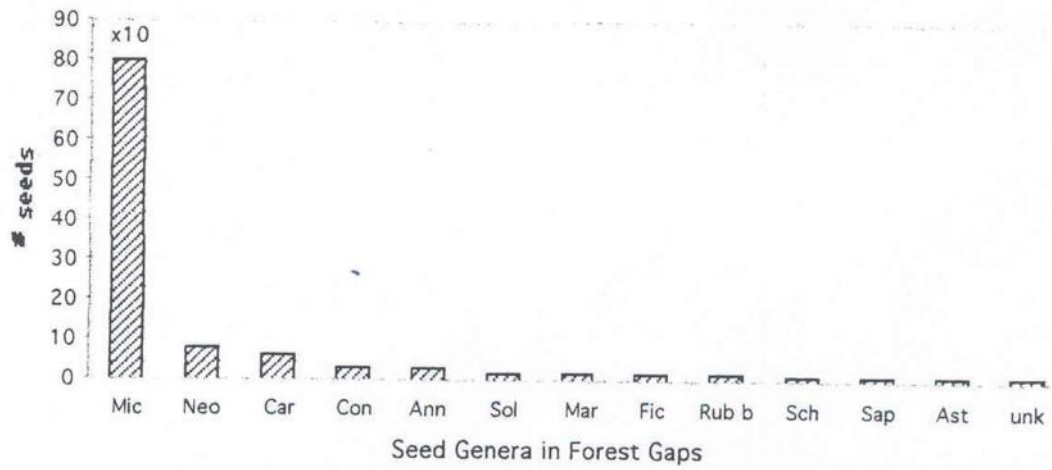


FIGURE 3. Relation of seed abundance in forest gaps (Mic=*Miconia*, Neo=*Neomirandia*, Car=*Carendishia*, Con=*Conostegia*, Ann=*Annonaceae*, Sol=*Solanum*, Mar=*Marcgravia*, Fic=*Ficus*, Rub b=*Rubiaceae b*, Sch=*Schefflera*, Sap=*Sapium*, Ast=*Asteraceae*, unk=unknown).

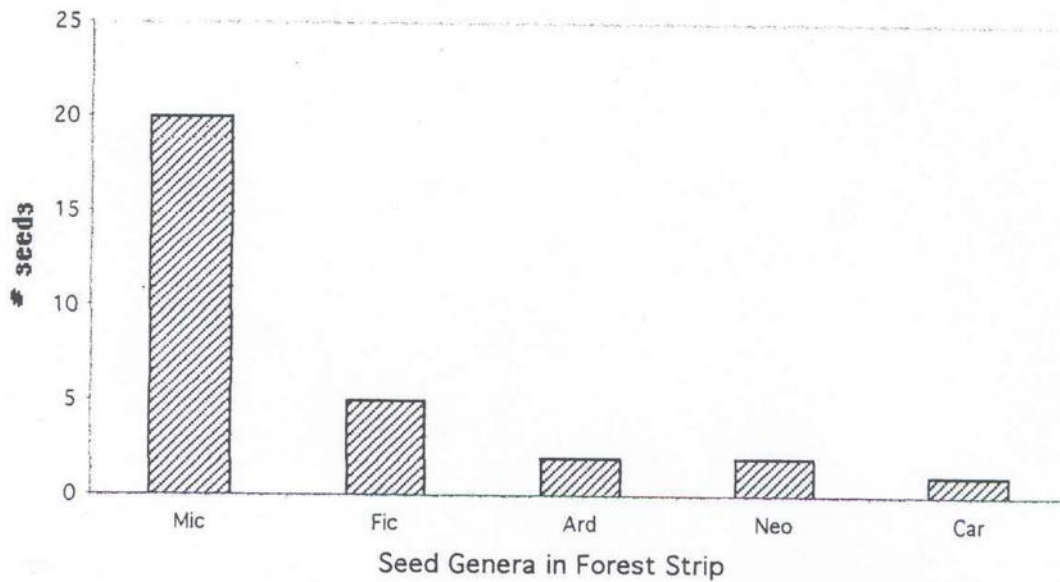


FIGURE 4. Relation of seed abundance in forest strip (Mic=*Miconia*, Fic=*Ficus*, Ard=*Ardisia*, Neo=*Neomirandia*, Car=*Carendishia*).

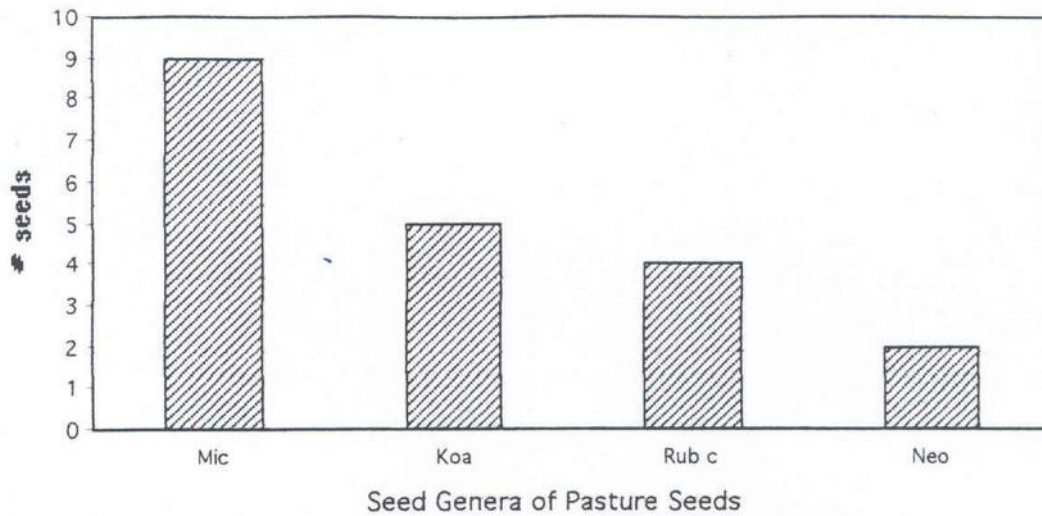


FIGURE 5. Relation of seed abundance in a pasture (Mic=*Miconia*, Koa=*Koanophyllon*, Rub c=*Rubiaceae c*, Neo=*Neomirandia*).

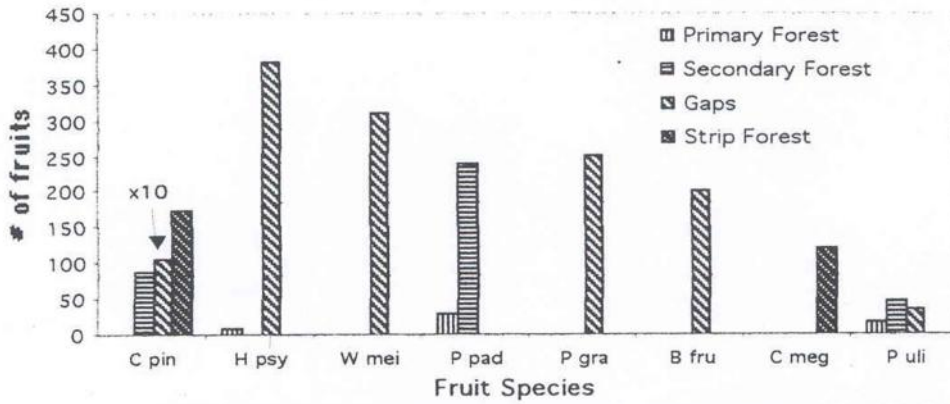


FIGURE 6. Relation of the abundance of the eight most common understory fruiting plants in varying levels of disturbance (C pin=*Chamaedorea pinnatifrons*, H psy=*Hoffmannia psychotriifolia*, W mei=*Witheringia meiantha*, P pad=*Palicourea padifolia*, P gra=*Psychotria gracifolia*, B fru=*Bocconia frutescens*, C meg=*Cestrum megalophyllum*, P uli=*Psychotria uliginosa*).

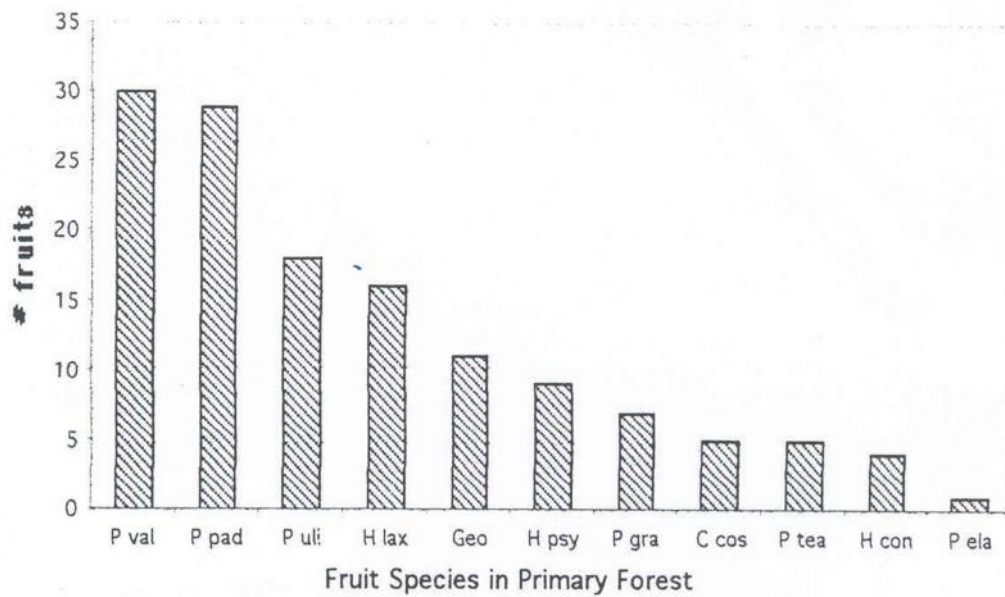


FIGURE 7. Relation of the understory fruit abundance in primary forest (P val=*Psychotria valeriana*, P pad=*Palicourea padifolia*, P uli=*Psychotria uliginosa*, H lax=*Hoffmannia laxa*, Geo=*Geonoma* sp, H psy=*Hoffmannia psychotriifolia*, P gra=*Psychotria gracifolia*, C cos=*Chamaedorea costaricana*, P tea=*Picramnia teapensis*, H con=*Hoffmannia congesta*, P ela=*Psychotria elata*).

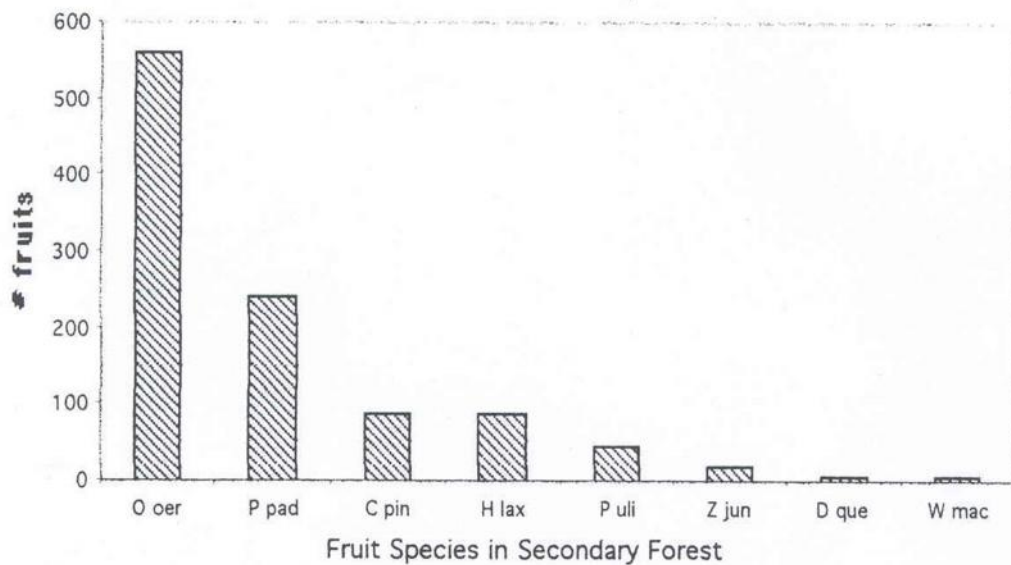


FIGURE 8. Relation of the understory fruit abundance in secondary forest (O oer=*Oreopanax oerstedianus*, P pad=*Palicourea padifolia*, C pin=*Chamaedorea pinnatifrons*, H lax=*Hoffmannia laxa*, P uli=*Psychotria uliginosa*, Z jun=*Zanthoxylum juniperinum*, D que=*Dendropanax querceti*, W mac=*Witheringia maculata*).

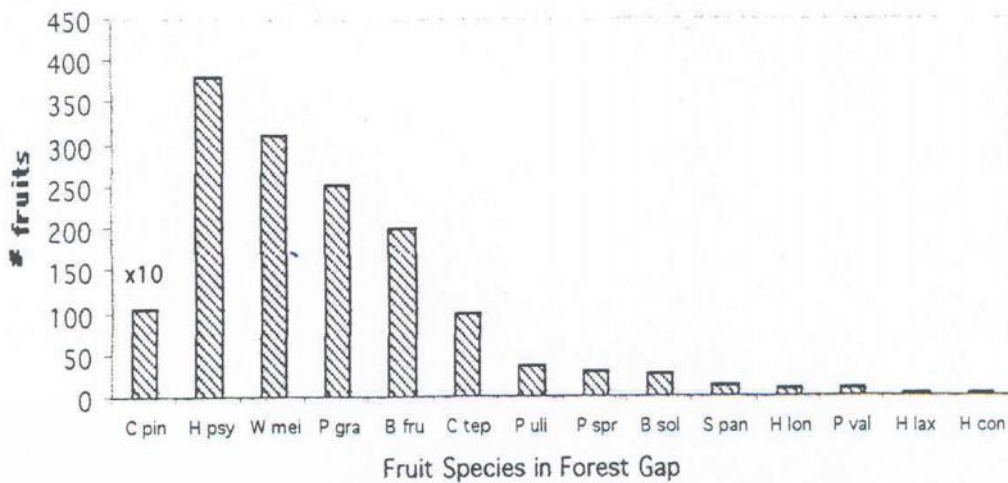


FIGURE 9. Relation of the understory fruit abundance in forest gaps (C pin=*Chamaedorea pinnatifrons*, H psy=*Hoffmannia psychotriifolia*, W mei=*Witheringia meiantha*, P gra=*Psychotria gracifolia*, B fru=*Bocconia frutescens*, C tep=*Chamaedorea tepejilote*, P uli=*Psychotria uliginosa*, P spr=*Pleuropetalum sprucei*, B sol=*Besleria solanoides*, S pan=*Smilax panamensis*, H lon=*Hoffmannia longipetiolata*, P val=*Psychotria valeriana*, H lax=*Hoffmannia laxa*, H con=*Hoffmannia congesta*).

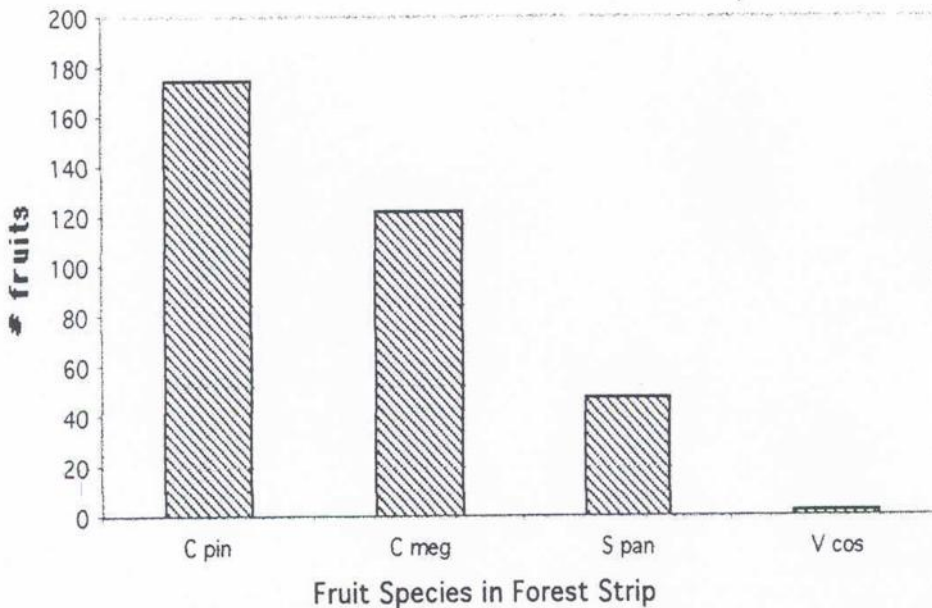
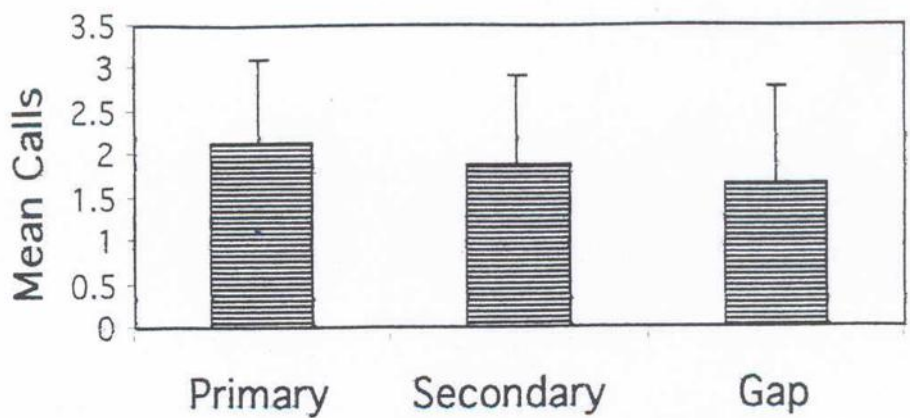


FIGURE 10. Relation of the understory fruit abundance in forest strip (C pin=*Chamaedorea pinnatifrons*, C meg=*Cestrum megalophyllum*, S pan=*Smilax panamensis*, V cos=*Vibrum costaricanum*).



Black-faced Solitaire Calls in Intact Forest

FIGURE 11. Mean Black-faced Solitaire calls analyzed using a One way ANOVA in primary forest (std. dev. = ± 0.99), secondary forest (std. dev. = ± 1.06), and forest gap (std. dev. = ± 1.15) F-value = 0.977, P-value = 0.3833.
