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ABSTRACT

It has been observed that birds are more common in forest habitats then along the edge of pastures. This study investigates the idea that birds forage less frequently in pastures and along forest edges and therefore that fewer seeds are dispersed in pastures than in forest. This would affect forest composition along edges and duration of reforestation. Clay fruits were placed on a gradient from forest to pasture, and the number of "fruits" with peck marks at each distance was recorded. A palm census was done along the gradients to determine if the diversity of palms differed from the edge to the forest. It was found that there were significantly more fruits pecked in the forest then at the edge (one way ANOVA $p = < 0.0001$, $F = 653.244$, $R^2 = 0.918$). Therefore birds are not dispersing fruits at the edge as much as in the forest. This could affect the diversity of species at the edge. This was confirmed in the palm census. The diversity of palms was significantly greater in the forest then the pasture (one-way ANOVA $p = 0.0093$, $F = 106.265$, $R^2 = 0.982$). There is a correlation between the expected diversity of palms due to dispersal events and the actual diversity.

RESUMEN

Ha sido observado que las aves se encuentran con más frecuencia en el bosque que en los bordes con pasto. Este estudio investiga la idea que las aves dispersan menos semillas en el pasto al dentro del bosque. Esto afectaría la composición del bosque que está en el borde del pasto y el tiempo necesario para su regeneración. Se pusieron frutos de arcilla en un gradiente de bosque a pasto y se contaba el número de frutas con picotazos a cada distancia (ANOVA una vía $p = < 0.0001$, $F = 653.244$, $R^2 = 0.918$). Se hicieron además censos de las palmas en el mismo gradiente para determinar si la diversidad de las palmas era diferente en el bosque que al borde del pasto. Se encontró diferencia significativa con las frutas que tenían más picotazos en el bosque que en los alrededor del pasto (ANOVA una vía $p = 0.0093$, $F = 106.265$, $R^2 = 0.982$). La diversidad de las palmas fue también significativamente más alta en el bosque también.

INTRODUCTION

It is becoming increasingly difficult to ignore the effects of deforestation in the tropics. In the 1980's over 15.4 million hectares of forest was cut every year, which was a 40% increase since 1980 (Dale et al 1994). This deforestation has left an enormous amount of edge and an even larger area of forest subject to edge effects. In the Amazon, the area within one km of an edge is equal to one and a half times the total area cut (Pimm 1998). Although abiotic edge effects are considered to extend only 50 m into the forest (Murcia

1995), biotic effects can penetrate up to 300m into the forest (Pimm 1998). Edge effects can include less competition for space in the soil from canopy roots and increased light, wind, humidity, hunting and predation (Malcolm 1998, Dale et al. 1994). These factors can make regeneration of the forest difficult, even if it is left fallow. Unfortunately, forest succession on degraded tropical lands is often slowed by impoverished seed banks and low rate of seed dispersal (Duncan and Duncan 2000).

Bird dispersed plants may have an especially difficult time dispersing their seeds to the fallow pastures due to low abundance of frugivorous birds in edge environments (Restrepo et al. 1999). Studies have shown that bird capture rates increase in the forest and decrease on the edge but do not respond to changes in fruit abundance. In addition, all but the rarest bird species are found in greater abundance in the forest than at the edge (Restrepo et al. 1999). The reproductive success of certain songbirds is reduced along edges due to high instances of nest parasitism and predation, which further reduces bird numbers. (Yahner 1988).

A low population of birds at the edge would disrupt mutualisms such as seed dispersal. Therefore many bird dispersed plants may encounter difficulties in colonizing edge habitat because of dispersal limitations. This unusual distribution would upset the balance of competition between plant species on the edge, beginning a cycle of artificially maintained populations of fruits and frugivores, which are lower than expected (Fagen, Cantrell and Cosner 1999). If post-dispersal seed predation is higher along the edge, this would further decrease the number of plants that can develop to maturity (Holl 1997). If plant species composition differs on the edge from that in the forest, it will attract different fauna, and thus bird community composition might be drastically different from that in the forest. This new community composition may contain fewer bird-dispersed plants, further influencing the number of edge-loving birds that can be supported and reducing the number of available bird dispersers (Fagen, Cantrell and Cosner 1999).

This disparity in the number of bird-dispersed trees in the forest and those on the edge could have drastic consequences. Since birds disperse 77% of the understory trees and shrubs and 63% of the canopy trees have fruit morphology suggestive of bird dispersal in Monteverde, a disrupted mutualism between birds and fruiting plants would have a large impact on the composition of regenerating forest (Wenny 2000). There may be reduced number of plants with bird dispersed fruits in the regenerating forest, and this would in turn affect other organisms depended on these plants. Therefore the community in the regenerating forest might be incomplete and less diverse. The forest over time would most likely return to its composition before deforestation; however this may take longer than previously expected.

Understory palms in Monteverde illustrate the effect of edges on community diversity. Palms are especially important in Monteverde as many of them fruit at the end of the dry season when few other plants are fruiting (Haber, Zuchowski and Bello 2000). Therefore frugivores rely on eating palm fruits when other fruits become rare or nonexistent. During the dry season intake of palm fruits by some frugivores can exceed that of all other fruits combined (Peres 1994). If this key resource is not available along the edge or pasture, the entire community can be affected. Fewer birds along pasture and edges would mean less fruits would be dispersed there. This is turn may influence plant diversity at the edge which may affect forest regeneration time. This study looked at the relationship between fruit dispersal by birds along a gradient from pasture to forest, and palm species diversity along the same gradient. It is expected that bird dispersal would be greater in the forest and therefore, and because palms in Monteverde are bird dispersed (Haber, Zuchowski and Bello 2000), palm diversity would also be greater in the forest.

MATERIALS AND METHODS

The study site was located on land owned by Marvin Hidalgo, Turid Forsyth, the Masters family and the Estación Biológica Monteverde, Monteverde, Puntarenas, Costa Rica, at an elevation of 1,540 m (Haber et al. 2000). The site has a large amount of edge bordered by pasture and has been cleared approximately every ten years. The forest is pre-montane tropical rainforest, which receives 2 to 2.5 meters of rainfall annually (Haber, Zuchowski and Bello 2000). The data collection period lasted for 16 days, from April 18th though May 6th, 2002. Ten, 75 m transects were partitioned at least 40 m apart from one another. All transects were run perpendicular to the forest edge, starting 15 m into open pasture to 60 m into primary and secondary forest. These transects penetrate far enough into the forest to negate abiotic edge effects, which according to Murcia (1995) disappear after the first 50 m of the forest.

Every 15 m along the transects stations of 10 red clay fruits one cm in diameter were placed on small trees. Previous studies have indicated that red clay balls provide sufficient stimulus for birds and are rarely touched by mammals (Alves-Costa and Lope 2001). The trees used were controlled for their basic outward appearance. All had terminally branching leaves about five cm in length and were about three meters tall. The fruits were placed terminally on the branches starting at about two meters in height within an area of one by one by one half meters in order to keep the density of balls constant. The number of clay balls with peck marks was counted and recorded every other day, after which the clay balls were reshaped.

Using the same transects, a census of the palm species present was conducted. The number and species of palms in a five meter radius were identified and recorded at each of the ten stations along the transects.

A regression analysis and a one-way ANOVA test of the recorded number of balls pecked at each distance and throughout the duration of the study were used to determine the relation between the two variables. The diversity of palms at each station was calculated and compared with a one-way ANOVA test to determine if there was a change in diversity at different distances.

RESULTS

The number of clay fruits pecked along the transect increased along the gradient from the pasture to the forest (Figure 1). The regression line showed a positive increase in number of balls pecked in relation to distance into the forest (one way ANOVA $p = < 0.0001$, $F = 653.244$, $R^2 = 0.918$). A regression line plotting each distance against the number of days the clay fruits were out showed no relation (one way ANOVA at -15m: $p = 0.3309$, $F = 0.957$, $R^2 = 0.012$, at 0 m: $p = 0.9719$, $F = 0.001$, $R^2 = 0.000016$, at 15 m: $p = 0.0642$, $F = 3.526$, $R^2 = 0.043$, at 30 m: $p = 0.0413$, $F = 4.306$, $R^2 = 0.052$, at 45 m: $p = 0.3412$, $F = 0.917$, $R^2 = 0.012$, at 60 m: $p = 0.4678$, $F = 0.532$, $R^2 = 0.007$).

Diversity at each distance was calculated using the Shannon-Weiner Diversity Index and the regression line between diversity from pasture to forest showed an increase. A regression line between the diversity index and distance showed a significant relationship (one-way ANOVA $p = 0.0093$, $F = 106.265$, $R^2 = 0.982$, Figure 2). Table 1 shows the number of species and the number of individuals for the palms found at each distance. There were six total species found and 177 individual palms recorded and *Chameadora costaricensis*, (Aracaceae) was the most commonly found species. Evenness ranged from 0.208 and 0.269 between 15 m and 60 m (Table 1).

DISCUSSION

Research conducted by Restrepo, Gomez and Heredia (1999) states that more birds are found in the forest than along edge habitat. This research supports the findings of this paper because decreased bird density at the edge could influence the number of fruits dispersed by birds in the forest and on the edge. In addition, the effects of this preference for forest habitat by birds would be reflected in the number of palm species found along that gradient, as palms have bird dispersed fruits (Haber, Zuchowski and Bello 2000).

Since more clay fruits were pecked in the forest than the pasture, this indicates that more frugivorous birds are visiting fruits in the forest then at the edge or in the pasture (Figure 1). This is most likely the result of the increased predation on birds along the edge. The area is much more open, making it easier for birds to be spotted by predators, and harder to escape as there are fewer trees to provide cover (Yahner 1988). The increased number of clay fruits pecked in the forest could be due to the habits of a few primary dispersers. The Emerald Toucanet (*Aulacorhynchus prasinus*, Ramphastidae), and Black Faced Solitare (*Mydestes melanops*, Turdidae), are the most important dispersers in Monteverde, as they disperse seeds of 95 and 51 plant species respectively (Murray 2000). Unfortunately the range of the birds are restricted almost entirely to interior forest and they only occasionally appear in disturbed areas (Stiles and Skutch 1989). This could influence the amount of clay fruits pecked at each habitat.

The number of fruits pecked does not asymptote in the forest, which suggests that if the experiment were run with stations extending further into the forest, the number of pecks there would increase. This is not unexpected as the 50-meter guideline for edge effects was only applied to control for abiotic conditions (Murcia 1995). Pimm's (1998) found biotic effects of an edge extend three hectares into the forest, so it is possible that the number of fruits pecked would asymptote near 300 m.

The amount if fruits pecked remained constant over the course of the study. This suggests that the birds either were not remembering that the "fruits" were clay, or that there was a continuous stream of new birds foraging in the area.

Once the fruits were dispersed, their location may determine their chance at a successful germination. Seeds dispersed to a pasture may have a decreased chance of germinating because of a thick ground cover, which the seed is not able to penetrate. In addition, the extreme environmental conditions of the edge itself, such as increased temperature, light and decreased moisture may disrupt the seed's required cues for germination (Bruna 1999). Seed predation is also higher in disturbed areas and may influence the number of seeds that germinate which would in turn influence diversity (Bruna 1999).

As with the number of fruits pecked, the diversity of palms also increased from pasture to forest (Figure 2). This data also did not asymptote which suggests that the diversity of palms would also increase if the transects were extended further into the forest.

The difference in diversity is most likely a result of many different factors, although some common problems for plants associated with pasture and edge habitat are not relevant with regards to palms. Poor soil quality and increased wind exposure are typical impediments in the recolonization of pasture; however palms seem to thrive in these conditions (Clark et al. 1995). Clark et al. (1995) did a study in the Amazon on understory palms and found that soils with the highest local palm diversity are the least fertile. She also found that palms do well in high wind environments and are often found in higher density on slope crests than at midslope. This implies that increased wind and decreased soil fertility might not negatively affect palm species around pasture in this study. Therefore the discrepancy in palm diversity from the edge to the pasture must be due to other factors.

Because of the strong correlation between clay fruits pecked and palm diversity, my data support the hypothesis that decreased palm diversity at the edge is partially a result of inadequate distribution of seeds. If the palm fruits were not being eaten as much around the edge than in the forest, it follows that less of the seeds at the edge were being dispersed. This would then affect the chances that a large number of seeds would successfully germinate at the edge. As seed predation has been shown to increase in disturbed areas (Bruna 1999) this would decrease the number of seeds on the edge relative to the interior forest. The result is that fewer plants reproduce along the edge than in the forest. The smaller population of palms will attract fewer birds and this will negatively affect the dispersal of the palms fruits.

Density dependent factors can play a role in the predation of palm seedlings. Because the density of palms increases in the forest, seedling predators may feed on the palm shoots more in the forest. This kind of density dependent predation has been shown to increase diversity (Harms et al. 2000). Therefore this could be a factor in the increased diversity of palms found in the forest.

The decreasing diversity of palms from forest to edge found in this study illustrates a problem with the recolonization of pasture. A different community might exist at the edge because of decreased diversity of palms. This community might have fewer bird dispersed plants and fewer birds. Eventually other plants might sufficiently colonize the edge so that edge effects would be reduced and would not deter the birds from dispersing fruits to the edge. However, this process would take longer than if the bird dispersed fruits were able to immediately colonize the edge. Therefore reforestation rates of pasture might be longer than previously believed. An extended study might be able to document the changes in fruit dispersal and forest composition over time, which would help in identifying ways to decrease reforestation time. Until then we must understand that cutting tropical forest can have complex consequences that are difficult to remedy.

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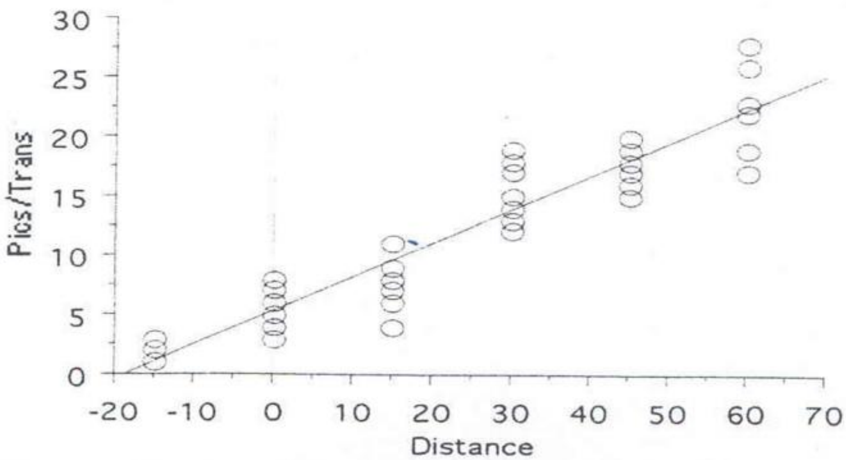

Figure 1. Number of clay fruits pecked as a function of distance (m) from pasture (-15 m) to inside the forest (60 m). (One-way ANOVA p = <0.0001, F = 653.244, R^2 = 0.918)

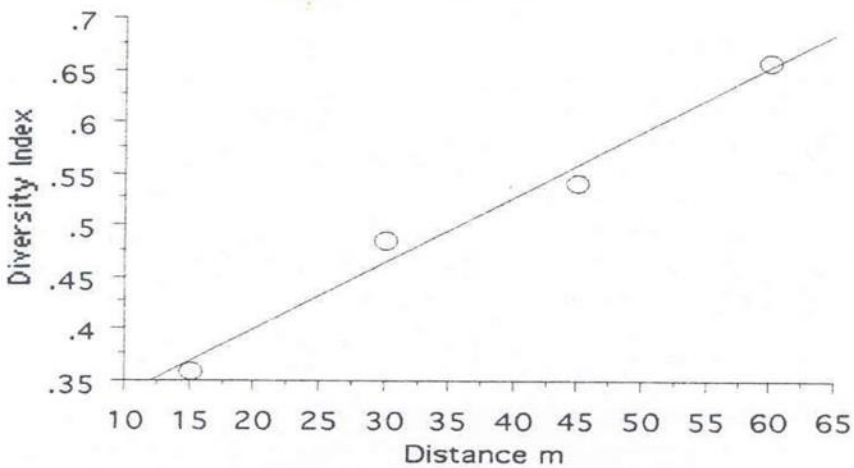

Figure 2. Shannon-Weinner Diversity index as a function of distance from pasture (-15 m) to inside the forest (60 m). (One way ANOVA p = 0.0093, F = 106.265, R2 = 0.982). Estación Biológia Monteverde, Monteverde, Puntarenas.

Table 1. Number of species, number of individuals, Shannon-Weinner Diversity index and evenness for each distance along the transect.

Distance	# of Indiv.	# of Species	Div. Index	Evenness
neg 15 m	0	0	0	0
0 m	2	1	0	0
15 m	25	3	0.36	0.208
30 m	56	5	0.485	0.217
45 m	56	6	0.542	0.221
60 m	59	6	0.658	0.269