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# **A Survey of Coleopteran Species Richness, Diversity and Abundance in Habitats along a Disturbance Gradient**

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## **ABSTRACT**

Three microhabitats in La Cruz, Costa Rica were surveyed for Coleopteran species richness, diversity and abundance in primary forest, secondary forest and active pasture. Survey sites correlated with levels of disturbance, which were hypothesized to reflect the availability and diversity of natural resources. A total of 865 Coleopterans were collected. Of the collected samples, 125 morpho-species and 22 families were identified. Species richness, diversity and abundance were calculated to see if they correlated with levels of habitat disturbance. It was hypothesized that natural resource abundance and diversity would be associated with levels of habitat disturbance. Forested areas with less habitat disturbance ought to have a greater variety of available resources on account of microclimate diversity and would therefore be able to sustain a greater diversity of Coleopterans. Results indicated that morpho-species richness was highest in primary forest whereas Coleopteran family analysis showed that family richness was highest in secondary forest. Results validate a correlation between habitat disturbance and Coleopteran diversity.

## **Resumen**

Tres microhábitats en La Cruz, Costa Rica fueron muestreados para conocer la riqueza de especies, diversidad y abundancia de los coleópteros en un bosque primario, un bosque secundario y un pastizal activo. Los sitios muestreados están correlacionados con niveles de alteración, los cuales son hipotéticamente los que reflejan la disponibilidad y diversidad de los recursos. Un total de 865 especies de escarabajos fueron colectadas. En las muestras colectadas, 125 morfo especies y 22 familias fueron identificadas. La riqueza de especies, diversidad y abundancia fue calculada para observar si la diversidad está asociada con niveles de alteración en el hábitat. Las áreas boscosas con menor alteración en el hábitat son las que presentan una mayor variedad de recursos disponibles en relación con una diversidad microclimática y por lo tanto son capaces de mantener una mayor diversidad de coleópteros. Los resultados indican que la riqueza de morfo-especies es más alta en el bosque primario, mientras que la riqueza de familias es mayor en el bosque secundario. Los resultados una correlación entre la alteración del hábitat y la riqueza de coleópteros.

## **INTRODUCTION**

Land transformation from forested habitat to agriculture, recreation and human settlement all have distinct effects on the environment. These disturbances often result in forest fragmentation, habitat shredding and edge effects, which disrupt the ecological conditions for organisms harbored there. Forest conversion to agriculture produces hotter, drier, windier, and brighter conditions than would, in secondary and primary forests. It has been proven that habitat disturbances caused by human activity have drastic effects on organism diversity (McNeely et al. 1995). The shifts in resource availability and diversity, and changes in the physical aspects of the environment, associated with land

transformation reduce the ability for resource-specialized organisms, including species-rich groups such as the beetles (Coleoptera). Land conversion may potentially alter the diversity of resources available to beetles with narrow niches and in turn may shift local Coleopteran composition. It has been hypothesized that a more diverse pool of resources supports a more diverse community of consumers (Brose 2003). The potential availability of these natural resources in habitats may be limiting factors in Coleopteran diversity, richness and abundance.

The insect order Coleoptera (beetles) is the largest of all taxa on the planet, containing approximately 400,000 described species and about 25% of all described organisms on Earth (Hanson 2000). Beetles can be found in terrestrial or even aquatic habitats, including in or upon leaf litter, canopy or understory vegetation, flowers, fruits, fungus and decaying logs (Solis 1999). Collectively, beetles have a wide variety of dietary habits: fungivory, predation, saprophagy, frugivory and phytophagy are a few examples (Hanson 2000). Hence Coleopteran community composition and richness may be correlated to alteration in the diversity and abundance of biological resources associated with environmental disturbances.

Studies in Sabah, Malaysia, comparing primary forest, logged forest, and plantations indicated that the species richness, abundance and composition of subterranean beetles correlated with amount of leaf litter (Chung et al. 2000). These studies also showed that sapling densities and plant species richness correlated with the composition, abundance and species richness of understory beetles. The magnitude of canopy cover was correlated with the presence of arboreal Coleopterans (Chung et al. 2000). Other studies found the diversity and abundance of many invertebrates on agricultural lands have been threatened by exhaustive farming practices (Carcamo et al. 1995) Rove beetles (Staphylinidae) and ground beetles (Carabidae) that prey on crop pests and are food for many members of higher trophic levels (Holland, 2007) were studied for the effects on diversity, species richness and abundance in relation to soil moisture levels on farmland. They found that soil moisture levels during the previous winter and summer were related to the oviposition selection by female beetles (Holland, 2007). Availability of natural resources like water, amongst others, may be limiting factors in Coleopteran habitation. These studies are significant in that they suggest that beetle species richness, diversity and abundance are influenced by the abundance and distribution of available resources. However, there is a lack of information regarding how habitat disturbance correlates with resource availability and how these factors may affect Coleopteran habitation.

This study examined the relationship between habitat disturbance and Coleopteran diversity in three habitats in La Cruz, Costa Rica: primary forest, secondary forest and pasture. Each habitat corresponds to a different level of disturbance, with primary forest being undisturbed, secondary forest being moderately disturbed and pastureland being highly disturbed. I hypothesized that the level of habitat disturbance correlates with the level of natural resource diversity, habitats that offer a wider variety of resources, e.g. fruit, fungus or detritus ought to potentially sustain an overall greater diversity of Coleopterans. It has been shown that insects are prevalent and vital elements within ecosystems (Janzen, 1987) that noticeably react to environmental alterations. Thus they potentially may be used as valid indicators of habitat conditions (Chung et al. 2000).

## **MATERIALS AND METHODS**

### **Study Sites**

Coleopterans were collected in three different habitats in La Cruz, Costa Rica: pastureland, primary forest and secondary forest. All three habitats were located on a privately-owned of land at approximately 1440 m in elevation. Habitats were in close proximity to one another, with pasture adjacent to secondary forest and secondary forest adjacent to primary forest. This created a habitat disturbance gradient. The pasture was actively grazed and was primarily comprised of tall grass. The secondary forest was relatively young, with an abundance of small trees and herbaceous understory plants whereas the primary forest was primarily made up of large canopy trees and scattered herbaceous understory.

### **Collecting Methods**

Collection took place within 300 m<sup>2</sup> transects in each microhabitat. Transect sites were surveyed seven times over the course of a three-week period between mid-April and the beginning of May. Three methods of collection were used: hand-collecting, beating the vegetation and sweep-netting. Beetles were collected for 1 hour in each site for 7 days. A sweep net was used to collect fallen specimens after plant matter was beaten with a wooden pole. Specimens captured within sweep-net were incrementally collected and placed in habitat specific collecting vials filled with ethanol. Ethanol served in killing and preserving specimens. Sweep-netting took place when it optimized collecting efficiency, generally being applied in the pasture and secondary forest where herbaceous plant matter was more abundant. These samples were also placed in habitat specific collecting vials filled with ethanol. Hand collecting occurred during beating and sweep-netting collection. Hand-collected samples were also placed in ethanol filled collecting vials that were habitat specific.

### **Sorting and Identification**

Specimens were kept in collecting vials that were labeled with habitat site and day of collection. Samples were then sorted into morpho-species according to family using a family reference guide and a dissecting microscope. If the family of a particular specimen could not be identified then it was placed in category called Unknown.

### **Statistical Analysis**

Samples were sorted to family level and identified to morpho-species. Species richness, evenness and diversity indices were calculated for morpho-species. Differences in Shannon-Weiner diversity index between all habitats were then compared using a modified t-test. Species richness, evenness and diversity were then calculated at the family level to indicate family composition within habitats. There was no modified t-tests performed comparing family diversity between habitats.

## RESULTS

A total of 865 beetles were collected, of which 125 morpho-species were identified along with 22 families. Species richness was found to be highest in primary forest habitats followed by secondary forest and then pasture (Figure 1). Diversity for the primary forest was greater than for either the pasture (modified t-test,  $t = 9.74$ ,  $P < 0.001$ ) or secondary forest (modified t-test,  $t = 2.43$ ,  $0.02 < P < 0.05$ ). Secondary forest had greater diversity than pasture (Modified t-test = 6.76,  $0.001 < P < 0.05$ ) The Margalef's diversity index for the primary forest was higher than for secondary forest, and pasture had the lowest diversity (Figure 1c). Pasture had a greater evenness than primary forest or secondary forest (Figure 1d).

Comparison of family composition indices indicated that family richness was highest in the secondary forest and that both primary and secondary forest had greater family richness than pasture (Figure 2a). Diversity was highest in primary forest followed by secondary forest, and then pasture (Figure 2c). The Margalef's index of diversity increased going from pasture to secondary forest and was greatest in primary forest (Figure 2b). Family evenness was higher in primary forest than in either secondary forest or pasture (Figure 2d).

There was noticeable turnover between the pasture and the primary forest, with Ptilodactylidae, Monotomidae, Carabidae, Lycidae and Scarabaeidae only found in the primary forest, whereas Staphylinidae, Brentidae and Coccinellidae were only found in the pasture. Between the pasture and secondary forest there was also turnover, with Passalidae and Coccinellidae only present in the pasture. The secondary forest had Ptilodactylidae, Cantharidae, Lycidae and Languriidae whereas the pasture did not have these families present. There were fewer turnovers between the primary forest and the secondary forest, with Buprestidae and Mordelidae only found in the primary forest and Cerambycidae only found in the secondary forest.

## DISCUSSION

The results here show that coleopteran species and family diversity differ significantly across a disturbance gradient. These differences may be due to reduction in the diversity may be correlated to the diversity or abundance of natural resources caused by conversion of forest to pastureland. Primary forest had the greatest morpho-species richness and diversity, indicating that forest systems can harbor more complex Coleopteran community by providing resource and microhabitat variation. In addition, the species and family composition, and the trophic levels, of beetle communities present changed dramatically between habitats, which may mirror resource and microhabitat availability. Niche diversity as inferred from species diversity, however, does not necessarily correlate with diversity of resource types, as many of the morpho-species may have been dependent upon exclusive resources; e.g. only herbaceous plant matter, only fungus, etc. Beetle species that are part of the same guild are primarily dependent upon similar resource types and therefore may not be good indicators of overall resource diversity.

Feeding guild diversity may be reflected by beetle family diversity, since many families are characterized by what they eat. The results here of the analyses of family-

level diversity show that primary forests harbor a greater diversity and this likely to be related to the variety of available foods. Collectively, beetle families possess a wide variety niches that fall into numerous feeding guilds, specialized on certain resources. For instance, the family Chrysomelidae feeds primarily on the foliage of herbaceous plants (Solis 1999). The family Curculionidae primarily feeds on various live plant matter, including leaves, seeds, fruits, stems, wood, flowers, etc. (Solis 1999). Other families such as the Carabidae, are characterized by being very predatory, feeding on small insects on the forest floor (Solis 1999).

Studies done in Yucatan, Mexico found that agricultural lands possessed significantly fewer beetle families than in primary dry forest (Goode 2003). This supports the concept that areas with low resource variation possess a low numbers of Coleopteran families. Agricultural lands are primarily made up of uniform vegetation and lack variable ground microclimates that would be conducive to terrestrial Coleopteran feeding guilds. Other studies done with dung and carrion beetles found that forest fragmentation drastically reduced mammal and bird populations. Mammals and birds produce wastes that carrion and dung beetles feed upon and are therefore limiting resources for these beetles. Fragmentation indirectly resulted in the reduction of dung and carrion beetle populations (Klein 1989).

Differences in beetle family diversity across habitats reflect differences in resource diversity and abundance. The great abundance of Chrysomelids in the primary forest can be explained by the higher abundance of plant material on which they feed, independent of the diversity of plants they use. Ptilodactylids, which are generally saprophageous, were highly abundant in the primary forest because of the great availability of rotting material. Carabid abundance was higher in the primary forest and secondary forest presumably on account of the leaf litter and ground cover abundance. The forest had a higher family diversity and family richness, which implicated greater resource diversity than in either the secondary forest or the pasture. The abundance of smaller trees and herbaceous plant matter in the secondary forest resulted in a high abundance of Curculionids. Family diversity and richness was moderate in the secondary forest indicating that resource diversity was higher than in the pasture but lower than in the forest. The pasture had a limited amount of vegetation, which was mainly tall grass. Thus there was a high abundance of phytophageous Chrysomelids who were feeding on the abundant grasses. The pasture also had a high abundance of Coccinelids, which typically are predators of small insects (Solis 1999) that were highly abundant in pasture. Diversity of resources proved to be lowest in the pasture as there was less family diversity and family richness.

Turnover of families within habitats along a disturbance gradient suggest that certain resources may be exclusive to certain habitats. The presence of Ptilodactylidae in the primary forest and secondary forest suggests that there is a relatively high abundance of decaying matter available in relation to in the pasture. Coccinelidae only being present in the pasture indicates that there may be a greater abundance of prey items that are potentially excluded from the secondary forest and primary forest. Not all turnovers seems to be significant, as many families that were found in a particular habitat, such as Languriidae in the secondary forest, only had a few individuals that may have only been present due to environmental stochasticity. Families with such low abundance may have

been an anomaly in a given habitat, thus such minimal turnover may not be a good representation of the families local composition.

The study shows that Coleopteran species and family diversity within habitats proved to correlate with levels of habitat disturbance. Decreased landscape heterogeneity, reduced habitat diversity and increased land use threaten biodiversity (Hendrickx 2007). Habitat disturbance associated with human land transformation causes forest fragmentation. Fragmentation causes changes in the biodiversity that shift resource diversity and abundance (Klein 1989). Coleopteran communities are significantly altered by these changes, as limitations in certain resources can prevent certain beetle guilds and or families from inhabiting affected areas. While this study offered significant results indicating that diversity differed between habitats, Coleopterans were only sampled from the understory level and no canopy level diversity was taken into account. The primary forest most likely possesses high diversity and abundance at the canopy level, whereas in the secondary forest and pasture the canopy would not be as significant. Additionally, because Coleoptera is such a large and diverse order of insects, there is little information regarding their ecological resilience of beetle communities. Future studies could look at how Coleopteran diversity and abundance changes in the periods immediately after forest fragmentation, to determine the following patterns of community turnover.

## **ACKNOWLEDGEMENTS**

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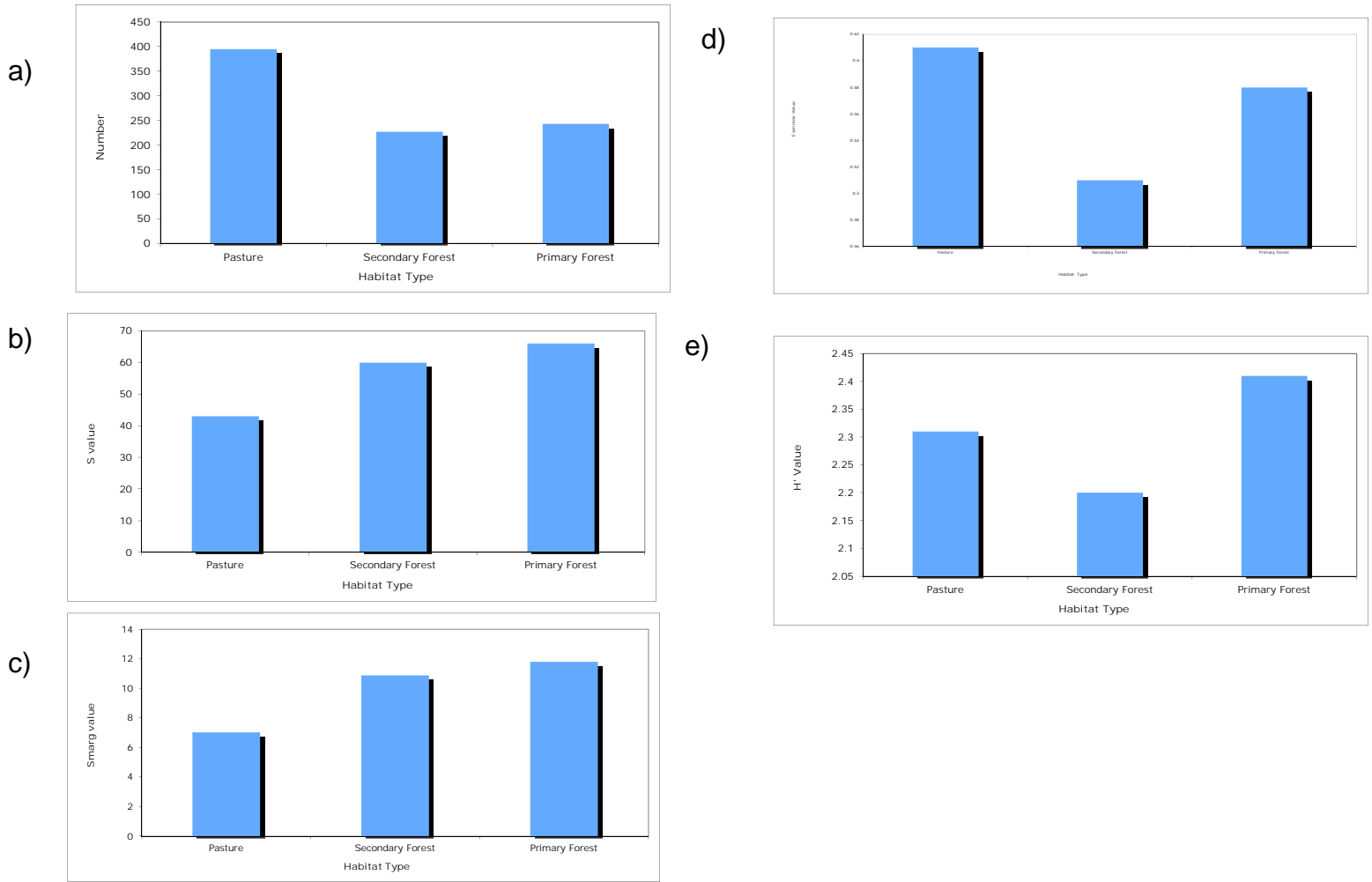
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**FIGURE 2.** Beetle community diversity and richness parameters for pastureland, secondary forest, and primary forest at La Cruz, Costa Rica. a) Number of individuals vs. habitat types, b) Species richness vs. habitat types, c) Margalef's index vs. habitat types, d) Evenness vs. habitat types, e) Shannon-Weiner Diversity Index vs. habitat types

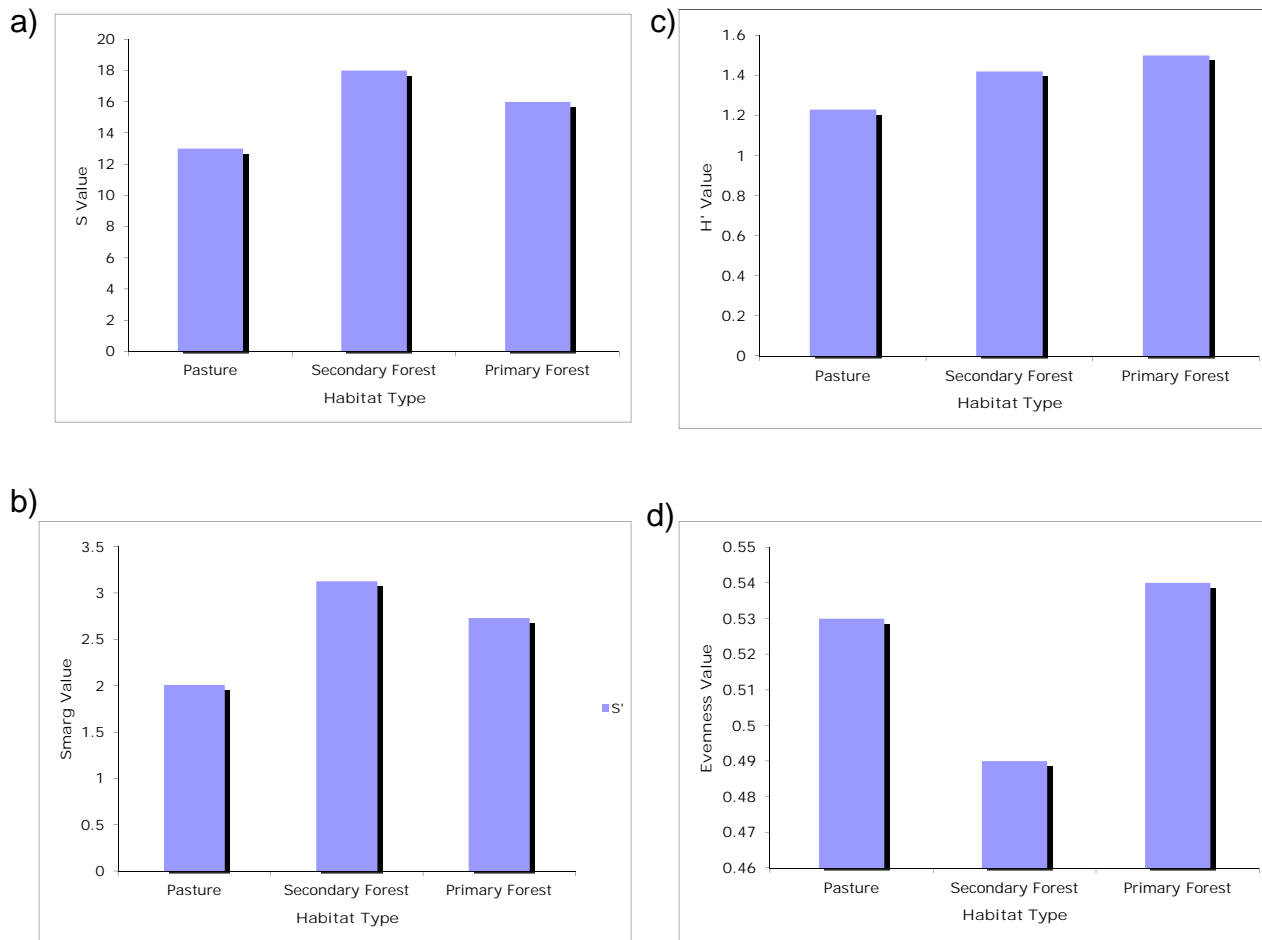
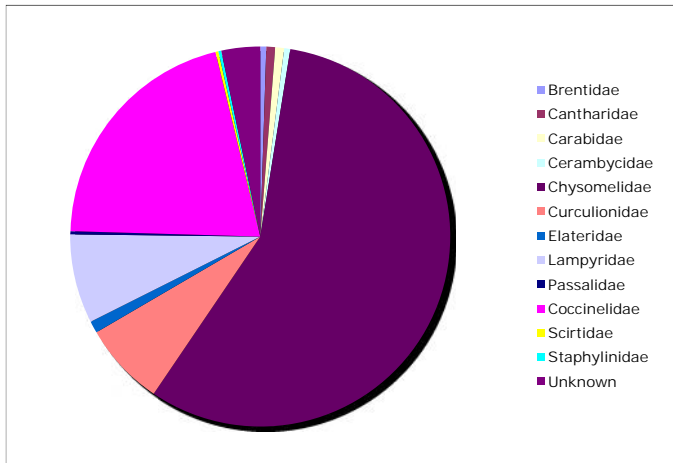
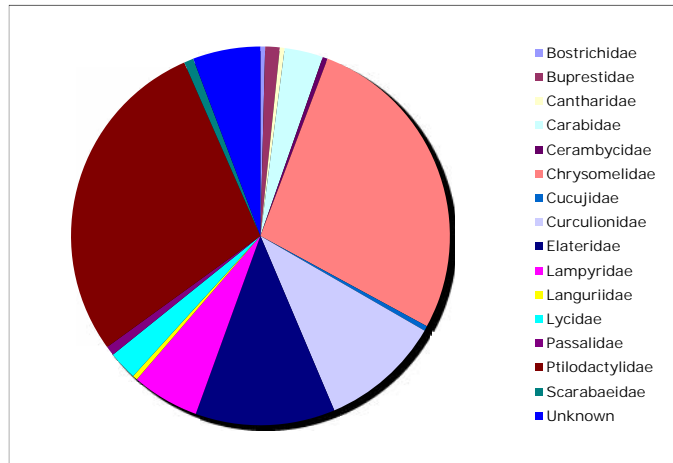


FIGURE 2. Coleopteran family diversity and richness across three habitats of variable disturbance. Results show that species richness is highest in the secondary forest, while diversity is highest in the primary forest. a) Species richness vs. habitat type, b) Margalef's index vs. habitat type, c) Shannon-Weiner Index vs. habitat type, and (d) Evenness vs. habitat type

a)



c)



b)

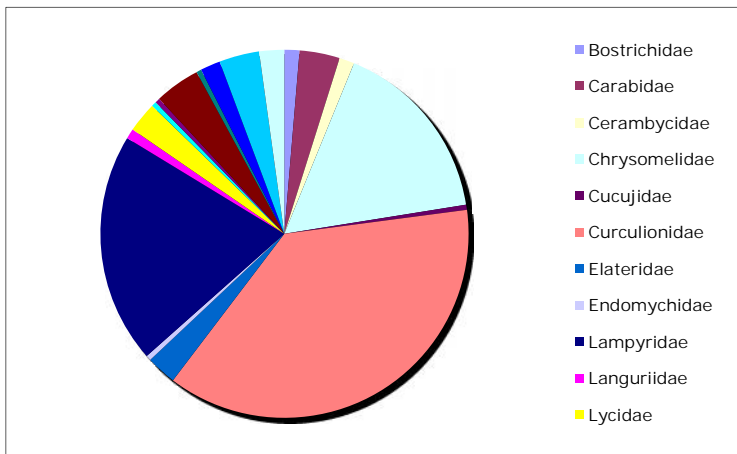


FIGURE 3. Percentage of beetle families found in pasture had a high percentage of Chrysomelidae. Secondary forest had a high percentage of Curculionidae. Primary forest had a high percentage of Ptilodactylidae and Chrysomelidae. a) Secondary Forest family composition, b) Primary Forest family composition c) Pasture family composition.

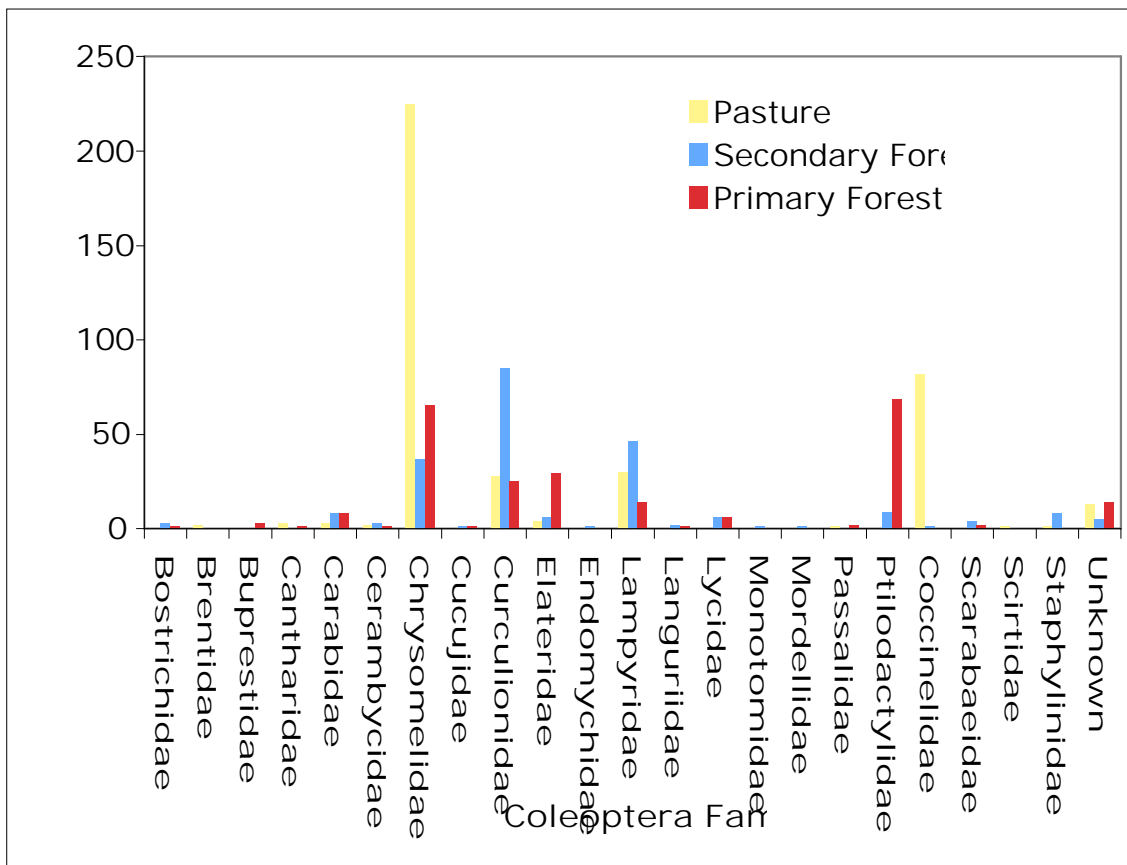


FIGURE 4. The number of individuals found for each family in three habitats of variable disturbance. Chrysomelids dominate pasture whereas Ptilodactylids dominate primary forest and Curculionids dominate secondary forest.

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APENDIX 1. The number of individuals found per morpho-species totals for pasture, secondary forest and primary forest.

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<u>Morpho Species</u>	<u>Pasture</u>	<u>Secondary Forest</u>	<u>Primary Forest</u>
Bostrich-Ablack	0	2	1
Bostrich-Bora	0	1	0
Brent-A	1	0	0
Brent-B	1	0	0
Bupres-A	0	0	3
Canth-A	1	0	0
Canth-B	2	0	0
Canth-C	0	0	1
Carab-A	0	2	8
Carab-B	0	4	0
Carab-Clineyel	0	2	0
Ceramb-A	1	0	0
Ceramb-B	1	1	0
Ceram-C	0	2	0
Ceram-C/sm	0	0	1
Chrsmelid-A	31	0	0
Chrsmelid-BG	5	0	0
Chrsmelid-C	2	0	0
Chrsmelid-D	3	0	0
Chrsmelid-EG	27	16	8
Chrsmelid-F	3	0	0
Chrsmelid-G/sm	146	1	4
Chry-brmetgr	0	2	0
Chrys_Tur-Y	0	0	1
Chrys-blgout	0	1	0
Chrys-BIO	4	2	2
Chrys-drkbr	0	1	0
Chrys-LGWS	0	1	0
Chrismelid-H	2	0	1
Chrismelid-I	2	0	1
Chrismelid-J	1	0	0
Chrismelid-K	0	0	1
Chrismelid-L	0	0	3
Chrismelid-M	0	2	1
Chrismelid-N/gmot	0	0	3
Chrismelid-O/wpock	0	0	1
Chrismelid-P	0	0	1
Chrismelid-Q/mb	0	0	6
Chrysm-whbluespot	0	0	1
Chrys-roundred	0	1	0
Chrys-smrflat	0	1	0
Chrys-smyblmot	0	1	0
Chrys-Tur-G	0	0	5

Chrys-Tur-R	1	1	17
Chrys-Tur-R	0	0	1
Chrys-whblspot	0	3	0
Chrys-white	0	2	3
Chrys-whlng	0	1	0
Chrys-whspotyhead	0	1	0
Chrysyshinyg	0	0	6
Cucu-A	0	1	1
Curculio-A	1	0	0
Curculio-B/sm	18	49	5
Curculio-blgw	3	2	2
Curculio-blwstr	0	0	1
Curculio-C	5	1	0
Curculio-D/WS	1	0	1
Curculio-E/Wh	0	2	2
Curculio-F	0	3	1
Curculio-G	0	18	3
Curculio-H	0	0	3
Curculio-I	0	2	2
Curculio-J/bs	0	1	1
Curculio-K/bb	0	3	1
Curculio-Lbigblack	0	0	1
Curculio-Mblk	0	1	0
Curculio-pinkgr	0	1	0
Curculio-smlbr	0	0	2
Curcuolio-brbspot	0	2	0
Elater-A	1	0	0
Elater-B	1	0	0
Elater-bllrg	0	1	0
Elater-blyllrg	0	1	0
Elater-byellin	0	0	1
Elater-C/cross	1	0	0
Elater-D	1	0	0
Elater-E	0	0	2
Elater-F	0	0	1
Elater-G	0	0	1
Elater-H	0	0	1
Elater-I	0	2	3
Elater-J	0	0	11
Elater-K	0	1	4
Elater-L	0	1	5
Endomych-Abrr	0	1	0
Lampyrid-A	14	40	5
Lampyrid-B	3	0	0
Lampyrid-C	8	0	1
Lampyrid-D	5	0	0
Lampyrid-E	0	6	7
Lampyrid-F	0	0	1
Langur-A	0	1	1

Langur-B	0	1	0
Lycid-A	0	6	6
Monot-A	0	1	0
Mordelid-A	0	1	0
Passalid	1	0	2
Ptilodac-A	0	2	57
Ptilodac-B	0	7	12
Redcocci	82	1	0
Scarab-A	0	0	2
Scarab-Bgrgeo	0	2	0
Scarab-snae	0	2	0
Scirtid-A	1	0	0
Staph-A/sm	1	4	0
Staph-B	0	4	0
Unk-chrys-twodot	0	1	0
Unknown 1	1	0	0
Unknown 3	2	0	0
Unknown 4	1	0	0
Unknown 5	1	0	0
Unknown 6	3	0	0
Unknown 7	1	0	0
Unknown 8	1	0	0
Unknown smg	0	1	2
Unknown-10	0	0	1
Unknown-11	0	0	1
Unknown-12/smfuzzspot	0	0	4
Unknown-13-whitepoint	0	0	1
Unknown-14orangespot	0	0	1
Unknown-15blackcom	0	0	2
Unknown-16-mord	0	1	0
Unknown-9	0	0	1
Unknown-coolant	0	1	0
Unknown-teneb	0	1	0
Unkown 2	4	0	0

APENDIX 2. The number of individuals per Coleopteran family in three habitat types. The pasture possessed a high abundance of Chrysomelids. Secondary forest possessed a high abundance of Curculionids. Primary forest possessed a high abundance of Ptilodactylids and Chrysomelids.

<u>Family</u>	<u>Pasture</u>	<u>Secondary Forest</u>	<u>Primary Forest</u>
Bostrichidae	0	3	1
Brentidae	2	0	0
Buprestidae	0	0	3
Cantharidae	3	0	1
Carabidae	3	8	8
Cerambycidae	2	3	1
Chysomelidae	225	37	66
Cucujidae	0	1	1
Curculionidae	28	85	25
Elateridae	4	6	29
Endomychidae	0	1	0
Lampyridae	30	46	14
Languriidae	0	2	1
Lycidae	0	6	6
Monotomidae	0	1	0
Mordellidae	0	1	0
Passalidae	1	0	2
Ptilodactylidae	0	9	69
Coccinelidae	82	1	0
Scarabaeidae	0	4	2
Scirtidae	1	0	0
Staphylinidae	1	8	0
Unknown	13	5	14