Diversity and Abundance of Subsoil and Leaf Litter Invertebrates Across Different levels of Disturbance in a Costa Rican Cloud Forest

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Introduction

The high diversity of plants, animals, and fungi species in the tropical forests creates a variety of biotic and abiotic interactions and processes which lead to high levels of productivity. For example, bacteria, fungus, and microinvertebrates living in the leaf litter and subsoil of the forest floor contribute to the health of the soil itself (Wolters 2000). As decomposers, they convert the detritus on the ground to organic soil. Their presence in the soil can add to or take away from the stability and richness of the soil in which plants take root. Additional invertebrates are the predators of the lower trophic levels which participate in such processes. Their control of the population numbers of the decomposers is also a variable in the health of the soil.

A consistent presence of a rich organic layer of soil provides a more stable place for invertebrates to live (Chauvat 2007). This creates a positive feedback mechanism, where the healthier soil promotes the presence of invertebrate populations, which in turn continue to convert litter into nutrient rich soil. However, population numbers of invertebrates vary in accordance with natural changes in season, temperature, amount of rainfall, altitude and other environmental gradients (Wiwatwitaya 2005, Wong & Nortcliff 1995). Additionally, uncharacteristic changes to an ecosystem such as floods (Tronstad et al 2005) or other human interference (Folgarit 1998) can cause drastic changes to invertebrate populations. Examination of the abundance and species richness of soil in forests prey to different degrees of disturbance should vary accordingly in their invertebrate population numbers. This study sets out to measure the difference in species diversity of subsoil and leaf litter invertebrates between old growth forest plots, reforested areas, and disturbed pasture land. The more undisturbed the location, the more abundant and diverse the species composition of the soil should be.

This study provides a baseline for healthy invertebrate population numbers on the Cloudbridge Reserve. Studies of humus composition of the soil have been used to get an insight on invertebrates which might inhabit the soil (Chauvat 2007). Here the data will be collected in the reverse direction; the invertebrates will be used to gain an insight into the richness of the soil and the decomposition of the humus. This data can allow comparisons to be made with populations in newly forested land, which will provide an option for a method to monitor progress in reforested land. Additionally, it will add to a general knowledge about the diversity of invertebrates which inhabit the cloud forest, particularly in Cloudbridge Reserve.

Methods

This study took place on the Cloudbridge Reserve, a tropical cloud forest located in the South Pacific foothills of Costa Rica at an elevation of about 1550 m. The reserve acquires pastureland in order to convert back to a forested area. The presence of forested, reforested, and recent pasture land makes this location ideal for comparative studies. Old growth and secondary growth sites were selected on the reserve while the pasture samples were collected from a neighbor's cow pasture. The secondary growth is the result of a plantation effort 18 months prior to the study. Since it has been found that soil invertebrate species have altitudinal ranges of about 500 m (Olson 1994), the samples were all taken from sites similar in elevation. One site was selected for each level of disturbance. At each site, a location was chosen sufficiently far from a trail or road to not be affected by foot traffic. A transect was placed at each site in order to prevent localized differences in samples from affecting the results. Three samples were removed from a 50 cm x 50 cm square to a depth of about 3 cm, with 1 m between samples. Samples were collected between November 5, 2007 and November 27, 2007, during the transition from the wet season to the dry season. A profile of the sites can be found in Table 1.

The goal was to collect any leaf litter resting on top of the soil, as well as the soil itself. Including soil in the study ensured that any small organisms on the surface would be collected, and it also allowed pasture land to be included in the study which does not contain significant amounts of leaf litter. First, any loose leaf litter or decaying wood was collected from the surface of the quadrant. Next, any small vegetation was chopped at a location close to the soil so invertebrates which rely on live plant material would not be included. Finally, the top layer of soil was removed to an approximate depth of 3 cm, which functionally was the soil within a system of thin roots. Removal of the sample was done quickly to minimize escape of organisms from the disturbance. The soil sample was carried down to an indoor lab in a closed bucket in order to be hand sorted. Looking for the invertebrates by hand turned out to be the most feasible method in an environment which is too wet to dry the samples through the use of a Berlese funnel without the use of electricity at amounts which were unavailable.

The richness and abundance of individuals of each Class or Order was noted, but the diversity of each community is a more relevant number to understanding community structure. The Shannon and Simpson diversity indices were used to measure the diversity of each sample. The Shannon diversity index is $H=\Sigma\ p_i * \text{Ln}\ p_i$, where p_i is the number of individuals of one group in proportion to the number of individuals in the whole community. The Simpson index calculates diversity with the formula $D=[\Sigma\ n(n-1)]/N(N-1)$, where n is the number of individuals of one group and N is the total number of individuals. The value of 1/D is usually used to represent a community's diversity because it allows the index to increase as diversity increases. The Simpson index gives more weight to the most dominant members of the community than the Shannon index.

Results

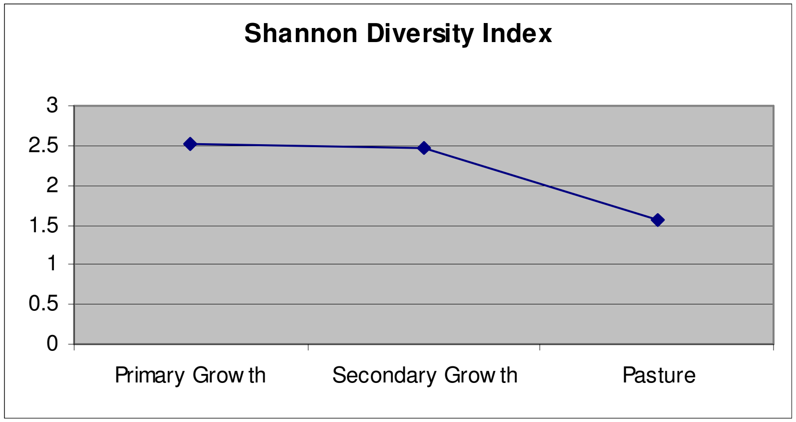
The number of specimens collected and identified can be seen in Table 2. Insects and Arachnids were identified down to Order, with some particularly specialized Families identified. Chilopods, Diplopods, Gastropods, and Oligochaetes were identified only to Class. This classification still gives a clear indication of community structure because any species within these groups would serve the same function in the community. Some Insects could not be identified due to their small size, but it is worth pointing out that these small specimens only occurred in old growth and secondary growth forest. Individuals of the Order Collembola, commonly known as

Table 1: Sample location profiles

	Primary Forest			Secondary Forest			Pasture		
	1	2	3	1	2	3	1	2	3
Elevation (m)	1795	1795	1795	1742	1742	1742	1520	1520	1520
Date Collected	11/5/2007	11/6/2006	11/9/2007	11/12/2007	11/13/2007	11/13/2007	11/23/2007	11/23/2007	11/27/2007
Time Collected	8:30am	9:30am	9:00am	9:45am	9:15am	9:55am	8:20am	8:30am	7:50am
Date Specimens Identified	11/7/2007	11/8/2007	11/9/2007	11/13/2007	11/13/2007	11/14/2007	11/23/2007	11/26/2007	11/27/2007
Rainfall Date Collected	38mm	38mm	13mm	10mm	8mm	8mm	2mm	2mm	trace
Temperature Range Date Collected (℃)	13.4-19.4	12.8-20.3	14.9-17.3	13.7-17.9	13.5-19.1	13.5-19.1	12.8-21.5	12.8-21.5	13.4-19.4
Distance From Trail/Road	15m	15m	15m	5m	5m	5m	20m	20m	20m
Vegetation Cover	80% litter	75% litter	25% stump	50% litter	100% litter	90% litter	100% low veg	100% low veg	100% low veg
	5% low veg	5% low veg	15% rock	50% low veg		10% low veg	rocky	rocky	rocky
			50% litter						

Figure 1: Graphs of Shannon and Simpson diversity indices illustrating a drop in diversity in the pasture samples

a)Shannon index



b)Simpson index

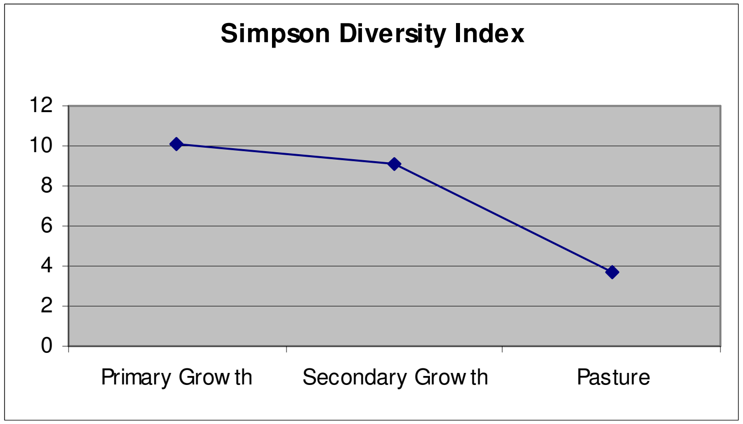


Table 2: Abundance, Richness, and Diversity of individuals found in the three levels of disturbance, each with samples collected from locations 1-3.

	Abundance:	Primary Forest			Secondary Forest			Pasture		
Class	**Order**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Insecta	Coleoptera (Leiodidae)	7	13	5	7	1	3	0	0	1
	Coleoptera (other)	1	2	0	5	9	3	1	0	1
	Coleoptera (Staphylinidae)	0	38	9	6	21	3	6	6	7
	Coleoptera(Carabidae)	0	0	0	0	1	1	0	0	0
	Collembola	18	51	17	29	39	31	22	16	62
	Dermaptera	5	9	4	0	0	0	0	0	0
	Diptera	1	0	1	1	0	0	0	0	0
	Hemiptera (Naucoridae)	0	0	0	0	0	0	1	1	1
	Hemiptera (other)	2	1	0	0	1	0	0	0	0
	Holometabolous larva	8	15	9	19	10	4	9	7	14
	Homoptera	1	1	4	1	0	5	1	1	0
	Hymenoptera (Formicidae)	22	12	3	25	14	6	64	24	108
	Isoptera	0	0	0	0	0	0	0	61	0
	Mecoptera*	3	28	4	1	0	0	0	0	1
	Orthoptera (Blattoidae)	1	0	0	0	1	0	0	0	0
	Orthoptera (other)	0	0	0	0	0	1	0	0	1
	Orthoptera (Phasmatidae)	0	0	1	0	0	0	0	0	0
	Psocoptera	3	5	1	0	12	15	0	0	0
	Thysanura	1	0	0	3	0	1	0	0	0
Chilopoda		1	8	7	19	24	16	1	0	0
Diplopoda		4	6	15	6	18	8	0	1	2
Crustacea	Isopoda	0	7	2	6	6	4	1	0	0
Arachnida	Acarina	10	28	0	7	3	5	0	0	0
	Araneae	2	8	0	6	26	7	0	4	7
	Pseudoscorpionidae	3	5	0	1	4	2	0	0	0
Oligochaete		0	7	0	32	8	1	23	32	32
Gastropoda		0	1	1	0	0	0	0	1	0
	Richness	18	19	15	17	17	18	10	11	12
	Shannon Diversity Index	2.5	2.5	2.6	2.4	2.5	2.5	1.5	1.7	1.5
	Simpson Diversity Index	9.2	9.5	11.6	9.1	9.7	8.4	3.2	4.3	3.7

*Uncertain Identification

springtails, were a dominant component of populations from all disturbance levels. Rove beetles (Family Staphylinidae) and ants (Family Formicidae) were also a common occurrence in most samples. Old growth forest had average diversity indices of 2.53 (Shannon) and 10.10 (Simpson). Secondary growth diversity was found to be 2.47 (Shannon) and 9.01 (Simpson). The pasture communities had much lower diversities of 1.57 (Shannon) and 3.71 (Simpson). This drop in diversity is illustrated in Figure 1a and 1b. Wild populations usually have a Shannon index between 1.5 and 3.5. The Simpson indexes can be understood relative to each other within this study. This drop in diversity went hand in hand with a much lower number of species in the pasture, with many of these groups being represented by only one individual (lower abundance).

Discussion

Invertebrate populations in the pasture were much lower in richness, abundance, and diversity than the old growth or secondary growth forest. The groups represented in the pasture population were a subset of those found in the nearby reserve, with specimens of the Order Isoptera (termites) being the only new members of the community. There was no significant difference between the richness, abundance, diversity, or structure of the community of the old growth and secondary forest. This can be seen as an indication that the soil of the secondary growth forest has already been restored to a natural state since replanting. Using the community structure of the old growth forest as a standard to compare to other soils is a methodology for using it as a bioindicator of soil health and plantation success.

A few invertebrate groups occurred across all three soil types in similar abundances. Representatives of the insect Family Collembola, commonly known as Springtails, were always found to be one of the most abundant members of each community. Springtail species are known to be fungus, humus, or soil consumers (Wiwatwitaya & Takeda, 2005). This places them in the category of decomposers and indicates that they play an important part in the breakdown of organic matter into new soil. Microinvertebrates, bacteria, and fungi are the most common decomposers. Many of the invertebrates involved in the scale of this study were not active decomposers and did not affect soil directly. Instead, they alter soil composition by controlling lower trophic level population numbers or by changing soil structure with their movements beneath the surface (Wolters 2000). Earthworms and other members of the Phylum Annelida are constantly turning over soil as they travel. Additionally, earthworms consume particles of soil in order to digest the microorganisms surrounding the particulate, which controls lower order populations, as well as the chemical composition of the soil when it is expelled as excrement. Worms were actually a more common occurrence in the pasture samples, although they did regularly occur in the secondary growth samples as well. Their absence from the primary growth may be just a characteristic of the location the sample was taken from. Ants of the Hymenoptera Family Formicidae were also a regular occurrence in all locations. Their buried tunnel system aerates, drains, and mixes the soil (Folgarait 1998). Additionally, their feces also change the soil's chemical composition. Many of the Families found in this study's samples contain some species which are consumers of decaying plant matter but other species which are predators, examples including Coleoptera, Acari, and Orthoptera. Further identification down to genus or species would be required to determine the role individuals found in these samples played. Additional Families such as Aranea, Chilopoda, or Diplopoda are likely to be the predators of these communities or feed on live plant matter such as Hemiptera or

Homoptera. Fewer predators and live plant eaters were found in the pasture samples, probably due to the decreased amount of prey and diverse vegetation.

The results of this study have laid a foundation for further research into invertebrate populations in Cloubdbridge Reserve, cloud forest habitats, or soil invertebrate studies in general. Invertebrate diversities can be seen as being along a continuum between the low diversity of the pasture and the higher diversity of the primary growth forest. Any forest location can be selected and placed along the continuum in order to judge its relative diversity. Alternatively, the basic structure discovered in this study may be compared to samples taken at differing elevations, soil types, or times of year. Collembolan and Acari populations are known to decrease during drought conditions and fluctuate throughout the year (Wiwatwitaya & Takeda, 2005). Also, a more specialized look can be made to identify specimens to the genera or species. This may give us a new concept of the diversity of the community with certain Families being more diverse than others turn out to be.

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