The Impact of Soil Quality on Macro-invertebrate and Tree Richness and Abundance at Glacial Sites

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Abstract

The purpose of our study was to test whether soil quality had an impact on the richness and abundance of soil invertebrates and trees, as well as tree growth, in an outwash plain and moraine. We measured the DBH and recorded the species and number of trees. We also collected invertebrates using pitfall traps and leaf litter plots and analyzed soil for moisture content, pH, %C and %N. We found that there was a significant difference in distribution of invertebrate classes between the two sites ($p<.05$), but the differences in biodiversity and abundance of soil invertebrates were not statistically significant. Trees grow larger, are more abundant, and more diverse in the moraine, which may be due to differences in pH. Trees may be better indicators of soil quality than soil invertebrates, and geographic location could play a bigger role in predicting biodiversity than glacial history.

Introduction

The study of soil quality is vital to the study of ecosystems as it affects all biotic processes in a community (Stork & Eggelton 1992). Soil invertebrates are organisms that are deeply interconnected with soil, which provides them with nutrients, water, and refuge from fluctuating atmospheric temperatures such as light and wind (Kamin 2011). The aspects of soil that affect its suitability for invertebrates include nutrient composition, moisture and acidity (Kamin 2011). Sediment deposition from past glacial events greatly impacts soil quality in moraines and outwash plains, like those from our study sites in Pellston, Michigan. Outwash plains are the result of glacial streams that form south of a terminal or end moraine and carry sediments from the glacier. Sediments become water sorted as the streams run south, resulting in a homogenous mixture of sediments that usually consists of larger permeable particles, like sand and gravel, which are poor for retaining moisture and nutrients. Lateral moraines build up next to the lobe of a glacier as it travels, depositing and accumulating non-sorted sediments, or till. Till contains has all sizes of debris, from erratics to clay, and finer particles that can hold moisture in the root zones which can be used more readily by organisms, resulting in more organic matter and higher soil productivity. (Pidwirny 2006)

Our question focuses on whether soil quality has a significant effect on the overall richness and abundance of certain populations, such as macro-invertebrates and trees. It is important to study these invertebrate soil communities because many soil invertebrates provide ecosystem services, including soil fertility, podsolization, decomposition, nutrient cycling, water filtration and carbon storage, the latter of which alleviates stress on the ecosystem caused by climate change (Sylvain & Wall 2011). We hypothesize that macro-invertebrate and tree populations will both have increased diversity and abundance in the lateral moraine compared to the outwash plain, and trees will also be larger in the moraine. We predict that there will be a significant difference in soil factors in both locations as well, as soil quality is expected to positively relate to population diversity or abundance. In addition, we compared the efficiency of two different invertebrate sampling methods. In conducting this study, we hope to gain a better understanding of the correlation between soil quality and biodiversity at different glacial sites.

Materials and Methods

We conducted our research in a lateral moraine on the far east side of Pellston, MI and an outwash plain on the northeast side. These glacial formations were carved out during the Wisconsinan glacial period from about 23,500 years ago to 10,000 years ago (Batra et al. 2010). At both sites, we used the same methods to gather data on tree growth, soil quality and invertebrate inhabitance.

Measuring Invertebrate Richness and Abundance

We used two invertebrate sampling methods at each site: leaf litter plots and pitfall traps. For the traps, we had four 10m x 50m transects set up at each site within a 40m x 50m square plot, containing a total of 24 pitfall traps. Traps were located on the two outer 10m x 50m transects, spaced 10m apart. We created the traps by inserting plastic cups into dug-out sections in the ground that contained an antifreeze solution to lure and kill the invertebrates. Soap was also added to deter vertebrates from falling in the traps. We checked the cups every day for four days to make sure no vertebrates had fallen into them. We then filtered out the antifreeze soap solution so that only the invertebrates remained and filled large jars with ethanol to preserve the invertebrates.

At each site we also sampled invertebrates by creating 24 random plots within the remaining two inner 10m x 50m squared plots, each of which had an area of .33m^2. Within these plots we sifted through the leaf litter at the very top of the "O" horizon, focusing on organic matter, and picked out any macro-invertebrates we could catch and recorded the ones we could not. Captured individuals went into glass jars containing ethanol to preserve them. We counted all of the invertebrates and then used a dissecting microscope to identify classes and orders. We took averages of the invertebrates found for the two methods and sites to determine mean abundance and diversity.

Measuring Growth of Forest Canopy and Richness of the Understory

We collected data from a previous class lab at the two glacial sites, supplementing them with our own measurements, as some data were missing or incorrect. For the class data, 21 students were divided into four groups and each group collected information from similar 10m x 50m transects, but these were done at random and not inside of our 40m x 50m plots. Flags were placed at each corner of the rectangular transects to define sampling areas. Students placed 1m x 1m plots every 10m, making a total of 12 plots within each transect. We recorded the diameter at breast height (DBH), of all trees two meters in height or taller in each 50m x 10m transect. We also recorded the number of species and their frequencies of all plants shorter than two meters within the smaller 12 plots at both sites. For this project, we replicated three transects, one at the moraine and two at the outwash plain, using the same methods.

Soil Analysis

Four soil samples were taken from each site using whirl-paks. They were collected from the "A" layer of soil at the four corners of each larger 50m x 40m plot. We used a pH kit to determine the acidity of the soil in each site and proceeded to measure the weight of the eight samples before and after drying them in an oven to determine moisture content. Samples were sent to the University of Michigan Biological Station Analytical Chemistry Lab for %C and %N analysis. After drying, we ground samples to prepare them for the tests, which involved sieving them, placing them in a SPEX SamplePrep 8000M Mixer/Mill for three minutes, and then into scintillation vials. We used soil probes at each site to have an observational comparison of the soil horizons. We also textured samples at both sites, using a technique that involved wetting soil and testing how well it remained intact.

Statistical Methods

To analyze the soil data, we ran a rank-sum test on moisture content, %C, and %N, which allowed us to test the difference between means of two independent samples that are not normally distributed and have a small sample size. For the tree data, we used the DBH measurements to run additional independent sample T-tests after testing for normality with a Q-Q plot. We also counted frequency of sapling and seedling species. For the invertebrate data, we ran two Chi-squared tests on the difference between distributions at the two sites using the pitfall trap versus the leaf litter plot methods since these do not require parametric samples. Chi-squared tests were also used to compare the distributions of overall sampling methods as well as comparing the methods at each site. In addition, we took measures of biodiversity at each site compared to the other. Using these tests, we can infer relationships between significantly higher soil quality and higher diversity and abundance of populations at the two sites.

Results

After running a T-test on the mean DBH of aspens at both sites, the results show that the mean DBH of aspens in the lateral moraine was significantly greater than in the outwash plain ($p < 0.05$). Aspens found in the lateral moraine had a mean DBH of 34.58 cm, whereas the aspens found in the outwash plain had a mean DBH of 18.51 cm. There was a greater frequency of saplings and seedlings counted in the lateral moraine, at 280, compared to 45 saplings and seedlings found in the outwash plain (Figure 1, Figure 2). In addition, there were 4 species of saplings and seedlings found in the outwash plain: red maple, amelanchier spp., white pine, and red pine. The moraine held 5 species of saplings and seedlings: red maple, striped maple, sugar maple, American beech, and amelanchier spp.

Our soil analysis showed that there was no significant difference between soil moisture content, %N or %C using an alpha of 0.05 significance between the moraine and outwash plain sites. The average moisture was 7.6g at the moraine and 5.7g at the outwash plain; 9.4% and 3.9% C; and .23% and .15% N, respectively. Our pH tests showed a pH of 5 at the outwash plain site compared to a pH between 7 and 8 at the moraine site.

The invertebrate biodiversity results were found using the Shannon-Weiner Diversity Index. We calculated an H' of 1.37, which is a measure of diversity, and an evenness of 0.7, for the pitfall trap method at the moraine site using invertebrate classes. At the outwash plain there was an H' of 1.41 and evenness of 0.73. Finally, we calculated an H' of 1.47 and an evenness of 0.82 at both sites for the leaf litter sampling method, also using class.

The Chi-squared test comparing distributions of specific species between classes at the moraine versus the outwash plain site showed a significant difference ($p < 0.05$). The same test comparing the efficiency of sampling methods, pitfall traps versus leaf litter collection, showed significant results ($p < 0.05$). The pitfall method collected significantly more invertebrates since the number captured from that method was 1425 invertebrates compared to 164 using the leaf litter method. We also performed Chi-squared tests comparing distributions in sampling methods at the two sites individually, where we found significance ($p < .05$) at each site as well. The pitfall method produced 685 captured invertebrates while the leaf litter produced 92 at the moraine, and there were 750 invertebrates captured by the pitfall versus 72 captured through the leaf litter method at the outwash plain. This also shows a clear increased number of invertebrates captured through the pitfall trapping method.

Discussion

Based on our statistical results, many of our predictions were not supported, which could be due to a number of factors. However, a few of our hypotheses were supported with statistical significance, namely our tree DBH, abundance, diversity, and soil pH comparisons. The results of our tree sampling supported our hypothesis that there would be increased diversity and abundance of trees in the lateral moraine compared to the outwash plain, and that aspens will have higher growth rates in the moraine. The larger size of aspens in the moraine indicates that some factors facilitate increased growth, since the trees are approximately the same age. Species richness was also greater in the lateral moraine than in the outwash plain, and a study suggests that a higher number of species may correlate with environmental stability and higher productivity in an area (Lehman and Tilman 2000).

One source of error could be discrepancies in tree and sapling identification leading to errors in the frequencies of trees and average DBH values. The trees were not flushed, so identification between different maples and aspens was difficult as they did not yet have their leaves. In the future, results would be more significant if the sample size was greater and if it was done later in the growing season.

Soil pH was the only significant difference identified between soils at the two areas sampled, which may have had the greatest impact on tree growth, abundance, and frequency. More acidic soils typically leach more nutrients such as carbon, nitrogen and phosphorus that simply wash out with rainfall; therefore pH can play a vital role in determining how well and which soil populations can thrive (Heino and Mijovic 2013). The outwash plain had a large abundance of conifers which typically grow in more acidic soils due to the low pH of their needles as they decompose, corresponding to the pH level of 5. In comparison, the moraine had deciduous trees like maples that grow best in more neutral pH levels (Heino and Mijovic 2013). Observing this phenomenon, there may be a positive feedback mechanism at play in the outwash plain, in which the conifers drop their acidic needles into the soil, increasing its acidity gradually over time. This can limit the growth of deciduous trees and allow the growth of more conifers, leading to the great pH difference between sites.

Errors in collecting soil data may include performing incorrect techniques, not taking enough soil samples, and the narrow ranges in which we sampled. According to Batra et al. (2010), who studied the same sites, soil moisture was significantly higher at the moraine site, leading us to conclude that human error played a role in our calculations. They also found that canopy coverage was greater at the moraine site, which was consistent with the larger DBH of trees sampled there, as well as indicative of increased fertility due to less soil evaporation. As seen in Figures 3 and 4, there is little difference between soil horizons. Both the "O" and "A" horizons are 1-3 cm thick with a 10-15 cm "E" horizon below that. Lastly, there is a "B" horizon at the bottom that consists of mostly sand (Nave et al. 2011). We also performed a soil texture technique, which showed that the outwash plain had somewhat sandier soil while the moraine contained loamy, still sandy, clay. Clay helps retain the water and nutrients in soil, which is helpful for plant growth. Additional qualitative observations at the moraine site include higher vegetation density, greater ground coverage, and general signs of life such as rustling and bird calls, suggesting more activity.

We performed the Shannon-Weiner diversity index test because it is important to know the diversity of populations in a community, as well as the species evenness of that diversity, or the relative abundance of the various groups. The scale for these measurements is 0-4 for diversity and 0-1 for evenness. The diversity and evenness of species were extremely similar across class, trapping method and site, which suggests that there is no significant difference between biodiversity at the two sites. This may result from to the fact that, although they have differing soil qualities, the two sites are in the same general region and are prone to colonization by similar species. Considering the average H' of 1.62, this region does not exhibit high diversity, which could further explain the lack of difference between sites, as there is a lesser chance for different species to colonize. The average evenness of 0.78 shows that the evenness is fairly high, suggesting that there are few dominant classes in either of the sites and species are distributed evenly. The low diversity at each site could be explained by such phenomena as the north-south gradient and the "Peninsula Effect," stating that as one moves from the base of a peninsula to the end of it, number of species accordingly decreases (Heinen 2014). Paquette and Messier (2010) also suggest that temperate forests in general tend to have lower species diversity, at least in animals compared to plants, due to such factors as highly variable seasonal conditions and extensive human intervention.

We found significant differences in invertebrate class distribution at the moraine and outwash plain sites, though no clear significant differences in abundance since the data did not allow us to perform the tests needed. Although the test is not directional, we might be able to infer that the moraine has greater abundance since increased leaching at the outwash plain seems to have impacted the number of trees, which could correlate to invertebrates. This is supported by the fact that invertebrates tend to concentrate in soils of favorable pH, namely less acidic soils (Lavelle et al, 1995). The moraine also had a thicker layer of leaf litter, which may contribute to increased abundance. The moraine leaf litter traps produced more captured individuals, 92 versus

72 at the outwash plain, which is supports our initial hypothesis. The pitfall traps, in contrast, produced more individuals in the outwash plain, 750 compared to 685 at the moraine. This may be due to sampling bias and the fact that invertebrates in the outwash plain have less available resources and therefore may be more attracted to the potential for resources in the traps. More invertebrates may also migrate from further away due to the sweet scent and taste of the antifreeze. The tests comparing distributions of trapping methods at each individual site were also significant, suggesting that the qualities of an area do not necessarily affect the efficacy of the pitfall trap.

To observe these different distributions, it is useful to do qualitative analysis as some invertebrates may be better suited for certain environments. Comparing Figures 3 and 4, Hymenoptera accounted for 21.4% of the relative abundance in the outwash plain versus only 4.2% in the moraine. In the Hymenopterans we found, the majority were ants, which may help explain why there were more at the outwash plain: ants usually prefer habitats with sandier soils. Another difference when comparing the figures is that there are more Araneae in the moraine compared to the outwash plain, 17% to 6.4%, respectively. Dermaptera, also known as earwigs, abundance was also greater in the moraine with 8.6% abundance whereas there were only two individuals, or 0.2% abundance found at the outwash plain. According to a study of Dermaptera by Petr Kocarek (1998), they have higher abundance in moist habitats. These findings help explain why we found Dermaptera in the moraine rather than the outwash plain due to the probable increased moisture. For the rest of the species, we found little difference in relative abundance. Diplopoda accounted for just over 33% of abundance in each site, while Coleoptera made up around 15-16%, both of which made up a large portion of the total abundance, suggesting that they may be generalists that can thrive in both habitats.

Regarding earthworms specifically, there were 31 found at the outwash plain compared to 41 found at the moraine, suggesting that they might slightly favor the clay-containing soils of the moraine. A study showed that earthworms are less acid tolerant than arthropods in general (Lavelle et al. 1995), which can account for why there are more earthworms in the moraine. In accordance with our qualitative finding that moraine soils have more clay and therefore prevent leaching, we can predict that that soil has higher nutrient availability which correlates directly with a larger number of earthworms who are soil engineers: they increase aeration, water holding capacity, and distribute organic materials (SEPA 2011). The earthworms found at these sites, however, are also exotic species that are thought to disturb the food chain, and further research is necessary on the rest of the forest food webs (Crumsey et al. 2013).

We did not propose a specific prediction regarding relative effectiveness of the two sampling methods, but the test comparing their overall distributions was significant. As shown in Figure 7, the pitfall trap technique captured more invertebrates overall. While collecting invertebrates in the leaf litter plots, we observed some of the faster individuals escaping because sampling the plots and rustling through the leaf litter creates disturbance in the form of noise and movement, encouraging the invertebrates to escape. Another advantage to the pitfall traps is that they are able to capture nocturnal invertebrates, allowing for continuous sampling. Some confounding variables to the pitfall trapping method include the size of pitfall and not taking into account the behavior of various species in reaction to the presence of the traps. The lure of the sweet tasting antifreeze also draws in more invertebrates from farther distances than the plots are able to, as previously mentioned. In the future, it might be useful to use pitfall traps in conjunction with something like Berlese traps which can capture all organisms in a given plot in order to get a more representative sample (Woodcock 2007).

This study shows that although there were no significant differences in diversity and abundance of invertebrates at the two glacial sites, it is possible to gauge which are more suited for an environment based on variables such as pH and soil moisture. We can conclude that both the regions we sampled might be of equal importance for invertebrate communities, since biodiversity was consistent across both sites. The fact that there were no statistically significant differences between soils at both sites may be due to human error, but could also be correct and useful in predicting abundance in places with similar glacial history and soil type. In addition, we could conclude that invertebrates are not a good indicator of soil quality, unlike factors such as leaf litter thickness could be, as suggested in a study by Altizer et al. (2013). A more applicable research project might be studying other taxa like birds to see if other factors, not just soil quality, are affecting biodiversity in an area.

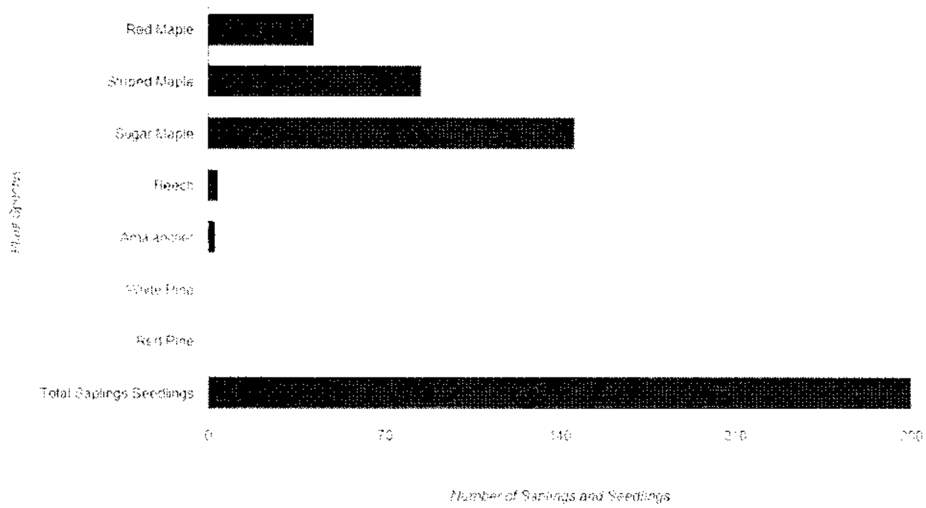

Figure 1: Frequency of Saplings and Seedlings in the Understory of the Lateral Moraine

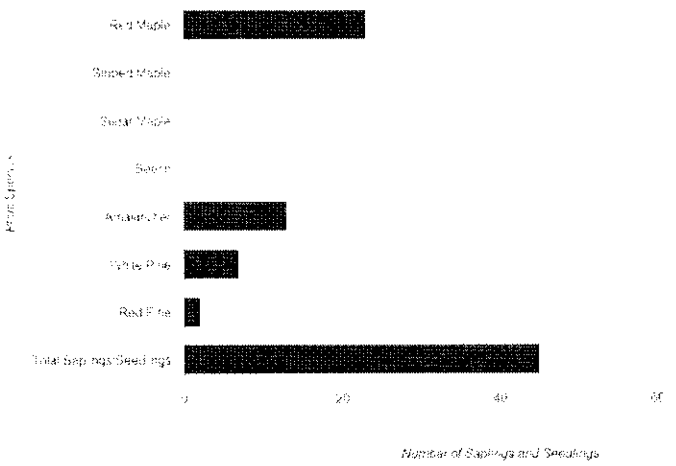

Figure 2: Frequency of Saplings and Seedlings in the Understory of the Outwash Plain

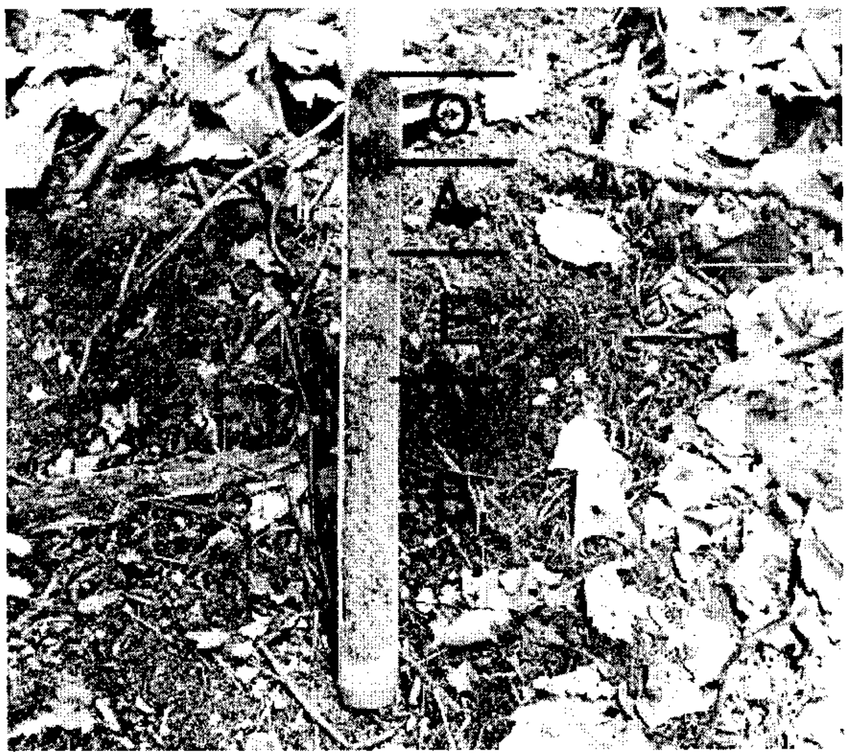

Figure 3: Soil Probe of Lateral Moraine

Figure 4: Soil Probe of Outwash Plain

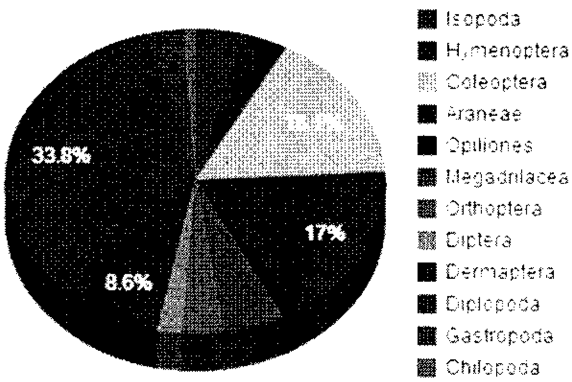

Figure 5: Relative Abundance of Invertebrate Orders at the Lateral Moraine

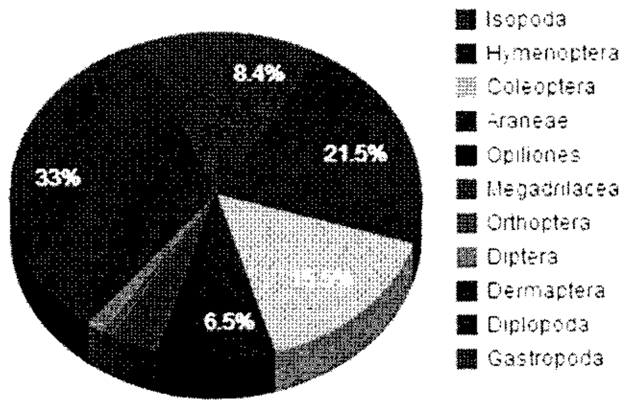

Figure 6: Relative Abundance of Invertebrate Orders at the Outwash Plain

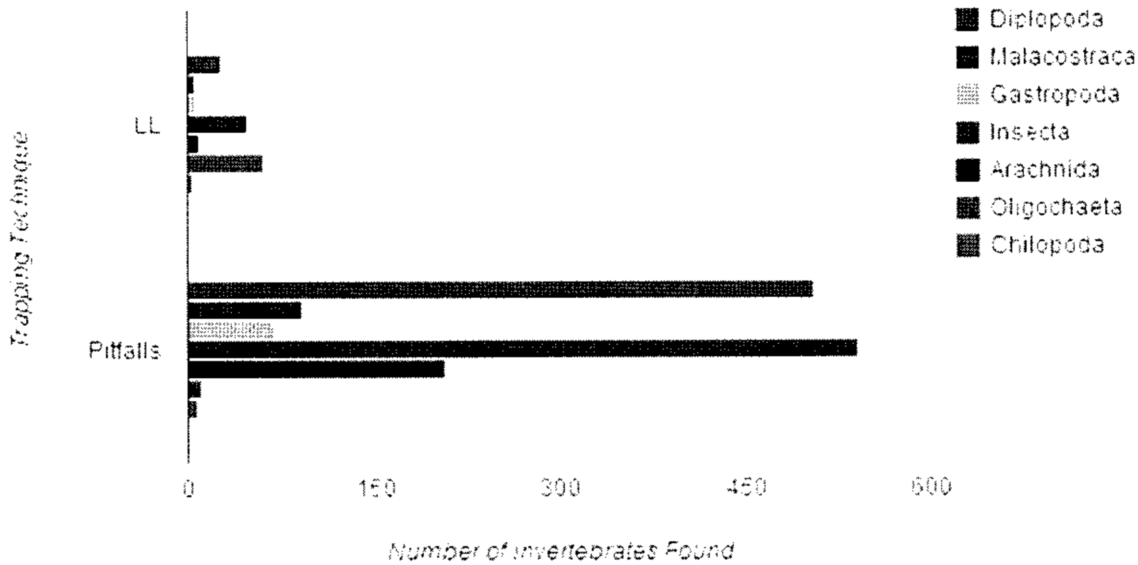

Figure 7: Effectiveness of Leaf Litter versus Pitfall Collection Techniques

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