Invertebrate Diversity as a Function of Forest Age at the University of Michigan Biological Station

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Abstract

As forests begin to recover from a major disturbance and undergo various stages of succession, changes in the species composition of trees and other vegetation become apparent. As vegetative succession occurs, it is likely that other components of the forest community will also change. This study was conducted to determine if, as forests undergo various successional stages, the diversity and abundance of leaf-litter invertebrates change as well. Leaf-litter samples were taken from three forest plots of various ages located at the University of Michigan Biological Station (UMBS). These plots were as a result of controlled burns in 1911, 1948, and 1998. We found that the abundance and species richness of these invertebrates increased with forest age. There was a significant increase in diversity between both the 1911 and 1998 and the 1948 and 1998 plots, but the difference between the 1911 and 1948 plots was less significant. These differences may be a function of the different amounts of time the invertebrate community has been changing after establishment, and the different canopy cover types available. Soil was also sampled in each of the plots to test if the concentration of nitrogen or phosphorus could be correlated to invertebrate presence. Soil analysis reported no significant difference between any of the three plots.

Introduction

Ecological disturbances are events that cause pronounced changes in an ecosystem. After a major disturbance, ecological communities begin to undergo succession. Throughout this process, the species composition of the community is constantly changing in accordance with both biotic and abiotic pressures. Beginning with a few pioneering species, the complexity of the community will continue to develop until it reaches a stable equilibrium in which the maximum number of species will survive at a sustainable level (Prichett, 1979). Arthropods and other invertebrates are forms of life, which commonly move into an area after a disturbance. Many reside in the leaf litter and topsoil of forest floors. For example, diverse assemblages of mites, spiders, isopods, earthworms, and molluscs are common in temperate forests, such as those located at University of Michigan Biological Station (UMBS) (Krebs 1994).

This study investigates the different effects that disturbance can have on a forest by analyzing arthropod abundance and diversity. Forests of different ages, which were cut and burned at different times in the past, at UMBS. From these plots resulting from burns in 1911, 1948, and 1998 were chosen. These plots were chosen because they represent the oldest, youngest, and one intermediate age of forest. These sites will be used to determine how the age of the forest affects the invertebrate diversity and abundance found in the leaf litter and topsoil of the forest. We expect to find abundance and diversity of invertebrates to increase forest age. It is likely that the invertebrate species diversity in the older forest would be higher because they have had more time to recover form disturbance. We also investigated the soil nutrient levels in the three different ages of forest and how these levels relate to invertebrate diversity. We also hypothesized that because the older forests have had a longer period of nutrient cycling they will have higher soil concentrations of phosphate and nitrogen. Higher levels of nutrients could lead to a higher diversity and abundance of invertebrates in those areas.

Methods

A total of 36 samples of leaf litter and the topsoil were collected, 12 from each of the 3 ages of burn plot. Each plot contained a pre-existing randomly centered grid. These grids were extended as to prevent sampling from interfering with ongoing research. The 1911 burn plot contained a 40 x 40 m grid, which for this study was extended outwards by 2 m on each side. Samples, 25 x 25 cm, of leaf litter were collected at intervals of 10 m around the perimeter of extended randomized grid. The same sampling procedure was utilized in the 1948 burn plot of 40 x 40 m, and the 1998 burn plot contained a 120 x 60 m grid. This grid was extended outward 1 m on each side, and samples were collected at intervals of 10 m around the perimeter (Figure 1).

To ensure uniform sampling, frames 25 x 25 cm were used. The frames were placed at the sample locations, and all leaf litter and topsoil within were quickly transferred into plastic bags. Air was left in the bags to create a cushioning effect when all bags were stacked together and to allow for the survival of captive invertebrates for later processing.

Berlese funnels were used to separate the invertebrates from the leaf litter. The funnels consist of heavy plastic draped around a metal loop to form a wide circular top, tapering into a small hole at the bottom. The funnels were tied around a support wire that ran across the width of the lab. Bulbs with 25-watt output were placed above each funnel. Both the light of the bulbs and their drying effects on the leaf litter were intended to drive invertebrates downward, into the narrower end of the funnel. Glass jars filled with 200 mL of 95% ethanol were attached at this narrower bottom end. A total of 36 funnels were assembled, so that each sample could be processed simultaneously. The leaf litter samples were placed into the funnels, the lights above the funnels were lit, and the entire apparatus was left to heat and dry for a total of 7 days.

After one week of drying, the leaf litter and topsoil were collected from the Berlese funnels and the ethanol jars containing filtered material and organisms were capped and collected. The filtrate was inspected using Bausch and Lomb 0.7x-3x magnification dissecting microscopes. All macroscopic invertebrates were collected and identified as thoroughly as possible. All other filtrate was discarded. The remaining leaf litter was likewise sorted for remaining invertebrates. After sorting, leaf litter was returned to its plot of origin.

Soil was collected from 5 random locations in each age of the sampled forests. A random number generator was used to determine which of the 12 locations where leaf litter had been gathered would be used to collect soil samples. The nutrients that were of concern in these tests were nitrogen and phosphorus. The soil samples were analyzed using an ammonium, nitrate, and orthophosphate test. The total soluble nitrogen value is the sum of the nitrate and ammonium for each sample. These tests were conducted by drying the gathered soil from each plot in an oven set at 60 °C for 24 hours. The dried soil was sifted and then ground using a Spex 8000 mixer/mill. The samples were analyzed using both a soil ortho-phosphate test for phosphorus and a soil soluble nitrogen test for total nitrogen content.

Results

To determine the difference in biodiversity between the three ages of forest, we compared the mean number of invertebrate classes found in each of the twelve samples collected from each of the individual burn plots. This was done using a one-way ANOVA. A significant difference was found between the mean number of species found in the 1911 and 1998 forests ($p=0.0001$) and between the 1948 and 1998 forests ($p= 0.0001$). The mean number of invertebrate classes found within the 1911 forest was greater than that of the 1948 forest ($p=.098$). This difference was not statistically significant at $\alpha = 0.05$, but would be at $\alpha = 0.1$.

Overall, leaf litter invertebrates were most abundant in the 1911 forest, followed by the 1948 and 1998 plots (Figures 2, 3, 4). Some taxa varied greatly in their relative abundance between plots (Figures 2, 3, 4). For example, Diplopoda represent a far greater portion of the invertebrate population within the 1911 plots than in either of the other forest ages. We utilized the Shannon-Wiener index to arrive at an H' value, an index that is used to characterize species diversity in a community. These H' values were 0.97, 1.03, and 0.81 for the 1911, 1948, and 1998 plots respectively. This indicates that that the 1948 plot was the most diverse and even of all the forests. However, these values could reflect either evenness or diversity. As such, it is difficult to draw any definite conclusions from this set of values.

Soil samples from each age of forest were analyzed for both nitrogen and phosphate content. The 1948 plot had the greatest average nutrient content, for both nitrogen and phosphate. However, these results did not prove to be statistically significant.

Discussion

There were a total of seventeen classes of invertebrates found in the samples collected from the burn plots (Figures 2, 3, 4). One possible explanation for the differences in distribution of the different types of organisms is the different types of cover available in the three ages of forest. The 1911 forest has the most trees and the most dense canopy cover (personal observation). Most soil invertebrates are repelled by light and require moist, cool conditions. This could provide a more hospitable habitat for invertebrates in the 1911 plot, less hospitable habitat in the 1948 plot, and least hospitable in the 1998 plot. Less dense canopy cover could lead to more predation on invertebrates by predators more dependent on light for vision.

Different taxa had varying levels of success, relative abundance, in different aged forests. Success in this context meaning the proportion of the overall invertebrate population one taxa represented. Diptera were most successful in the 1911 forest. This could be reflective of their relatively high mobility, which may increase their ability to compete as a pioneering species. Many Coleoptera are small and fairly immobile. This would make them more susceptible to fires, as well as impairing their ability to colonize areas after burnings (Moretti et al., 2006). This could be a factor in the success of Coleoptera in the 1911 forests. Hymenoptera had a much greater relative abundance in the 1911 population than in either of the other forests. Previous studies have suggested that this may be the result of Hymenoptera being dependent on dead wood for certain stages of their development (Moretti et al., 2006).

The analysis of biodiversity showed a statistically larger number of different invertebrates in the 1911 and 1948 forests than the 1998 forest. This result supports our hypothesis that older forests would have greater biodiversity. Although there was not a significant difference between the numbers of organisms found in the 1911 forest as compared to the 1948 forest, the post hoc Tukey test showed that this difference was approaching significance (Table 2). This suggests that further investigation, using a larger sample size, could more effectively demonstrate a significant difference between the biodiversity in these forests.

Although the 1911 plot had the greatest taxa diversity, the 1948 plot had the highest H' value on the Shannon-Weiner Index. This was due to the relatively high level of taxa evenness in the 1948 plot. The lesser evenness in the 1911 plot may reflect superior competitors beginning to competitively exclude lesser competitors as the community reaches a more stable equilibrium. The 1998 plot had the lowest H' value reflecting low levels of taxa diversity and evenness.

Data on soil nutrient content were collected to determine if any differences in soil composition could explain diversity or abundance of invertebrates. The soil analysis showed that there is no difference in phosphorus or nitrogen levels, between different ages of forest. A larger sample set may have provided a more representative description of soil nutrients. Although the average levels of both phosphorus and nitrogen were highest in the 1948 forest, more data would need to be collected in order to comment on the statistical significance of this conclusion (Figure 6).

There were a number of potential sources of error in this experiment. The noise and movement resulting from the placement of frames before leaf litter collection may have alarmed more mobile invertebrates, allowing them to escape before we could collect them. Additionally, it is possible that these larger, more mobile invertebrates were able to escape during the seven days our samples were in the Berlese funnels. A possible solution could be to include a mesh cap to the funnel, to prevent the escape of more mobile invertebrates.

Our findings suggest that greater biodiversity of leaf litter invertebrates within temperate forests is associated with later stages in succession. This is consistent with the idea that forests in their early successional stages will have a few colonizing species, building complexity and eventually reaching a more stable equilibrium.

Acknowledgments

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Appendix

Figure 1: Layout of Burn Plots 1911, 1948, and 1998

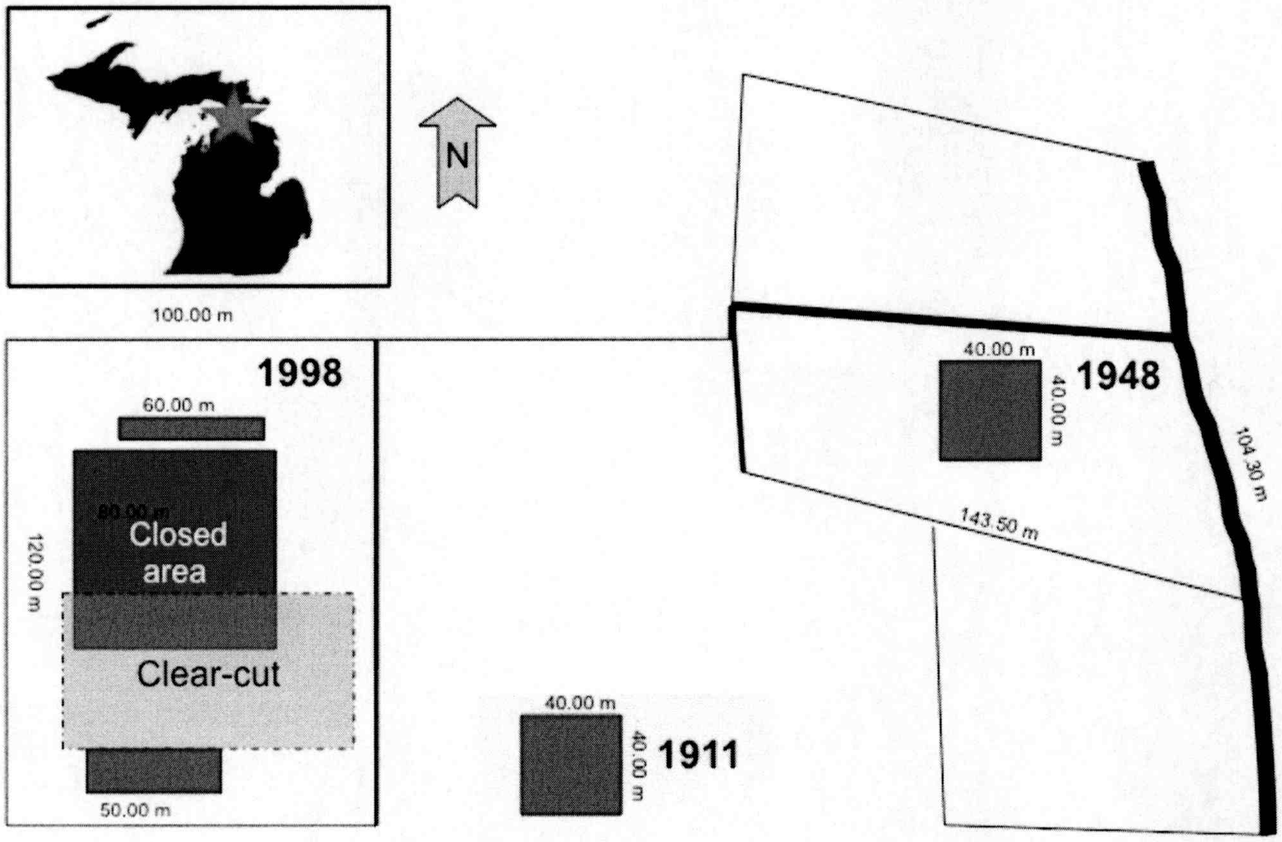

Table 1: Tukey test showing significance values between plots

Year Comparison	Significance
1911-1948	.098
1911-1998	.00
1948-1998	.00

Table 2: Chi squared analysis between invertebrate species between 1911, 1948, and 1998

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	88.389	2	44.194	24.649	.000
Within Groups	59.167	33	1.793		
Total	147.556	35			

Figure 2: Relative Abundance of taxa in 1911 burn plot of UMBS

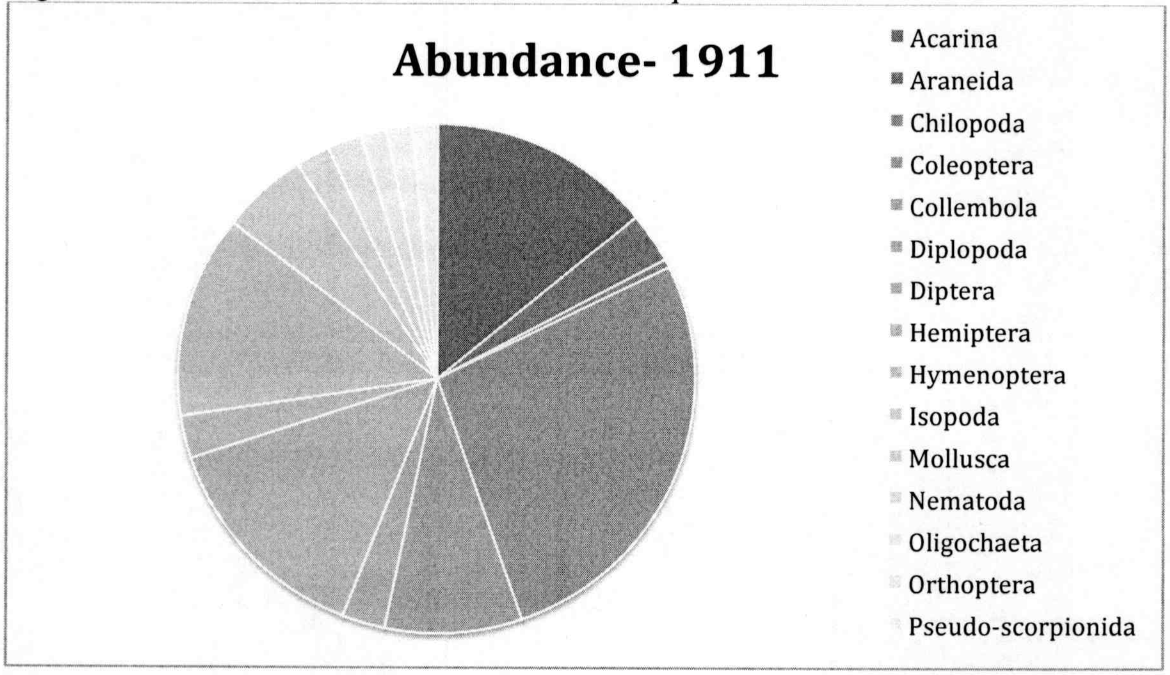

Figure 3: Relative Abundance of taxa in 1948 burn plot of UMBS

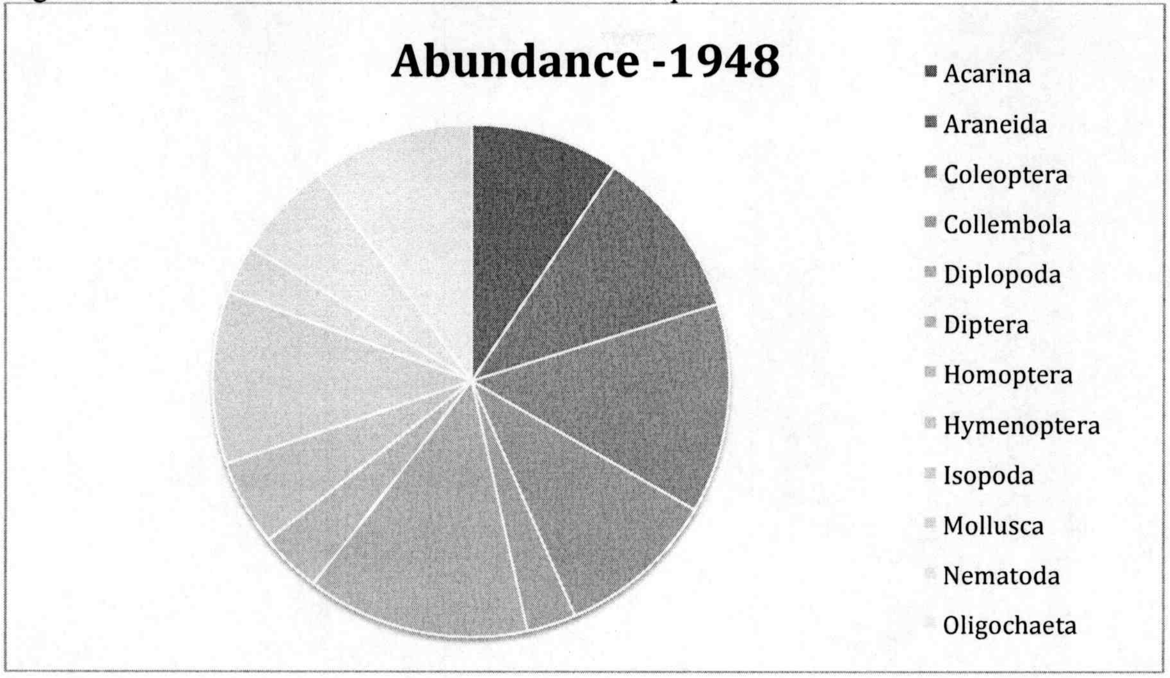

Figure 4: Relative Abundance of taxa in 1998 burn plot of UMBS

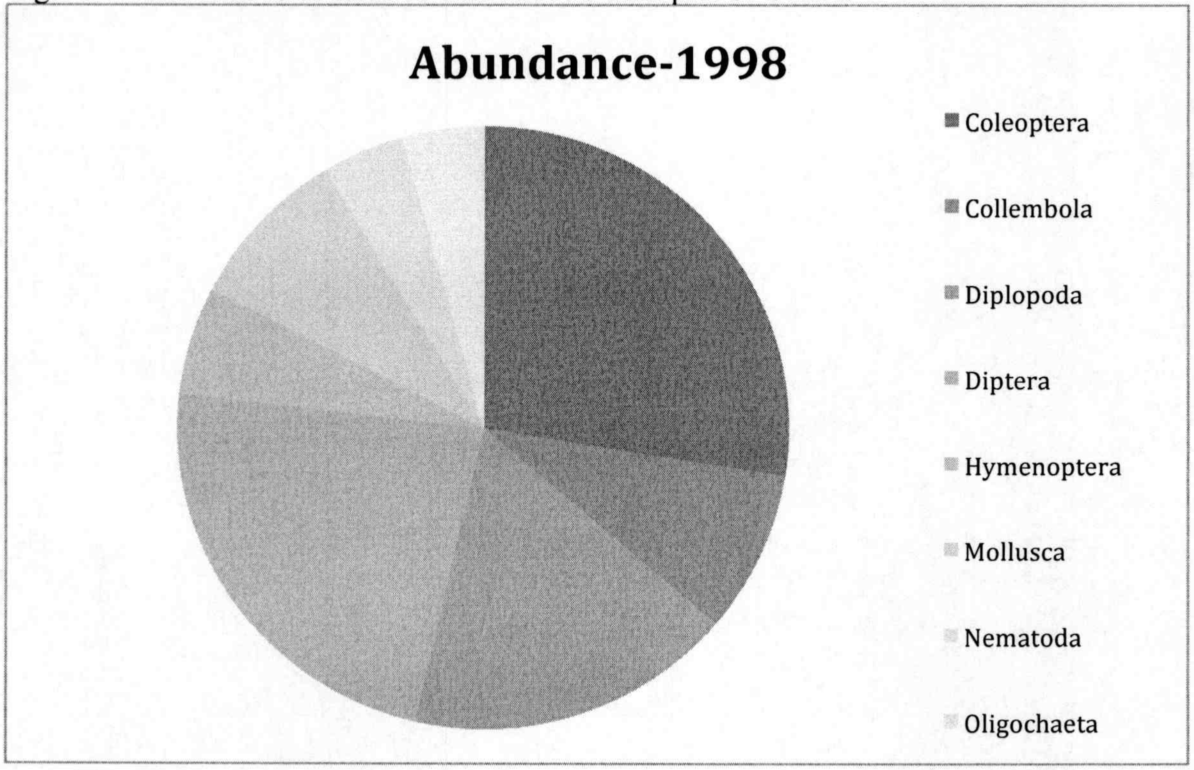

Figure 5: Abundance of Arthropods within each Burn Plot

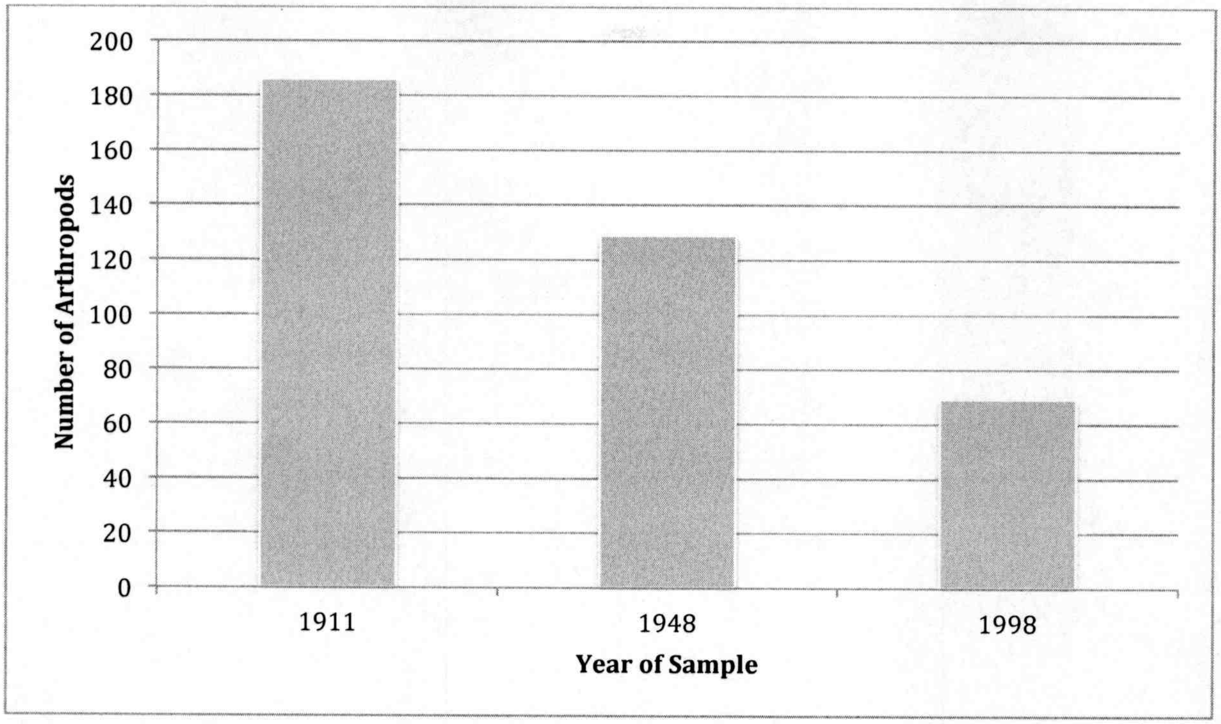

Figure 6: Mean Concentrations of Phosphorus and Nitrogen in Each Burn Plot