THE EFFECTS OF MOWING AND FERTILIZATION ON PLANT SPECIES DIVERSITY

by

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Abstract

It is thought that species diversity is maximized when ecological disturbance is present because both weedy species and good competitors can coexist. In addition, nutrient availability maximizes species diversity when it is neither abundant nor poor because plant species will not outgrow one another causing light resources to become limited. To be able to determine the validity of this I examined the effect that mowing, fertilization, and the interaction between both have on plant species diversity at East Carolina University's West Research Campus. My research was a part of a long-term study that has been running for 17 years. I analyzed species diversity by recording the stem count and percent cover of all species in four different treatments. The treatments included mowed and fertilized, unmowed and fertilized, mowed and unfertilized, and unmowed and unfertilized (control). After calculating all species present within the treatments, I conducted an analysis of variance (ANOVA) to test what effect my independent variables (mowing and fertilization) had on my dependent variable (species richness), which is defined as the number of different species present within a 1 by 1 m quadrat. The results from my ANOVA test revealed that all independent variables had an effect on species diversity. Fertilization alone decreases species diversity, mowing alone increases species diversity the most, and the effect of fertilizer is greater in mowed treatments. This was concluded by comparing the averages of each independent variable to my control. Mowing and fertilization had an average of 12.25 plant species per quadrat, fertilization alone had an average of 7.71, mowing alone had an average of 15.96, and the control (unmowed and unfertilized) had an average of 7.79. These results show that species diversity is indeed maximized when ecological disturbance is applied but decreased when nutrients are overly abundant.

Introduction

Biodiversity is an important aspect of ecological communities. It helps increase the stability of ecosystem functions and it has a great influence on community productivity. In biodiverse communities, the differences in traits among the species helps increase total resource capture, which is how quickly food turns into resources like fuel through compost methods. Also, biomass production and total resource capture usually follow the same trends in diverse communities, which is what helps the biodiverse community maintain stability. Studies show evidence that when biodiversity decreases, the rate at which communities obtain resources, decompose, have biomass production, and are able to recycle nutrients is diminished (Cardinale, et al., 2012). To maintain species diversity, the number of different species that are located in a region, it is important to analyze the ecological aspects that help maximize biodiversity.

It is believed that species diversity is maximized when ecological disturbance, an event that kills and changes the arrangement of species in an ecosystem, is present because both weedy species and good competitors can coexist. Plant species can coexist with disturbance since it creates equal resources for all species. It is also believed that nutrient availability maximizes species diversity when it is neither abundant nor poor. When nutrient availability is abundant plant species will compete for light and taller plants will win. When nutrient availability is extremely [CG1]low only stress tolerator species will grow because there will not be enough nutrients for others (Grime, 1977). Fertilization is a method of increasing nutrient availability. The introduction of fertilizer can increase the availability of nitrogen, phosphorus, potassium, and micronutrients such as manganese, zinc, or iron in soil. Nutrient availability and disturbance both affect the species diversity of an area.

Nutrient availability and disturbance are important to analyze due to anthropogenic effects of industrial activity and climate change. With industrial activity on the rise, eastern NC is receiving a lot of nitrogen in its soil. This is due to deposition, which is the process of dust and gas particles entering the atmosphere then later being precipitated back on earth. With eastern, NC being located in a nutrient deposition hot spot, the soil is becoming abundantly fertilized. This can be in an issue in jurisdictional wetlands because the addition of fertilizer has the potential to create a toxic environment for the wetland soils that are typically low in nutrients. Since wetland soils are low in nutrients, wetland species become adapted to that environment so large amounts of fertilization can disrupt that environment. Studies that analyze the effects of N and P fertilization on wetland habitats have found that species richness in these environments decrease when N/P is less than or greater than 9.5 Tg N because anytime N/P deviates from its optimal value, soil of the wetland is affected negatively (Zhiguo et al., 2007).

Industrial activity has also contributed to climate change, which has increased wildfires in some parts of the world. In addition to humans increasing wildfires by contributing to climate change through the usage of fossil fuels and deforestations, humans also suppress wildfires by the development highways and other human landscapes. Studies show that wildfires affect species diversity differently for various plant species. Species diversity is greatest in unburned areas for trees but forbs and grasses benefit from yearly fires (Peterson et al., 2008).

This study of species diversity is a part of a long-term study that has taken place at the West Research Campus at East Carolina University. The long-term study began in August of 2004 after the plots at the West Research Campus were burned, mowed, and tilled in October of 2002. The overall goal of the long-term experiment is to study the effects of disturbance and nutrient availability on the plant community within the experimental area.

The goal of the 2020 analysis was to examine the effects of fertilization and mowing on species diversity within a wetland site in eastern North Carolina. It was important for the effects of fertilization and mowing to be analyzed to monitor how anthropogenic factors effect disturbance and nutrient availability, thus affecting the amount of species present within an area.

Plant species diversity was compared in four different treatment types within the experiment: fertilized and mowed, fertilized and unmowed, nonfertilized and mowed, and nonfertilized and unmowed. These comparisons were made to determine the effects of fertilization, mowing, and the interaction between both independent variables on species diversity.

Methods

Study Site

The study took place on a 235-hectare (ha) tract of land that used to be a Voice of America (VOA) radio broadcasting site. This site is now used by East Carolina University (ECU) as a research campus. During the VOA installation, the site was logged, and drainage ditches were created. The study site has elevations of 22-25 meters, soil with medium to low fertility and low organic content, and over half of the site has been classified as jurisdictional wetlands.

Experimental Design and Sampling

There are eight blocks located within the study site, all of which are 20 x 30 meters in size. The study site was last burned in March of 2002 to remove vegetation, and four treatments were assigned to plots by randomization. Each treatment took place in a different plot within a block, and the four treatments included the following based on mowing and fertilization in a two-factor with replication design:

1) No mowing and no fertilizer

2) No mowing and fertilizer

3) Mowing and no fertilizer

4) Mowing and fertilizer

Mowing is done once yearly, and fertilizer is applied every February, June, and October. The species diversity data used in this study was obtained in August 2020. Species presence was collected by randomly placing 1 by 1meter quadrats on each plot and taking note of stem count and percent cover of all species that each quadrat contained. This allowed me to record the effects that mowing, fertilization, and the interaction between both independent variables had on all species located within the study site.

Analysis

To test the effect of fertilization and mowing on species diversity, I conducted an analysis of variance (ANOVA) test on Excel. The null hypotheses were that fertilization has no effect on species diversity, mowing has no effect on species diversity, and that there is no interaction between the effects of fertilization and mowing on species diversity. Preparing my data for the ANOVA, I first transposed my data set, deleted all stem count data, performed a COUNTIF function to count the number of species with stem count or percent cover > 0 in each quadrat, and sorted the data based on treatment type. This allowed the data to be displayed in two columns and two sets of rows that included mowed/unmowed and fertilized/unfertilized for the ANOVA to be able to analyze species diversity for each independent variable and their interactions. The ANOVA test revealed if the findings for species diversity on each independent variable were statistically significant to reject the null hypotheses by providing the fertilized/unfertilized, mowed/unmowed, and interaction results with a P and F-value.

Results

After conducting an ANOVA two-factor with replication, the statistics obtained can be seen below.

Table 1: Results of Analysis of Variance

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Fertilization	86.26042	1	86.26042	18.52573	4.18E-05	3.944539
Mowing	969.0104	1	969.0104	208.1096	2.38E-25	3.944539
Interaction	78.84375	1	78.84375	16.93289	8.43E-05	3.944539
Within	428.375	92	4.65625			
Total	1562.49	95				

It is rejected that fertilization does not affect species diversity. Average species diversity in both mowed and unmowed plots with fertilization is less than the average species diversity in the unfertilized plots. The average species diversity of mowed and fertilized is 12.25, 7.71 for unmowed and fertilized, 15.96 for mowed and fertilized, and 7.79 for unmowed and unfertilized. This statistic exhibited significance based on the fertilized/unfertilized F value (18.53) being larger than the F critical value (3.94) and its P-value being less than 0.05. These statistics show that the difference between the fertilized and unfertilized plots is great; in addition, the variance of within the fertilized and unfertilized groups is low indicating that the data points are not spread out from the mean. A visualization of the effect that fertilization has on species diversity can be seen in Figure 1.

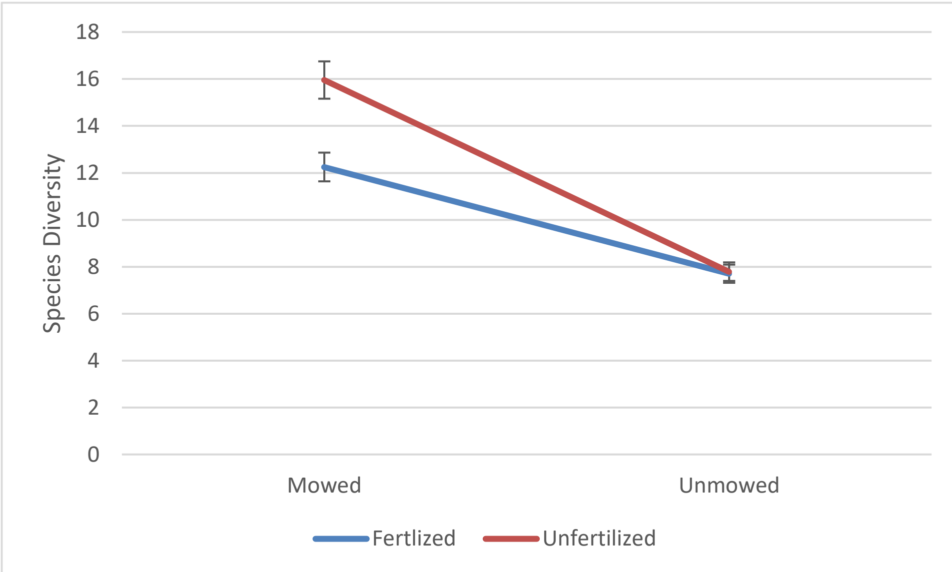

Figure 1: Long-term Experiment about the Effects of Fertilization and Mowing on Species Diversity. The comparison of the effect that mowing and fertilization has on species diversity demonstrates that mowing increases species diversity, while fertilization decreases it. Mowing increases species diversity the most without the addition of fertilizer, but fertilizer only increases species diversity when mowing is also done to the plot. The error bars indicate the 95% confidence interval for the mean.

It was also rejected that mowing does not affect species diversity. The average species diversity from mowed and fertilized is 12.25 compared to 7.71 in the unmowed and fertilized. Following the same pattern, the average species diversity from mowed and unfertilized plots is 15.96 compared to 7.79 in the unmowed and unfertilized plots. This pattern did not occur by chance and has significance because the F value in mowed/unmowed plots (208.11) is greater than the F critical (3.94) and the p-value is less than 0.05. Based on these statistics, the difference between mowed and un-mowed is great; in addition the variance within the mowed and unmowed groups is low. A visualization of the effect that mowing has on species diversity can be seen in figure 2.

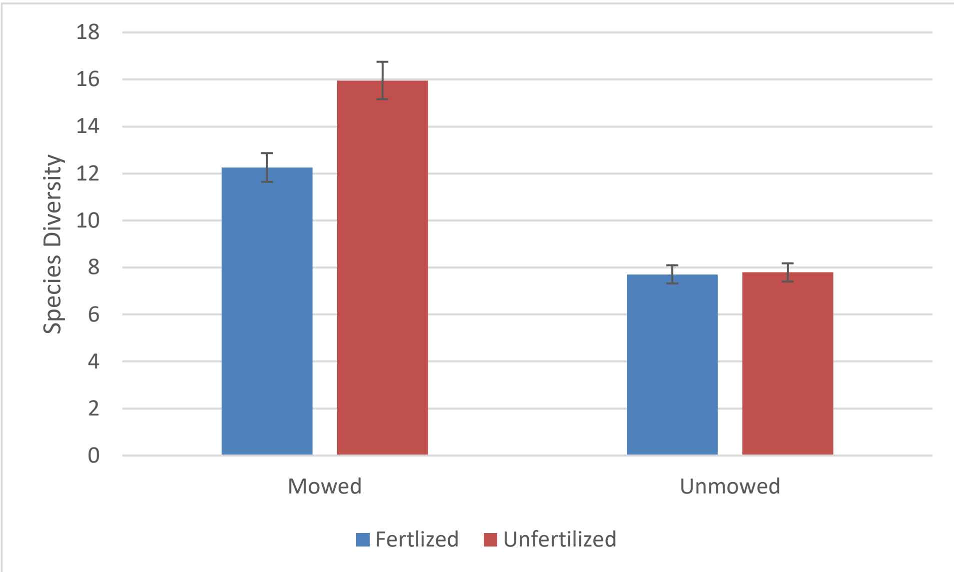

Figure 2: Long-term Experiment about the Effects of Mowing and Fertilization on Species Diversity located Within a Jurisdictional Wetland. This illustrates that mowing has a stronger effect on species diversity than fertilization. The addition of fertilization in unmowed plots did not make a significant difference in species diversity in unfertilized plots. However, in mowed plots there is a big difference in the average species diversity, with it being greater in mowed plots without fertilization. The error bars display the 95% confidence interval for the mean.

The null hypothesis that there is no interaction between the effects of fertilization and mowing on species diversity was also rejected and can be explained by table 1. The F value for interaction (16.93), is greater than the F critical value (3.94), and the P-value is less than 0.05. The relationship between the independent variables can be seen in figure 1; it shows mowing had different effects in fertilized and unfertilized plots as indicated by the slope of the lines. Therefore, the two-factor ANOVA with replication, allowed all null hypotheses to be rejected because fertilization decreases species diversity, mowing increases species diversity, and the effect of fertilizer is greater in mowed treatments.

Discussion

This study showed that fertilization decreases species diversity, mowing increases species diversity, and that the effect of fertilization is greatest when it is combined with mowing while the effect of mowing is greatest without fertilization. In this experiment, mowing was meant to replicate the natural disturbance of wildfires and fertilization related to nutrient availability. Based on the results, it can be concluded that natural disturbance helps increase species diversity, whether it is by mowing or wildfires. However, since fertilized and unfertilized plots only differed in average species diversity by 8%, it cannot be fully assumed that fertilization always decreases species diversity because this finding can be due to various reasons based on the plot site of this experiment.

Simply adding nutrients to soil does guarantee the growth of the species located within the plot. Nutrient availability is based on other factors beyond nutrient content such as temperature, the ability to retain moisture, pH, and the presence of toxic elements within the soil (Baligar et al., 2005). It is possible that fertilization decreased species diversity due to the site being a wetland because species wetlands are typically low in nutrients and species adapted to this type of habitat might find a high nutrient environment to be toxic. Another possibility is that fertilization caused certain woody species to grow larger than shorter species, making woody species dominant and limiting light resources for other plants. Some woody competitors within the site that grew tall, limiting light resources, include red maple and red chokeberry. Examples of species that became limited include sweet leaf and sweet bay magnolia. The phenomenon of species diversity decreasing with the addition of nutrients is a pattern that has been observed and accepted in ecological communities. However, while light limitation is a possible factor in this pattern, other experiments have found that low species diversity is also due to the limitation by nitrogen (Goldberg et al., 1990).

With industrialism on the rise, there are large amounts of nitrogen being emitted into the atmosphere and on earth's surface through dry deposition. Studies show that almost 60% of annual surface deposition arises from dry deposition and that the total annual amount of nitrogen deposition is 34.26 Tg/N. However, nitrogen dry deposition has begun to decrease in the eastern United States area due to finding ways to better control emissions, but the experimental site area is still considered a nutrient deposition hot spot due to high levels of nitrogen in the soil (Jia et al., 2016). This creates a confounding variable since nitrogen levels being emitted into the study site through deposition cannot be controlled.

While addition of nutrient can increase the intensity of competition for light, mowing and natural forms of disturbance decrease light competition since it cuts down species that may be taller than others and creates equal light resources for all plant species. Allowing all resources to be equal may be the reason why species diversity was highest in mowed plots without fertilization. Earlier data from this study site also yielded the same results that mowing maintains species diversity. Previous analyses of data from this experiment found that, without mowing, average species richness declined from 14 to 2 species per square meter (Goodwillie et al., 2020). Other studies looked at the effects of disturbance in the form of grazing. They also found a general decrease in species richness when they excluded grazing in their experiment (Beltman et al., 2003). Thus, there appears to be a trend that increasing the disturbance within plots helps increase species diversity. Once again this is likely due to light competition decreasing, and disturbance may also spread out seedlings from other plants around the plot. Species abundantly present in mowed plots include those that were lower to the ground such as Maryland meadow beauty and slender flattop goldenrod. On the other hand, species that were not able to grow well in mowed plots include those that grow tall such as black gum and sweet gum since they would repeatedly be cut and not be able to compete well with other species.

With climate change on the rise in some areas, the occurrence of wildfires is potentially affecting species diversity by occuring too frequently. On the other hand, suppression of wildfires by active firefighting or landscape fragmentation is decreasing the frequency of wildfires in some areas. Studies have shown that species richness is greatest in unburned areas for tree species, fires occurring every other year for forbs, and yearly fires for grasses. (Peterson et al., 2008). This is consistent with the data we found since it was discovered that tall species did not compete well in mowed plots while the smaller species did, which suggests that the mowing is effectively replicating the effects of fire.

While the data obtained in this experiment yielded statistically significant results, more work needs to be done to further analyze this topic. For better results, data would need to be obtained more than once a year and there should be sampling of more than 96 quadrats conducted because the relatively small sample might not accurately reflect the entire community. Also, to be able to fully determine if industrial pollution impacted the fertilization results of this experiment, data needs to be taken in areas with extreme industrial pollution, average industrial pollution, and low amounts of industrial pollution to be able to fully correlate if dry deposition alters nutrient availability significantly. As stated earlier, mowing was also not able to completely replicate wildfires due to it only damaging vegetation aboveground. Further experimentation using prescribed fires would be needed to analyze the effects wildfires have on species diversity. Some experiments have been conducted on prescribed fires and found that prescribed fires correlate to a large increase in plant species richness in understory plant richness and overstory trees species richness remaining unaffected (Brockway et al., 1996).

Overall, fertilization may have decreased species diversity in this experiment due to tall species becoming dominant and creating light competition for shorter species or due to the site being located in a nutrient deposition hotspot creating a toxic environment for the wetland species adapted to low nutrients. Mowing potentially increased species diversity by eliminating light competition or the disturbance spreading out plant seedlings across the plot.

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