EFFECT OF SPECIES DIVERSITY AND HABITAT TYPE ON DISPERSAL OF BLACK TAR SPOT DISEASE IN *ACER PLATANOIDES*

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ABSTRACT

Acer platanoides is an invasive tree species in the eastern Unites States that has negatively impacted native tree populations. One of its natural pests, Black Tar Spot (Rhytisma acerinum) infects A. platanoides with few deleterious effects on tree health and it shows up as large black spots on leaves. We measured the varying degrees of severity of R. acerinum infection on A. platanoides, in edge and non- edge (interior) habitats, and the diversity of tree species around the tree. We randomly selected trees to sample severity and we found that trees in edge habitat had a higher severity of the fungus as opposed to trees in interior forest habitat. The average severity for edge habitat was 2.2 compared to interior habitat average of 0.7. It was found that habitat type significantly correlated with severity of tar spot infection. (P = 0.001).

Keywords. Habitat type; invasive species; Norway maple; species richness; Tar Spot disease.

INTRODUCTION

Invasive species can have a significant impact on the species diversity, species richness, and species evenness of an ecosystem. Impacts on native forest structure depend on the invading species. The height and canopy cover of the invading tree species will affect the fluctuation of native forest composition and structure (Hejda 2009). The abundance and dispersal rate of non-native tree species are dependant upon light and soil conditions; however, in the case of *Acer platanoides* (Norway maple), light and soil limit growth rate only, not dispersal. Dispersal limitations and varying forest stability dynamics have the greatest effect on dispersal rates (Martin 2006).

A. platanoides, a native of Eurasia, had its first documented introduction approximately 250 years ago when saplings were imported from England. It is estimated that *A. platanoides* is the most abundant ornamental tree planted in the United States, favored for its rapid early growth rate, as well as its hardiness. Ideal for transplantation, *A. platanoides* fares well against urban impacts, and outcompetes native maples when it comes to frost resistance and soil tolerance (Nowak & Rowntree 1990). Creation of edge habitat or disturbed soils can facilitate the establishment of *A. platanoides*, which can have detrimental effects on species richness and tree regeneration in forest understories (Lapointe & Brisson 2012). In its native range, the average total herbivory on *A. platanoides* leaves was significantly higher at 7.4% compared to 1.6% in North America. In both continents the main forms of herbivory were chewing and skeletonizing with a positive correlation of leaf herbivory and temperature. In all sites but one studied in North America, the total herbivory or fungal damage did not exceed 4% compared to European sites (Adams et. al 2009).

Experimentation has shown that *A. platanoides* grow taller and faster in simulated gap conditions; however, in deep shade simulated understory the growth rates of *A. platanoides* and sugar maples were not significantly different. It also found that the *A. platanoides* had significantly greater photosynthetic capacity in all lighting conditions compared to sugar maples, enabling *A. platanoides* to recruit in the overstory 12-22 years faster than sugar maples. Contrary to sugar maples, *A. platanoides* have longer growth periods through the fall. *A. platanoides* can reach minimum canopy height in as little as 21 years while native trees take between 47 and 82 years to reach the same height. *A. platanoides* were considerably more pernicious in gap scenarios and due to their low root: shoot ratio are capable of outcompeting many species as they will exceed them in overall growth rate (Paquette et. al 2012, Webster et. al 2005). *A. platanoides* is a shade-tolerant species, and intact forests provide weak resistance to its colonization (Martin & Marks 2006).

Tar spot, which appears as a large dark blemish on the leaves of *A. platanoides*, has been increasing in prevalence in the Eastern United States since the 1990's. Tar spot affects both native and non-native maples, but each infection is caused by different species of fungus: *Rhytisma acerinum* and *Rhytisma americanum* (Hsiang & Tsian 2007). For the purpose of this study, we will focus on *Rhytisma acerinum* (Black Tar Spot), a non-native fungal species that affects its host *A. platanoides*, in its native range as well as in North America. Tar spot fungus overwinters in the fallen tar spot-bearing leaves of the *A. platanoides*. Once the maple's leaves begin to bloom again in early spring, spores are released from the previous year's leaf litter to infect the new growth. It takes about two months after initial infection for symptoms of tar spot to appear. Since tar spot infected leaves lose mass slower than uninfected leaves, a higher concentration of leaf litter could increase the frequency of tar spot in *A. platanoides* trees in North America (Gosling et. al 2016, Grimmett et. al 2012).

We hypothesized that tar spot severity would be highest in areas with high densities of *A. platanoides* and fewer non-maple tree species and in edge habitat due to the prevalence of *A. platanoides* in edge habitats on campus. Our goals were to determine: the effect of *A. platanoides* abundance within sampling sites on tar spot severity, the effect of tree diversity within sampling sites on tar spot severity, and the effect of habitat type on tar spot severity.

METHODS

Field site. There were 20 sites randomly sampled on the north side of SUNY Purchase College campus (Figure 1). The forest containing most of our sites is a 90-year-old hardwood forest located behind the Alumni Village apartments. It contains *Acer platanoides* (Norway Maple), *Acer saccharum* (Sugar Maple), *Quercus spp.* (Oak tree genus), *Liriodendron spp.* (Tulip tree), *Fagus* (Beech tree), and *Carya ovata* (Shagbark hickory). Other sites were located on edge habitats on the main road (Lincoln Ave.) and hardwood forest located behind the Music Building. This forest contains a stormwater basin and is classified as a wetland, although it is dry in most areas (includes most of the trees mentioned above). These sites were chosen due to the stands of *A. platanoides*.

Site Selection. A region was chosen based on the number of *A. platanoides* and the size of the area. One member of our team then selected a point of reference (usually a rock) and we measured a 15 m radius to assign numbers to each *A. platanoides* in the plot. We then used a random number generator app called "Pretty Random", to select a tree to study. Once we selected a Norway maple we used a 5 m radius around the tree of interest to determine the tree diversity in the plot. We determined tree diversity of sample sites by ascribing them the values of "No diversity", "Low diversity", "Moderate Diversity", and "High diversity". We assigned these values based on the number of *A. platanoides* compared to non-Norway maples, with no trees other than *A. platanoides* within the sample site as no diversity, non-Norway maples making up less than half of total trees within sample site as low diversity, non-Norway maples about half of the total trees as moderate diversity, and non-Norway maples dominating over half of the total tree species as high diversity. To measure severity of black tar spot on our tree of interest each member of our group viewed the tree from a different angle for 1 minute then changed positions and observed for another minute. If we differed in our severity rating we discussed and settled on a rating with which we all agreed. A tree with no observed black tar spots was categorized as "No presence", a tree with a few scattered spots on either the treetop or the bottom of the crown was categorized as "Low" severity, a tree with many tar spots on either the treetop or the bottom of the crown as categorized as "Moderate" severity, and a tree with many tar spots located all over the tree crown was categorized as "Severe".

Statistical analysis. Due to zeros in our data we do not have a normally distributed data, which lead us to use the nonparametric Mann Whitney U test to compare the fungus severity with the habitat type. We also performed a Mann Whitney U test to test the significance of severity and diversity.

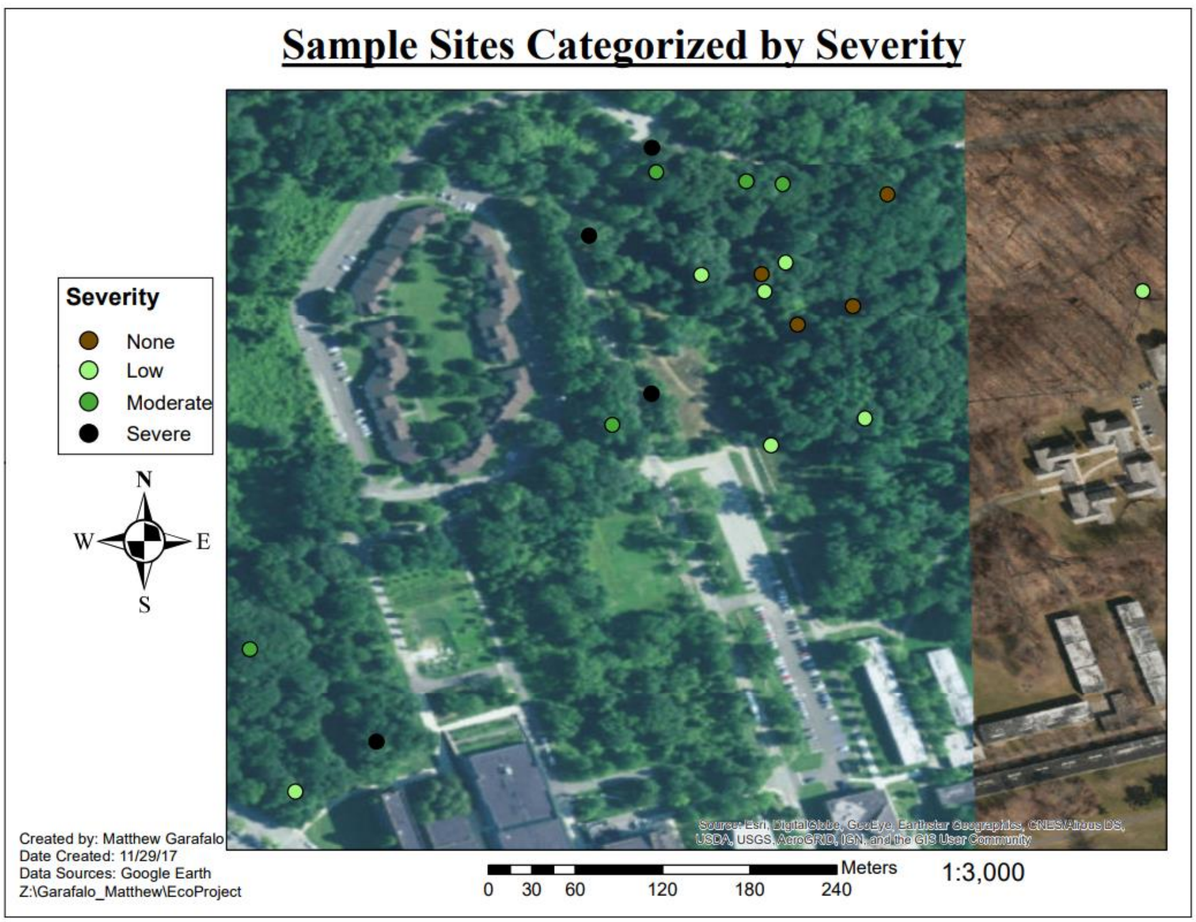

Figure 1: Our 20 sample sites shown on SUNY Purchase College Campus.

RESULTS

While conducting the experiment it was clear the edge habitat sites had a higher severity than interior sites. Our data supports that a higher mean severity in edge habitat sites of 2.2 differs significantly than a mean severity of 0.7 in interior habitat sites ($p < .05$, Table 1). The mean severity did not differ significantly for diversity levels of *A. platanoides* ($p > 0.05$).

Figure 2 and 3 show that on average tar spot was more prevalent in areas of some diversity as opposed to those areas of *A. platanoides* only. Figure 3 shows that low diversity has the highest average of severity. Figure 2 shows higher average presence and severity of tar spot on edge habitants.

Table 2 represents the distribution of severity between edge and interior habitats of our 20 sample sites. Low severity sites were the most abundant with 7 sites, followed by moderate severity with 5 sites, while no presence and severe had 4 sites. It should be noted that no presence of tar spot was only observed in interior habitats and severe presence occurred only in edge habitats.

Table 1: Average severity between edge and interior habitats between edge and interior habitats.

Average of Severity	
Edge	2.2
Interior	0.7

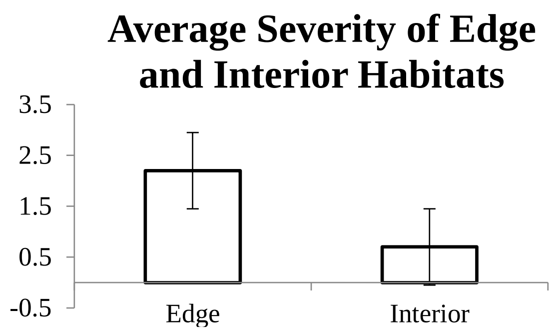

Figure 2: A visual of Table 1 with error bars representing the standard deviation of the data.

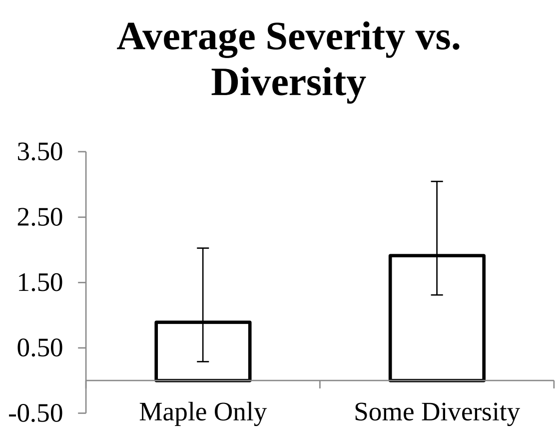

Figure 3: This graph shows the average severity with two groups: *A. platanoides* only and some tree diversity. There are also error bars representing the standard deviation.

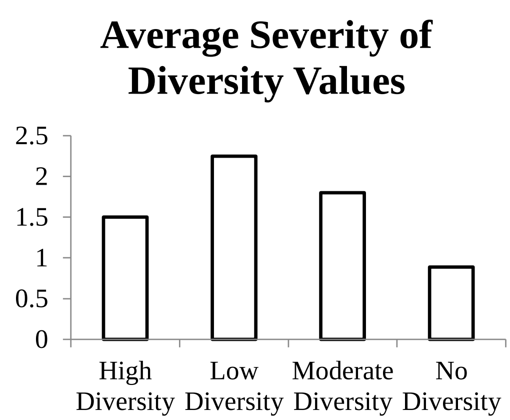

Figure 4: This graph is similar to Figure 3 but shows the average severity for all levels of diversity.

Table 2: Distribution of severity

Count of Severity	**Number of trees**
Low	**7**
Edge	2
Interior	5
Moderate	**5**
Edge	4
Interior	1
No Presence	**4**
Interior	4
Severe	**4**
Edge	4
Total Number of Sites	**20**

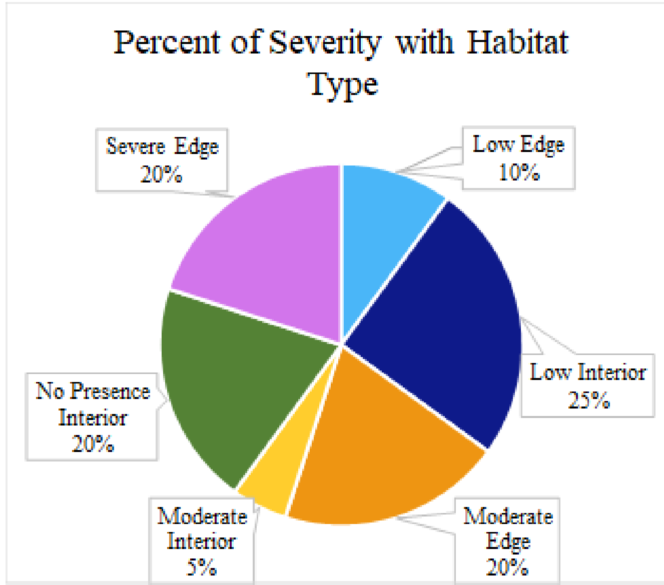

Figure 5: Percent distribution for all of our sample sites. Low severity in interior habitats had the largest percentage followed by moderate severity in edge habitats, no presence in interior habitat, and severe presence of tar spot; low severity in interior; and finally moderate severity in the interior.

DISCUSSION

Our results showed that the severity of tar spot was higher in trees that resided in edge habitat rather than interior forest habitat, thus supporting our hypothesis. This was most likely due to the fact that most of our edge habitat sites consisted predominantly of *A. platanoides*, thus leading to an increase in *R. acerinum* spore-containing leaves. Other considerations could be that leaf litter has a lower rate of decomposition in edge habitat (Riutta et al. 2012), leading to a higher concentration of infectious leaf litter. On average, sample sites with lower diversity had the highest severity of infection, more so than sites that only contained *A. platanoides*. This discrepancy could be explained by the method in which we used to determine tree diversity. There was a gradual decrease in severity as diversity increased, a finding that was in line with our hypothesis. More accurate identification of tree species and more sampling sites could allow for different results.

The presence and abundance of tar spot in maples has been used as a bioindicator of elevated atmospheric SO_2 and NO_2 concentrations. Multiple studies have shown that tar spot severity is lower at sites with high SO_2 and NO_2 concentrations (Gosling et. al 2016). According to Leith and Fowler (1988), distribution of tar spot is primarily controlled by the presence of overwintered *R. acerinum* infected leaves. Observations from a study conducted by Van Der Kolk et. al (2010), led authors to conclude that maple leaves infected with *R. acerinum,* possibly caused equine acquired multiple acyl-CoA dehydrogenase deficiency (MADD), an enzyme deficiency that typically results in the death of horses.

From our results, we can conclude that tar spot has an increased presence in edge habitats, which could be due to the fact that *A. platanoides* were initially planted as an edge habitat, border, and ornamental tree species. However, due to insufficient data at this time, the study was not able to show significantly whether or not the abundance of *A. platanoides* on the SUNY Purchase campus has any effect on tar spot disease severity or dispersal rate. *A. platanoides* have a decreased dispersal rate in dense intact forest and the spread of tar spot disease affects the growth rate of sapling *A. platanoides* (Lapointe, 2010& Martin, 2006). Statistical analysis models, human development and landscape augmenting can lead to increased invasions of woody plant non-native species (Allen et. al. 2013).

In order to further clarify our findings, future researchers would need to increase sample size and refine the methods used in data collection by referencing sufficient literature prior to data collection. Our expectation that *A. platanoides* abundance would correlate to tar spot disease abundance was incorrect. This was probably due to the fact that habitat type has a greater influence on the dispersal of the invasive Norway itself in addition to the spread of the pathogen.

As shown by Lapointe and Brisson (2011) tar spot disease does in fact influence the growth rate and photosynthetic production rate of the *A. platanoides*. If future studies took into account *A. platanoides* sapling abundance and health, the gathered data could show increased consistency between finds on campus and those of researchers further north of Purchase.

CONCLUSIONS

The findings of our study proved our original hypothesis of increased tar spot in more *A. platanoides* dense areas to be falsifiable. Rather, our data showed that our second hypothesis about prevalence in edge habitat to be non-falsifiable. The implications of the study are important for future researchers on the Purchase campus, as increasing sample sizes over the years will give the opportunity for more statistical analyses and increased significance in differentiating factors. The tar spot pathogen, as a co-invasive, is the Norway maple's only natural enemy in North America; perhaps, more studies into the effects of these species cohabitation can lead to a better understanding of how to manage invasives.

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