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INCREASED TOLERANCE OF HUMAN PRESENCE OBSERVED IN URBAN COMPARED TO RURAL EASTERN GRAY SQUIRRELS

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ABSTRACT

As urbanization spreads in a world with drastically increasing human population, wildlife are forced to adapt or face the reality of anthropogenic caused extinction. According to data collected at SUNY Purchase College in Westchester County, New York, urban squirrels have adapted to increase their tolerance of human presence due to frequent anthropogenic disturbances and habitat fragmentation. We sampled 20 squirrels total with 10 sampled from an urban site and 10 sampled at a rural site. We observed that urban squirrels tolerated more distance moved towards them by humans than rural squirrels tolerated. Eastern gray squirrels show promising ability to adapt their behaviors to better survive in these urban environments, as observed in this study as the loss of fear to some extent represented by the increased amount of human presence that was tolerated by the urban squirrels.

Keywords: Habitat Fragmentation; Urban; Rural; Tolerance; Squirrels.

INTRODUCTION

The reality of the world we live in is that human overpopulation is a huge problem, resulting in widespread distress across ecosystems that had maintained their ecological functions for thousands of years before. The exponential growth of human population size is the root of a variety of some of the world’s most complex ecological issues (Bavel 2013). One of the main factors in the damage that is being done by the expansion of mankind is the huge amount of habitat fragmentation that is occurring. Urbanization is causing habitats all over the world to become isolated from one another, barricaded by anthropogenic walls (Austin et al. 2015). Urbanization and habitat fragmentation have a direct relationship meaning as one increases, the other does as well (Liu et al. 2016). Habitat fragmentation causes a decrease in available natural habitat in the environment for organisms to utilize, and has been a leading cause of habit loss throughout the eastern United States (Austin et al. 2015). With the increasing global temperature limiting the habitat range of mammals, fragmentation can prove to be detrimental to wildlife.

Many mammals are negatively impacted by habitat fragmentation. Habitat fragmentation can be defined as the reduction and isolation of natural environments (Franklin et al. 2002). On the Purchase

College campus, fragmentation includes roads, paths, and building structures that separate the vegetative plots of land from each other. Fragmented land often leads to displacement and loss of habitat depending on the range size of the animal. However, some animals have the ability to adapt to their surroundings despite the urbanization of their environment, altering it from its natural state. By adjusting food preferences, changing their foraging and anti-predator behaviors, extending the length of their reproduction season, and other adaptive techniques, animals are able to maximize the benefits that they receive from urbanization (Jokimäki et al. 2011).

The eastern gray squirrel originated from the eastern United States and was introduced throughout the world between the late 1800's and early 1900's (Palmer and Koprowski 2007). They are typically known for their aggressive behavior towards humans and other animals, their spread of dangerous diseases, and their destruction of trees and property. The eastern gray squirrel seems to have better adapted to the increase of urbanization. As predation pressure decreases, the squirrels have a higher chance of accumulating in fragmented areas. As a result, the squirrels are able to adapt very quickly to their environment (Koprowski 2005). We have begun to see changes in squirrel behavior based on their location notably for squirrels living in urban environments (Bertolino et al. 2016). Human activity is thought to be a driver of behavioral changes in eastern gray squirrels.

In contrast to the urban adapted squirrels, rural squirrels tend to be more wary of human interactions being that they face the pressures of potential threat and predation. This is observed through behavioral responses including tail flagging. Tail flagging is a warning for other nearby squirrels that danger is present and is one advantage of group living that squirrels experience (Fulmer et al. 2010).

We hypothesized that the urban squirrels would tolerate more movement towards them by the human researcher than the rural squirrels would.

METHODS

Field Site. The location of both of the field sites were on the property of SUNY Purchase College in Westchester, New York. We collected data on 20 squirrels total. The 10 rural squirrels were surveyed in the old growth forest behind Alumni Village and the 10 urban squirrels were surveyed behind and to the west side of the dance building, a frequently utilized area on campus.

Data Collection. We collected data on October 18, 24, and 25, 2018. These days were chosen on the basis of having similar weather conditions to preserve consistency. Using meter tape, we measured the distance tolerated that the researcher was allowed to move towards the subject before it fled the area. We accomplished this by using a three person system. The three of us stood in one spot and wait for a squirrel to be insight and in our direct line of view. Then, one designated person cautiously approached the squirrel and paid careful attention to keep their pace constant. The person with the stopwatch stood next to the designated approacher and signaled when to begin moving toward the squirrel. When the squirrel displayed distress, either by tail flagging or fleeing the area, the approacher signaled to stop the timer and remained where they stopped. The third person then measured the distance tolerated with the meter tape. We measured from the starting point of the approacher, determined by the time-keeper, to the point where the approacher signaled to stop. We then imputed our data into Microsoft Excel and analyzed it in graph form.

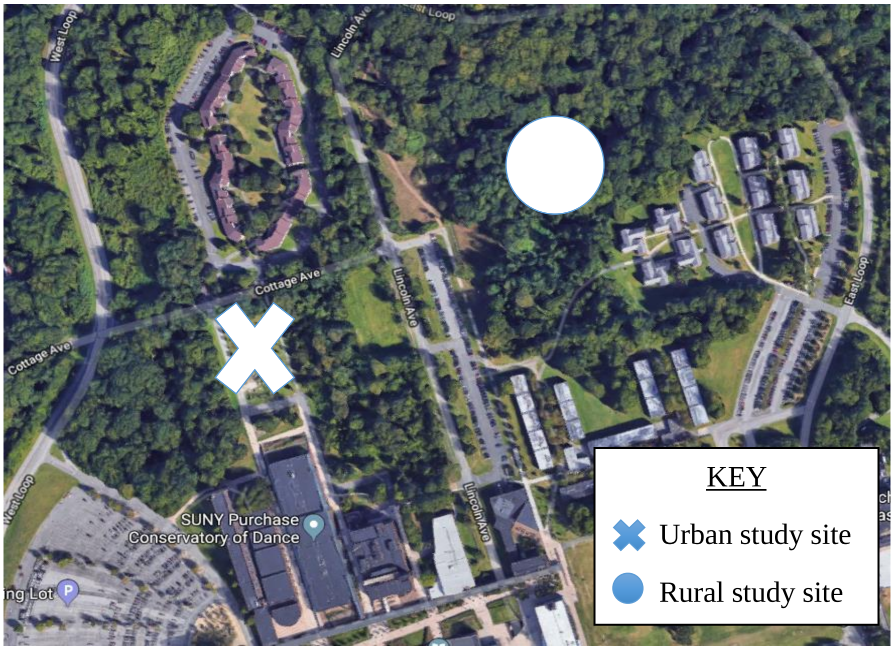

Figure 1. Study Area on Purchase College Campus (Aerial photo courtesy of Google Maps 2018)

RESULTS

Throughout our experiment, 20 squirrels in total were surveyed. Ten of which were found in a rural environment, and the remainder were surveyed in an urban setting. All of the areas chosen were found on the north side of Purchase College campus. We measured the average distance travelled by the approacher tolerated by squirrels in each environment (Figure 4) and the time it took for the squirrel to react to the approacher (Figure 5). Figures 2 and 3 display the detailed results of each individual squirrel that was surveyed for each site.

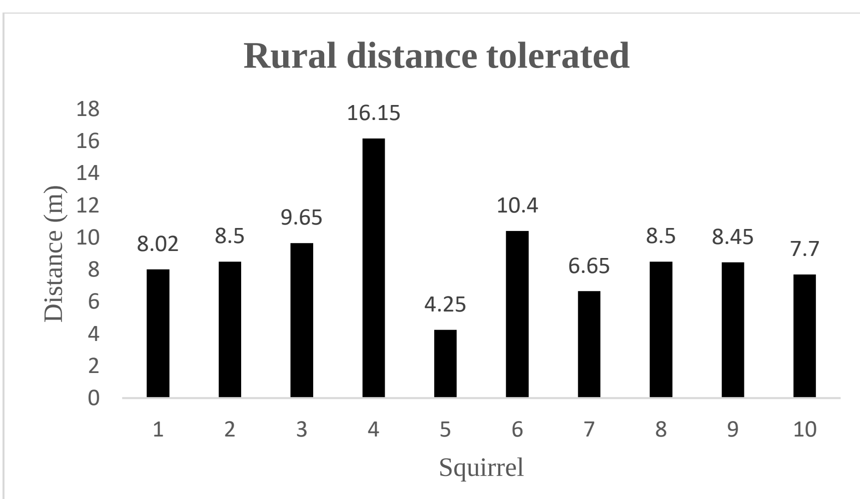

Figure 2. Rural distance tolerated for each individual squirrel

Figure 2 is a graph that shows the distance tolerated in meters for each individual squirrel sampled in the rural setting. We observed that the greatest distance allowed was 16.15 meters by squirrel number 4, and the least tolerated was 4.25 meters by squirrel number 5.

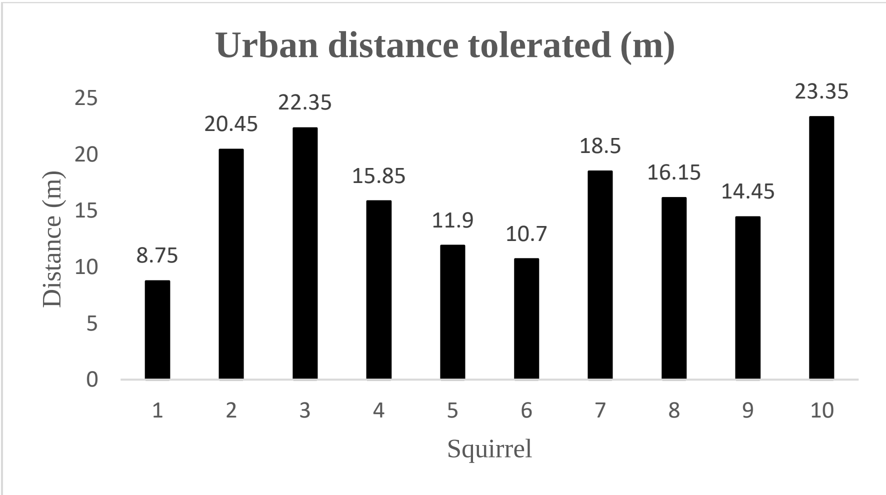

Figure 3. Urban distance tolerated for each individual squirrel

In figure 3, the distances tolerated by each individual urban squirrel sampled is represented. The highest distance tolerated was 23.35 meters tolerated by squirrel number 10. The least distance tolerated was 8.76 meters by squirrel number 1.

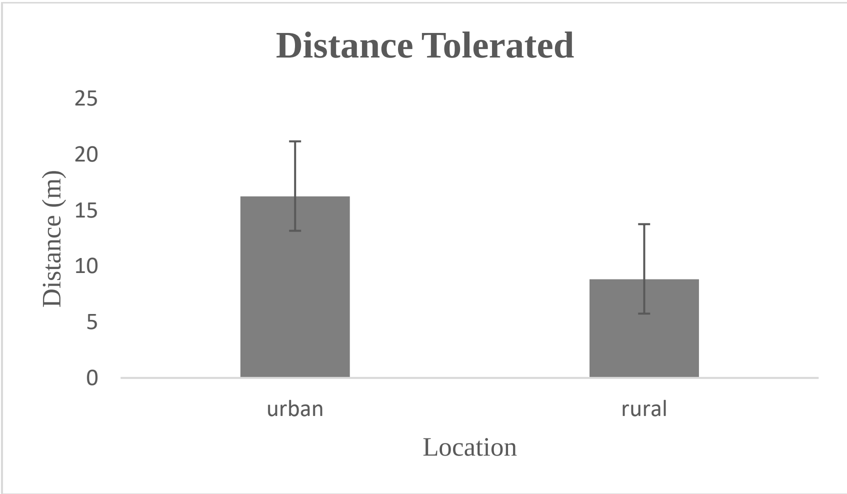

Figure 4. Average distance tolerated

Figure 4 represents the average distance in meters that was tolerated by squirrels in the urban survey site as well as the rural survey site. The standard deviation of both is represented by error bars. We observed that the urban squirrels tolerated humans to move further distances towards them before displaying defensive behaviors than the rural squirrels did. The average distance tolerated by the urban squirrels was 16.2 meters, which is greater than the average distance tolerated for rural squirrels, which was 8.8 meters. The standard deviation for the urban survey sample group is 4.9 meters, and the standard deviation for the rural survey sample group is 6.6 meters.

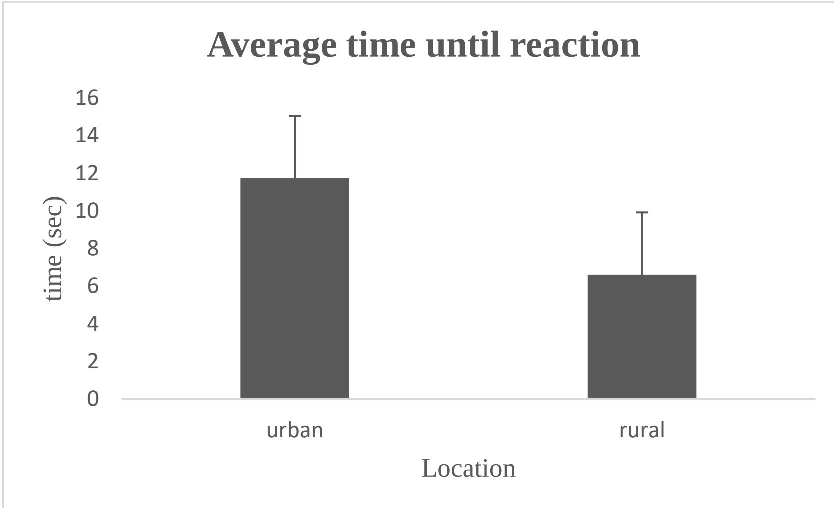

Figure 5. Average time until reaction

As represented in figure 5, our data showed that urban squirrels tolerated a longer average time before they displayed a behavioral reaction due to a human's motion towards it. The standard deviation of the urban and rural squirrels reaction times are represented by this figure as well. The average time until reaction for the urban squirrels sampled was 11.7 seconds, which is greater than the average time for the rural squirrels which was 6.6 seconds. The standard deviation for the urban survey sample group is 3.3 seconds, and the standard deviation for the rural survey samples sample is 2.9 seconds.

DISCUSSION

We hypothesized that the urban squirrels would tolerate more movement towards them by the human researcher than the rural squirrels would, which was supported by our data. Based on our research, we see that urban squirrels had a much higher tolerance for human presence than rural squirrels. Urbanized mammals tend to no longer display the same fear for humans as rural animals do. They have adapted to coexist with humans due to the pressures of habitat fragmentation and edge effects by utilizing alternative food sources (Jessen et al. 2018). Throughout our data collection, we witnessed many instances where urbanized squirrels were rummaging through trash cans in search of food near the dance building. These alternate food sources as well as the lack of predators in urban environments are both beneficial to squirrels (Jokimäki et al. 2016). Due to the vast opportunity for foraging, as well as the limitations posed by fragmentation, urbanized squirrels have tolerated increased interaction with human populations over time, causing them to lose some fear of humans. Similar studies have been done with marmots, which are in the same family as squirrels. These studies showed that increased human presence caused increased antipredator responses from the marmots (Griffin et al. 2007, Neuhaus and Mainini 1998).

Depending on human activity levels, eastern gray squirrels display different behaviors based on their environment. There have been studies that display eastern gray squirrels in areas with high human density showing increased antipredator behaviors when compared to squirrels in areas with lower human population densities. However, the opposite hypothesis was supported by our data. A notable variation between the study that we conducted and the study described in Cooper et al. (2008) was that the survey site for urban squirrels contained only few trees, where our urbanized site still had many trees present. Researchers in the 2008 study determined that due to the lack of trees, squirrels displayed an increased fear of humans, explaining why we did not obtain the same results (Cooper et al. 2008).

As we began our experiment, we faced a few problems with data collection. The most ideal way to record squirrel behavioral response would be to measure how close the approacher from the same start line each time, and also record its corresponding time measurement. Particularly for the rural sample group, data would have been almost impossible to achieve by those means. This is another possible reasons why our results strayed from the data collected by Cooper et al. (2008). In that study, they measured the distance between the approacher and the initial sighting point of the squirrel, which could result in inconsistencies since there is no viable way to record the exact spot the squirrel fled from. That being said, we had to work out a different strategy. That is when we came up with the concept of measuring the distance travelled by the approacher to standardize our data, rather than measuring the distance between the approacher and the site that the squirrel fled from. To ensure consistency, the approaching was done by the same person each time, with a walking pace that was as constant as possible for each of the trials. Another issue is that squirrels have a fairly large range and many urbanized squirrels retreat at times into the rural areas nearby, causing some overlap in data that we did not take into account. If future researchers were to replicate this experiment, it would be advised to sample a rural area that is very far from any urbanization, a difficult task for many locations. One way of achieving this would be to sample within a large preserved area that has little human interference. This would ensure that there would not be urban squirrels mixed into the rural sample set. Additionally, it would benefit the study to increase the sample size for each group surveyed.

Fear of predation is important in prey animals as it has a significant effect on their reproductive rates and emigration, through the “landscape of fear.” The landscape of fear is a term used to describe the predation risk perceived by the prey population. This is determined by the social response of the prey animal (Croft et al. 2017). When a predator is introduced into a prey population, the prey itself will either retreat from the area overtime, adapt to live with their predators or die due to predation (Forrester et al. 2017).

Although squirrels are capable of adapting to urbanized environment, increased urbanization can lead to reduced overall biodiversity across many taxa. The alteration of native habitats can have detrimental effects on species (Franklin et al. 2002). Habitat fragmentation and edge habitat can reduce the quality of nesting areas for birds and lead to increased nest predation. Additionally, birds cannot get the necessary nutrients and supplies for nesting in these fragmented areas due to decreased vegetative complexity and degradation of habitat (Marzluff 2001).

CONCLUSION

In an increasingly anthropogenic world, it is important to acknowledge that the actions of humans are having a vast and exponential impact on the behaviors of animals, in this case eastern gray squirrels. The overpopulation of humans and increasing urbanization is resulting in habitat fragmentation that is changing the way that the squirrels react to humans from their natural responses. This is represented in this study by the increased distance moved towards the squirrel by the researcher seen in the urban site, as opposed to the lesser tolerance to the approaching researcher observed in the rural squirrels.

ACKNOWLEDGEMENTS

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BIRD PREFERENCE OF NATIVE VS INTRODUCED FOOD SOURCES AT PURCHASE COLLEGE

Kayla VanHouten and William Yates

ABSTRACT

As the effects of climate change and anthropogenic land usage increase, native plant species are being pushed out. In the place of these plants, invasive plants and anthropogenic food sources are left as the dominant providers for bird fall foraging. In this study, we examine bird preference for native vs introduced food choices on the Purchase College campus. The three forging options we observed include one native fruit-bearing plant, the American pokeweed, one invasive fruit-bearing plant, the porcelain berry, and one introduced anthropogenic food source, a bird feeder containing safflower seeds. Results of this study show that birds preferred both non-natural food sources, the porcelain berries, and the safflower seeds, over the natural American pokeweed berries. However, birds preferred the safflower seeds in the bird feeder over all other options. Birds on the Purchase College campus show a strong preference for non-native food sources, encouraging us to conclude that the major source of food for fall foraging on campus is introduced, or non-native.

Keywords: Invasive species; Bird foraging; Bird feeder; Porcelain Berries; Pokeweed Berries.

INTRODUCTION

As humans continue to interact, trade, and globalize, we spread around different species of plants and animals that would not naturally live in these new environments. Specifically, an invasive plant species is not native to the ecosystem that they have been introduced to. These invasive species are invading completely new environments that are very different from their own native one. Since these invasive species have not evolved in this new environment, they often cause a disruption to the ecosystem's natural order, often even inducing environmental harm. Invasive plants are often able to spread and disperse at a much more efficient rate than the native species that have lived there. Therefore, invasive species are very effective at taking over the new environments they are introduced to (Laufer et al. 2006).

Seeds of native and invasive plants have many other ways of spreading that do not involve any interactions with humans. Birds have played a significant role in this dispersal of seeds (Murray 2012). One way birds help spread seeds is through seed consumption as they move either north or south during the change of seasons. There is still a lot unknown about birds and their relationships between invasive plants compared to their relationship with native plants, but the research has been growing in recent years (Gosper et al. 2005). A significant amount of invasive plants are high in carbohydrates, while natives are full of proteins and lipids, meaning they have a greater nutritional value. This means that birds are choosing food that may taste better, but is possibly a little less nutritious and healthy (Randall). Invasive species aren't all bad however, they tend to last longer into the early colder months and provide birds with food when food would generally be limited (Drummond 2005).

The relationship between birds and bird feeders is also something researchers still have a lot to learn about. Feeders provide an introduced source of food to birds that would not naturally occur without human interference. Birds can easily rely on this supplied food source when the natural sources of food might be compromised or unavailable due to weather conditions. Feeders can improve health, increase antioxidant levels and decrease stress in an individual bird's health, but there has also been an increased occurrence in infectious diseases in birds that use bird feeders (Gosper et al. 2005).

There is a substantial population of invasive plants on the Purchase College campus that have done a significant job at taking over and interfering with the native plants. One of the most abundant invasive plant species that we have on campus is Ampelopsis brevipedunculata, otherwise known as the porcelain berry. The porcelain berry was originally brought to the United States around the 1870s but has quickly out-competed native plants and has been spreading rapidly (FWS 2006). One native plant species on the Purchase College campus is the American pokeweed, or Phytolacca Americana. The American pokeweed is a perennial plant, native to most parts of the U.S. and some parts of Canada (USDA.) This campus has an abundance of birds that rely on all of our invasive and native species, as well as our bird feeders. These food sources are an important supply of food for the birds as the weather gets colder. This study investigates the relationship between birds and invasive porcelain berries, native pokeweed berries, and introduced bird seeds in bird feeders during the change of seasons on the SUNY Purchase campus. We predict that the birds on campus will prefer the food in the bird feeders over all else, followed by the invasive porcelain berries and then the native pokeweed berries. We hope our findings in this study will further help us understand the relationship between birds and invasive plants and how these invasive species are affecting our ecosystems.

METHODS

Field Site. We selected three sites on the SUNY Purchase College Campus to observe for our study. All of these sites are located between the Dance Building and The Commons apartments. Each site accounts for one of our potential food sources. We chose our sites first by using iNaturalist to assist in finding one native and one invasive type of berry on the Purchase College campus. We located these two sites and used a tape measure and flagging ribbon to measure out our study sites and mark them. Our first site consisted of a $20.25m^2$ lot of porcelain berries, along the path that runs between the academic buildings and The Commons apartments. Our second site was a $20.25m^2$ lot of American pokeweed berries located on the road that runs in front of the common's apartments. Next, we added a third site, with an anthropogenic food source. Our third field site consisted of a platform bird feeder located in close proximity to the other sites that contained Wagner's brand safflower seeds. This site was located in a tree directly behind the dance building. We checked this bird feeder each day of our observations to make sure it contained enough seed. Each of these sites can be seen in Figure 1.

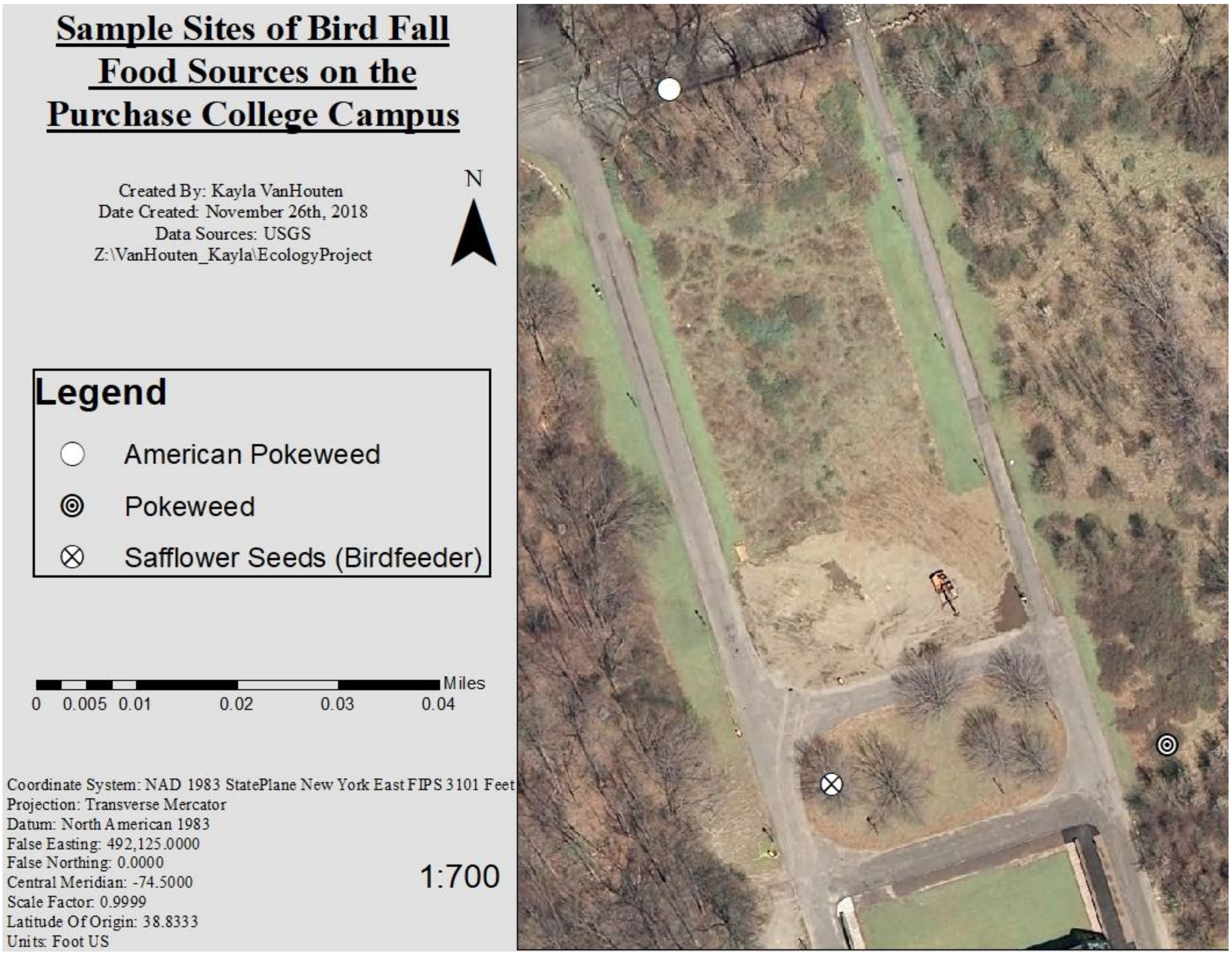

Figure 1. Our 3 study sites on the Purchase College Campus.

At each of our sites, we completed three separate hours of observation. All of the observations took place between October 24th, 2018 and November 1st, 2018 between the hours of 9:20 am and 12:10 pm. At each site, we sat a minimum distance of 20 ft from our study site so as not to disturb the birds and skew our findings. We observed the area with Eagle Optics brand binoculars and tallied the total number of birds at each site after each individual hour of observation.

RESULTS

At our first site, consisting of porcelain berries, we observed a total of four birds utilizing the berries over 3 hours of observation (Table 1) At our second site, consisting of American pokeweed berries, we observed a total of zero birds utilizing the berries over 3 hours of observation (Table 2.) At our third site, consisting of safflower seeds in a bird feeder, we observed a total of 40 birds over three hours of observation (Table 3). It is important to note that there were birds in the vicinity of all three sites during periods of observation. The variation in abundance of birds at each food source is presented in Figure 2. At the pokeweed berry site, we observed zero birds during all three days of observation. At the porcelain berry site, we observed one bird during the first hour of observation, two birds during the second hour, and one bird during the third. At the bird feeder site, we observed 14 birds eating the safflower seeds during the first hour of observation, 19 birds during the second hour, and 7 birds during the third hour. The sum of birds observed at each site over all hours of observation is shown in Figure 3.

Table 1. Porcelain Berries

Date	Time	Number of Birds Observed
10/24/18	10:20 am – 11:20 am	1
10/25/18	10:00 am – 11:00 am	2
10/30/18	9:30 am – 10:30 am	1

Table 2. American Pokeweed Berries

Date	Time	Number of Birds Observed
10/24/18	11:00 am – 12:00 pm	0
10/25/18	11:10 am – 12:10 pm	0
10/31/18	10:30 am – 11:30 am	0

Table 3. Bird Feeder- Safflower Seed

Date	Time	Number of Birds Observed
10/31/18	9:20 am – 10:20 am	14
10/31/18	10:30 am – 11:30 am	19
11/01/18	9:45 am – 10:45 am	7

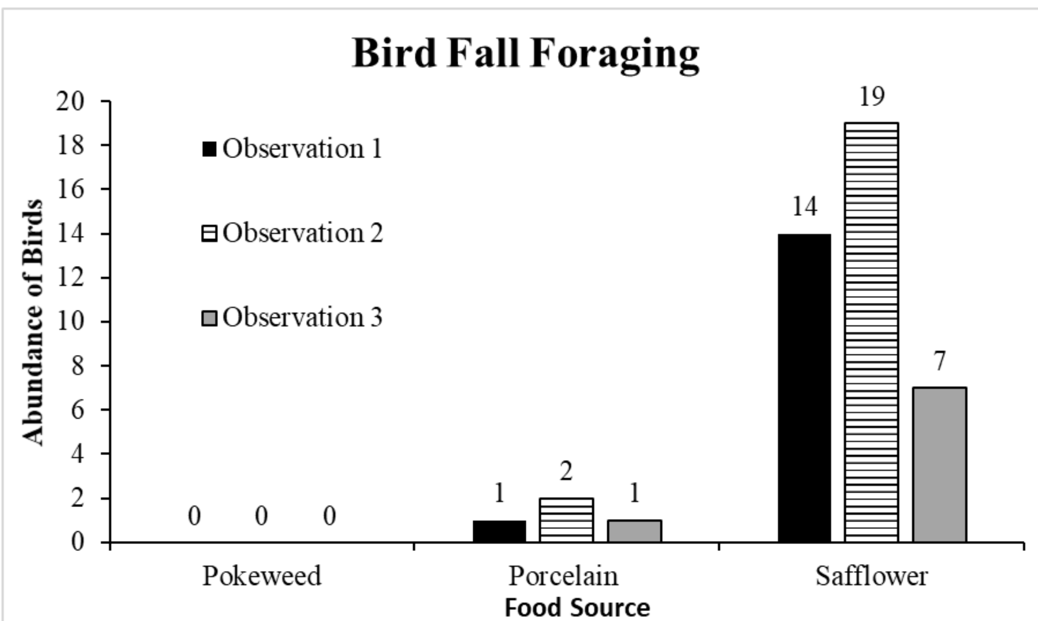

Figure 2. The abundance of birds at each food source separated into the three different periods of observation.

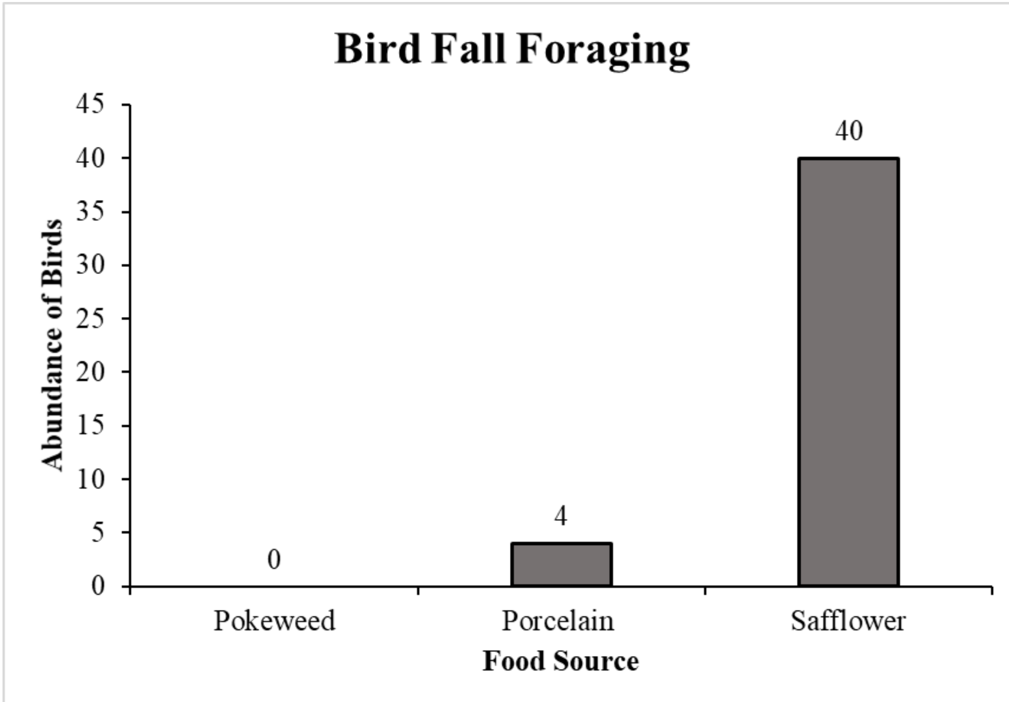

Figure 3. The total abundance of birds observed foraging overall at each one of the three food sources across all observation periods. Overall there were 40 birds observed at the bird feeder containing safflower seeds, four birds observed at the porcelain berry site, and no birds observed at the pokeweed berry site.

DISCUSSION

Our results showed that birds preferred both non-natural food sources, the porcelain berries, and the safflower seeds, over the natural American pokeweed berries, but preferred the safflower seeds in the bird feeder over all else. In several ecosystems, invasive species have become more dominant and now play key roles as providers in these ecosystems. These roles were originally taken on by native plant species but due to the effects of climate change and increased anthropogenic land use, these plants have experienced a decline (Davis 2011). This decline in native species means a decrease in foraging options for the birds. At such a critical foraging time birds are forced to turn to other options.

Regardless of the available berries, the birds favored the safflower seeds in the bird feeder over all other options. This could be due to the fact that the safflower seeds were easiest to obtain for the birds. We also considered that the results of our study may be linked to the possibility that the birds on Purchase College campus have already moved on from the berries as a winter food source. Migratory birds forage in a much different way than a wintering bird would. Migratory birds may experience inconsistent feeding conditions and are forced to adjust their diet and behavior in order to prepare for the possibility of varying prey throughout their migration (Martins et al. 2013). Migrating species require higher energy intake, in some cases, even attaining 65% higher energy intake rates than that of wintering birds. It is possible that if this study had been completed at a different time of the year, in early fall, we would find different results, possibly favoring the berries over the seeds.

We found that both the American pokeweed and the porcelain berries had a significant amount of fruit still left on the bushes but the safflower seeds were still easiest to forage. Knowing that hunger level is a determinant for feeding location is important to know in this study. When birds are satiated, they will prefer the uncertain feeding location, such as the berries, but when they were hungry, they will prefer the more consistent feeding location, such as the bird feeder (Talling et al. 2002). If the birds are foraging at the location with the greatest relative benefit, then it is clear that they will favor the bird feeders. The birds may also prefer the bird feeders because they had the greatest relative benefit in terms of nutritional value and increased body condition. One study found that after a year of being present at bird feeder sites, the birds showed an increase in body condition, concluding that this non-native food source had a positive influence on the birds (Wilcoxen et al. 2015). Invasive berries may not be as highly preferred as the birdseed, but they are preferred over native berries. Invasive plants are often higher in carbohydrates and native plants are higher in proteins (Randall). Essentially, the invasive plants are more like a junk food. This is potentially a reason for why the birds would prefer the porcelain berries over the American pokeweed.

To find more conclusive results in the future we would modify this study in a few different ways. First, we might try to observe at different times of the year. This might allow us to make broader conclusions on the foraging preferences of birds on Purchase College Campus, not only in the fall, but during each separate season. Another change we would make would be to look at other types of invasive and native food sources, as well as increase the number of patches we completed our observations at. This change would allow us to determine if other native or invasive plants may be favored over the safflower seeds. The last change we would make would be to observe for longer periods of time, for example, observing for 10 hours at each site instead of three.

CONCLUSIONS

Higher bird foraging activity was observed at the bird feeders than at each berry location. However, there was still more birds utilizing the porcelain berries than the sweed berries, allowing us to conclude that the introduced food sources were favored, the native berries were the least favorable, and our hypothesis was supported by our findings. We believe that more studies on bird foraging behaviors on the Purchase College campus would be beneficial.

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USING A CONTROLLED ENVIRONMENT TO TEST PORCELAIN BERRY (AMPELOPSIS BREVIPEDUNCULATE) SHADE TOLERANCE IN COMPARISON TO LIGHT LEVELS IN A NATURAL HABITAT

Leo Frampton, Paola Valencia, Alivia Zimmerman

ABSTRACT

The anthropogenic introduction of invasive species has posed an ecological threat to the native ecosystems of the eastern United States. Understanding the properties of these species is an important part of trying to maintain them. Ampelopsis brevipedunculata (porcelain berry) is a plant from eastern Asia and has become a more common invasive in eastern North America. This species may pose a threat to stands of young forests, replacing the biome with a secondary successional ecosystem which is mostly composed of Ampelopsis. This plant does well in many parts of forests and our experiment tested one property: light exposure. By figuring out a limiting factor of porcelain berry an effective removal strategy can be better determined. We exposed samples from the Purchase College campus woods to three different light settings. We found that porcelain berry continues to grow in the three light settings we tested, but high and medium did not differ as much as expected considering the large difference in the levels. Porcelain berry shows adaptive abilities and should be further studied and contained.

Keywords. Invasive, Growth rate, Limiting Factors, Light

INTRODUCTION

Human activities are altering habitats on a global level. The warming of the earth is moving species to areas they were never capable of colonizing because harsh winters wouldn't permit their growth (Walther et al. 2009). Changes in temperature can harm native species because they are adapted to lower temperatures and invasive species use elevated temperatures to their advantage when competing with native plants by increasing their chlorophyll contents (Song 2017). Milder winters now allow ornamental species that would die under cold conditions to survive through the winter (Walther et al. 2009). Many invasive species do better in non-ancestral regions because the new habitat may have variant qualities compared to its native niche such as more pollinators that allow them to create more flowers and spread faster (Petanidou et al. 2018).

The eastern United States has a history of agriculture which altered the original landscape (Robertson et al. 1994). Post-agricultural land that consists of new forests tend to have more invasive species which alter the herbaceous and woody ratios, and natives become more sporadic due to their inability to compete against non-natives (Kuebbing et al. 2014). In these sites, diversity, soil pH, carbon and nitrogen content, and soil makeup are different compared to undisturbed areas (J.L Dupouey et al.

2002). One example of an invasive that benefits from post-agricultural forest characteristics is porcelain berry (*Ampelopsis brevipedunculata)*.

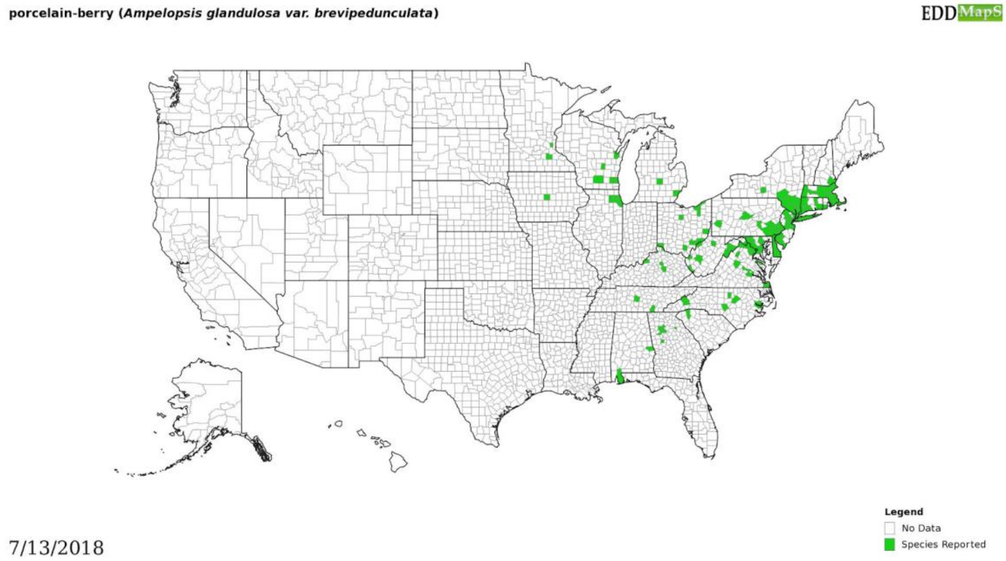

Image 1. Porcelain berry distribution in the United States (Center for Invasive Species and Ecosystem Health).

This invasive has become more prevalent in the eastern part of the United States (Image 1). *A. brevipedunculata* is a climbing vine native to Eastern Asia that was brought to America for its pastel colors and ability to curtain a landscape (Waggy 2009). As urbanization increases more edge habitats exist from roads and like many invaders porcelain berry benefits from increased sunlight. Porcelain berry has a shade-tolerance that allows for the plant to expand its distribution. Its abilities to grow in versatile habitats result in out-competing natives like Virginia creeper (Emerine et al. 2013).

The purpose of this study is to test porcelain berry under different light conditions. This invader is common in Purchase College's young woods. We wanted to understand which parts of the woods the plant has a higher growth rate in. Porcelain berries abilities to survive in shade and along the edges is an increasing problem and its decreasing biodiversity (Emerine et al. 2013). Since these plants are both present in low and high light areas there is a need for understanding where it does better. Exposing porcelain berries to a different level of light will show whether or not this is a limiting factor in its growth rate. This data can then be used in a removal strategy where a weakness is targeted and to either focus on shaded areas or edge habitats. We predict that the leaf and stem growth rate will be higher at stronger light exposure and slowest at low light exposure.

METHODS

To conduct this experiment, on 10/18/2018 we started off by collecting our 12 samples of young porcelain berries and placed them into our 18x15 plastic pots. Our collection site was located in the woodlot behind the science building at Purchase College Campus (Figure 1). We used hand shovels to carefully dig up our porcelain berries and placed each individually into our pots filled with ¾ of soil. We placed a piece of tape on each pot and labeled them accordingly; low 1, 2, 3, 4, medium 1, 2, 3, 4 and high 1, 2, 3 and 4. To obtain porcelain berry natural habitat light levels, we measured light intensities every 2m for 10m along a transect tape in the woods under a hardwood canopy located next to alumni village at Purchase College Campus (Figure 1). We started our measurements at a patch of porcelain berry that had invaded the understory and went from there, 10m out, using a transect tape and PAR (Photosynthetically Active Radiation) meter, which measures in micro-mole per meter squared per second (μmol/s-m2), for the light intensities (Table 1). We followed up by placing our pots into an incubator, in which we had a total of 4 pots for each 3 different light exposures; 4 pots were under high, 4 pots were under medium and 4 pots were under low light levels. Multiple pots were assigned to each light level to account for human error. The 3 different light exposures spanned on the observed light intensities measured along the transect tape. Our high exposure corresponded to 86.7 μmol/s-m2, our medium exposure corresponded to 15.1 μmol/s-m2 and our low exposure corresponded to 2.4 μmol/s-m2. Lastly, our porcelain berries were under the constant temperature of 26.7° Celsius and were watered every 2 days with 100 ml of water. We collected data every 5 days over the two weeks with the exception of our last data set which was taken on the 4th day (October 18, 23, 28 and November 1st 2018).

Additionally, to study the effect of the abiotic factor light on our invasive porcelain berry we measured the length (in centimeters) of the stem on every porcelain berry using a ruler. We also chose a leaf on each porcelain berry to measure their growth over the 2 weeks. To do so, we placed each leaf against a ruler, serving as the scale, and took a picture which was later analyzed using ImageJ. ImageJ is an image processing program that allowed us to measure the length (in centimeters) of each leaf. Each set of 4 porcelain berries were statistically recorded by how much stem and leaf growth occurred between each collection date throughout the 2 weeks. This data was analyzed into figures and tables which would then be compared to each other to display differences and/or possible similarities between growth under each controlled light level and furthermore to its natural habitat light levels.

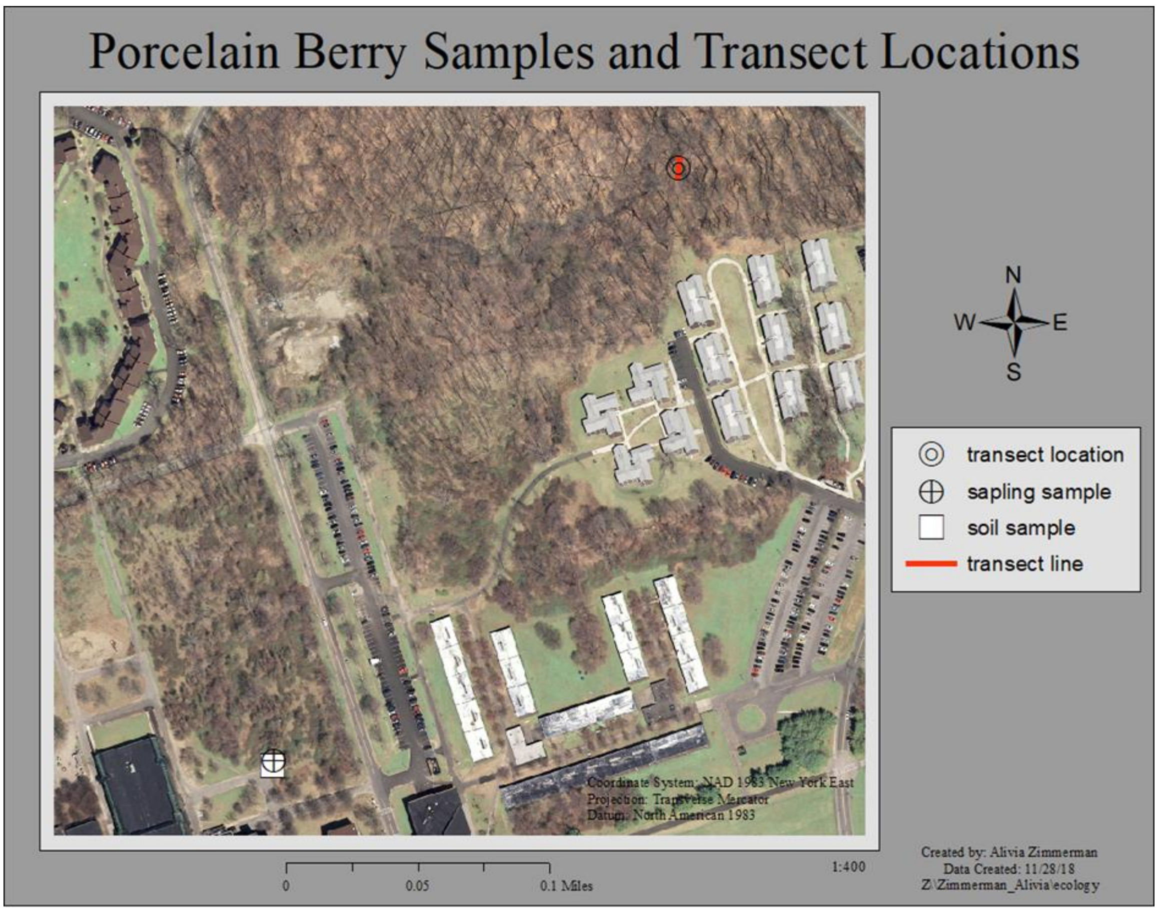

Figure 1. Transect, sapling and soil sample locations at Purchase College Campus

RESULTS

Transect Tape. Throughout the 10m along the transect tape the light intensities fluctuated every 2m (Table 1).

Table 1. PAR meter measurements, µmol/s-m2, in relation to distance from porcelain berry.

Distance From Porcelain Berry (meters)	µmol/s-m^2 Observed
10m	19.15
8m	41.38
6m	21.62
4m	17.23
2m	34.88
0m	40.3

Stem Growth. All stem lengths had different starting points, however all increased under the different light exposures throughout days 0-14 (Figure 2). Stem growth averages increased through each light level and differed more between low and high exposures (Figure 3). Medium exposure shows only 3 datasets because medium 3 died prior to day 10, therefore its measurements were excluded from both figures.

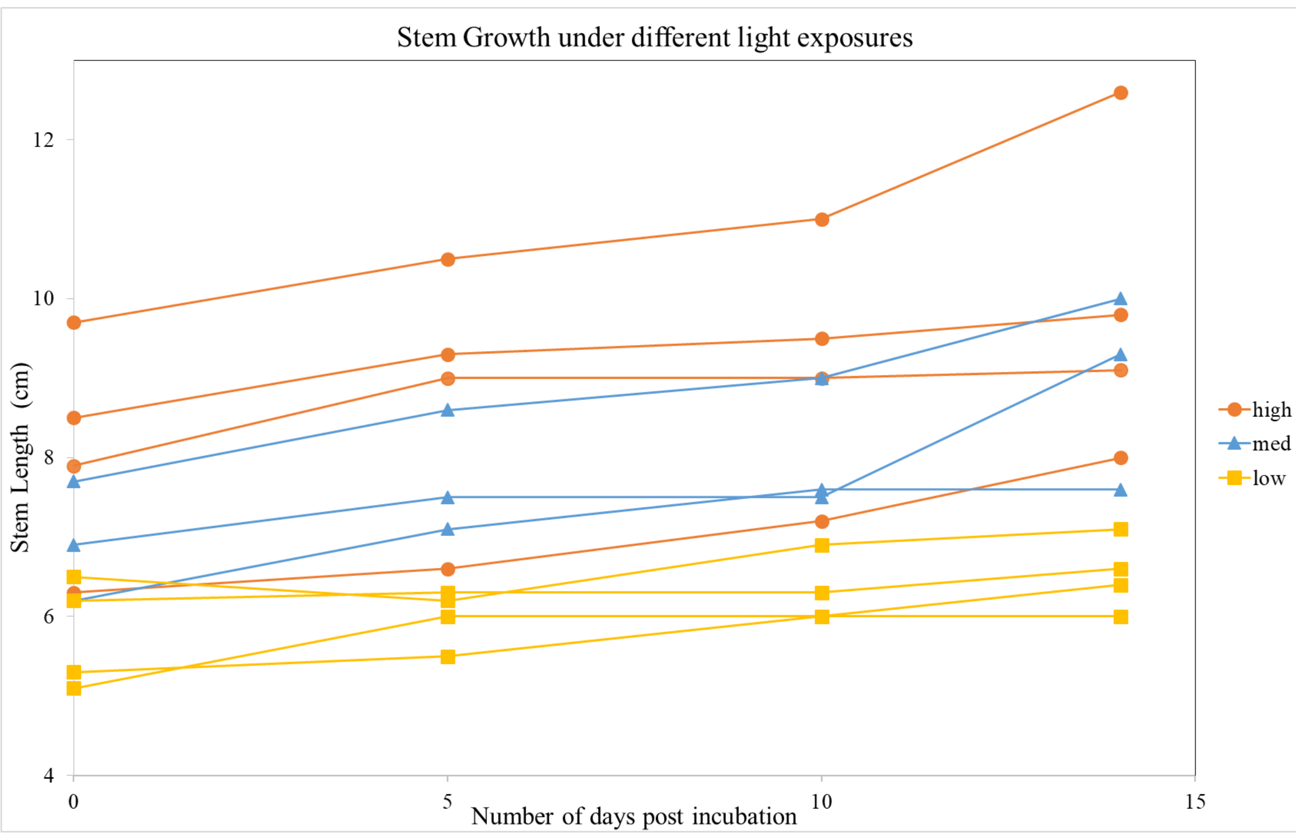

Figure 2. Stem lengths (cm) under high, medium (exclusion of medium 3) and low light exposures throughout days 0 to 14.

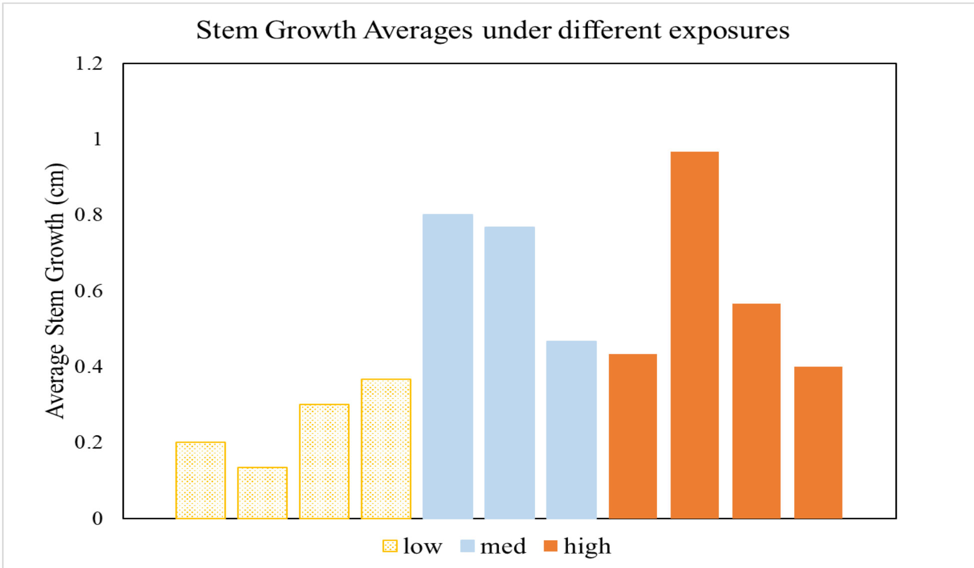

Figure 3. Stem growth averages for each porcelain berry under high, medium (exclusion of medium 3) and low light exposures. Standard deviation for stem growth averages varied from 0.2 to 0.9.

Leaf Growth. Overall leaf growth displayed the same relationship as stem growth; leaf lengths had different starting points and increased throughout days 0-14 (Figure 4). Leaf growth averages differed more between medium and low/high exposures. Additionally, medium exposure measurements were excluded from both figures 4 and 5 due to the same reason stated for its exclusion from stem growth and averages.

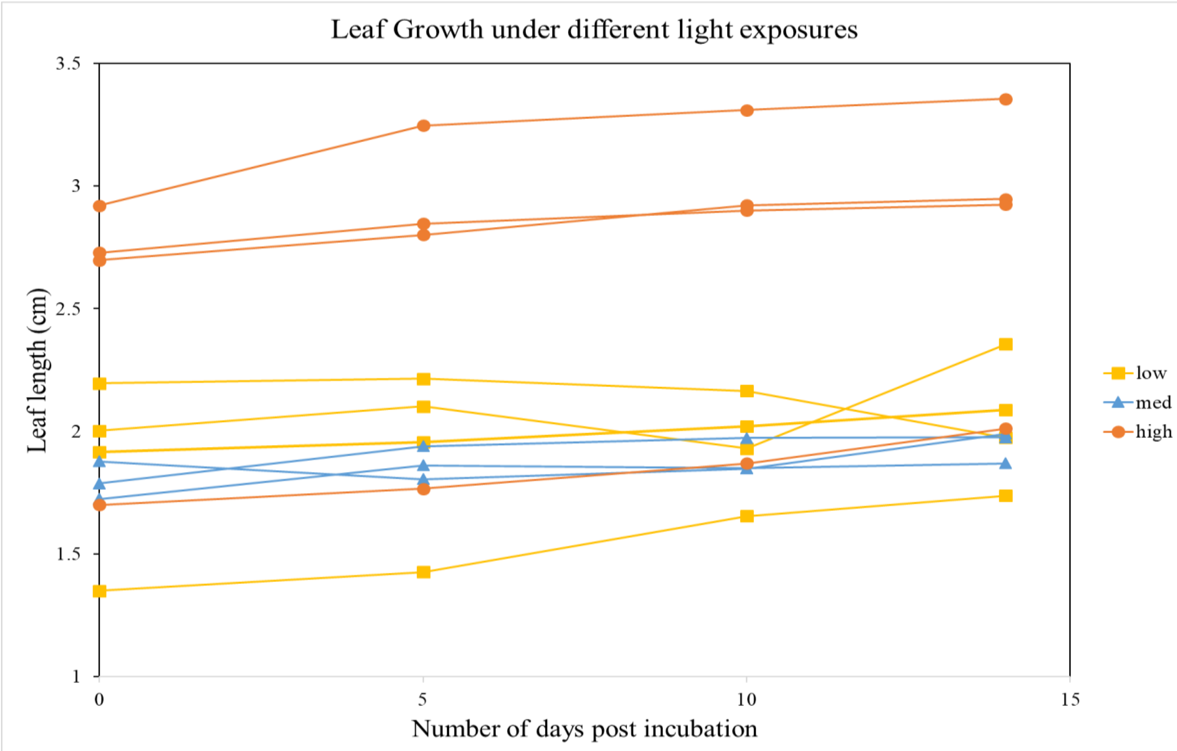

Figure 4. Leaf lengths (cm) under high, medium (exclusion on medium 3) and low light exposures throughout days 0 to 14.

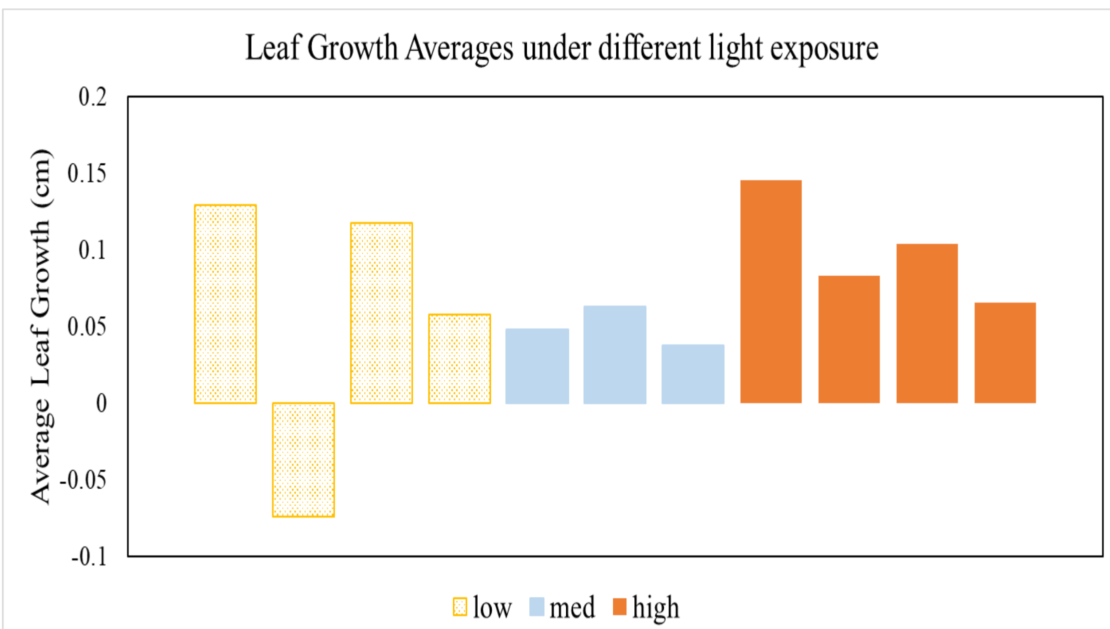

Figure 5. Leaf growth averages under low, medium and high light exposures; with the exclusion of medium 3. Standard deviation for leaf growth averages varied from 0.01 to 0.30.

DISCUSSION

Our results show a consistent rate of growth for saplings subjected to all three differing light levels. In our hypothesis, we expected saplings exposed to low levels of light to exhibit no growth over time or potentially to die during the course of the experiment. Instead, the specimens exhibited a consistent average rate of growth which only differed about three centimeters from the average growth rate of specimens subjected to high light levels.

On average, stem growth rose at a faster rate than leaf length. Light intensity appeared to have a stronger effect on average stem growth differences than average leaf length differences.
On days 10 and 14, we did not record data on the leaf length or stem growth of 'Medium 3' due to its apparent senescence. We extrapolated the death of this specimen due to frayed leaves which quickly fell off when touched. However, on day 14 new sprouts were observed extending out of the stem. Despite the fact that the specimen had continued to live, we were not able to gather leaf length data from the specimen. While we cannot state an exact reason as to why Medium 3 exhibited such dramatic changes, it is within reason to assume that a transplanting error caused significant health problems for the specimen. As demonstrated in all figures, specimens subjected to a medium light intensity show a much steadier rate of growth when 'Medium 3' is removed from the model.

When analyzed individually, consistency in growth rate varied depending on specimen and light intensity. While the leaf and stem length of most saplings ended up higher than at the start of the experiment, some specimens displayed negative rates of growth at different points in the experiment. One of these instances (low 3 in ImageJ) can be attributed to human error. On day 10, a different leaf was measured than the leaf which had been sampled on day 1 and day 5. Despite this mistake, the average growth in leaf length of saplings exposed to low light intensity rose consistently.

Comparison to Natural Light Levels. Saplings exposed to medium light intensity were subjected to 15.1 μmol/s-m^2. This level of light was significantly closer to the "low" light intensity than it was to the "high" light intensity. In our transect, the average μmol/s-m^2 recorded was 29.08 μmol/s-m^2. This level is almost twice the μmol/s-m^2 saplings in the 'medium' category were exposed to in our experiment. This data presents the possibility that porcelain berry plants in the wild may grow at a faster rate than the samples exposed to 'medium' μmol/s-m^2 levels in our experiment. Other research suggest that the light levels which had recorded in the field and in the lab were considerably lower than potential areas of open canopy in different seasons, areas, and times of day. Field studies of light levels in other projects which have measured shade tolerance have tested the effects of light levels up to 1500 μmol/s-m^2 (Dlugos et al. 2015, Kuehne et al. 2014).

Limits of Experimental Setup and Suggestions Going Forward. Conducting an experiment on transplanted saplings requires a high sample size in order to achieve significant results. The need for adequate sample size limited the range of abiotic conditions we could test on our saplings. With a larger amount of samples, it would be useful to test other limiting factors on transplanted saplings such as moisture or temperature.

It is also important to note limitations caused by using a controlled environment to conduct experiments on *A. brevipedunculata*. Comparison between transplanted lab samples and non-transplanted wild specimens may be useful to determine the effects transplantation may have on growth rate. When replicating this experiment more time for recovery should be allotted allowing the plant to recuperate after transplant (Coughlan et al. 2018). Our plants may have experienced a period of time where growth was stunted due to the shock of changed environments.

Other invasive shrubs local to southern New York have had their shade tolerance tested in more extensive, longer term studies. A project examining the shade tolerance of *Rosa multiflora* included an experimental indoor component as well as an outdoor component which observed the invasives in forest and forest edge habitats. This project, which was undertaken from spring until the end of fall in 2013, was able to consider additional variables such as fertility (fecundity) of the plants in a variety of shade environments. Although their sample size and range of light treatments was considerably larger than ours, indoor lab results showed a greater difference in growth rate between different levels of light than was showed with our *A. brevipedunculata* samples. In the field, fecundity of *R. multiflora* specimens was found to increase in areas with higher light. The differences in fecundity depended on light level to a greater degree than *R. multiflora* leaf area ratio, which did not show considerable differences in their results (Dlugos et al. 2015). This demonstrates that the leaf and stem measurements we took in our experiment could show a smaller connection between light and species success than a field study might, or than another variable may demonstrate (such as fecundity). Furthermore, comparing *A. brevipedunculata* shade tolerance to *R. multiflora* shade tolerance may be useful in the future. If *A. brevipedunculata* shows a greater level of shade tolerance than *R. multiflora*, that information can be used in consideration for management priorities.

The effects of light on *A. brevipedunculata* could also be also compared to saplings of a similar native species, such as *Parthenocissus quinqhefola* (Virginia creeper) and even other nonnative species in the *Ampelopsis* family such as *Cayratia japonica* (bushkiller) (Emerine et al. 2013). Comparison between porcelain berry and Virginia creeper may show how competitive the porcelain berry is to Virginia creeper. Emerine et al. found that porcelain berry had less effect on Virginia creeper than bushkiller. When porcelain berry was grown in competition with Virginia creeper it grew more buds, but both had a similar growth rate. They concluded that when these plants were grown together there could be an increased growth rate since they are competing with each other. These plants grow alongside each other in the woods and compete with each other for light and other resources; including them in an experiment could result in more realistic results.

Other studies have focused on invasives species in their original range to examine whether shade tolerance is the limiting factor that controls the dominance of the organism in their natural habitat. Some researchers have predicted that shade and light conditions could lead to genetic differences in abilities to tolerate low-light environments (Dewalt et al. 2013). Others have suggested that certain species are born in forests amongst other plant species which provide darker canopies. (Kuehne et al. 2014) *A. brevipedunculata* should be further examined in its native range to better understand the natural conditions which regulate the spread of the organism.

Despite the scale of our experiment, data from projects such as ours could eventually be compiled in order to make a model projecting areas which may have a high risk of *A. brevipedunculata* invasion. A model may also be able to give a projection of the speed which *Ampelopsis* could overtake a given area of land depending on different ecological features such as the presence or lack of a canopy. Although conventional wisdom may dictate shaded areas to be ‘lower risk’ of invasion than open fields, our results suggest that shade my not by a significant factor in the limitation of the spread of *A. brevipedunculata*.

CONCLUSION

Although significantly limiting light levels in a lab incubator did slow the growth of transplanted porcelain berry saplings, all but one of the specimens continued to grow throughout the experiment. It is possible that in a natural habitat, even under the shade of a canopy, much more light would be available to wild porcelain berry species than in our experiment. As porcelain berry rapidly increases its geographical range in the United States, there is much work to be done within the field of invasion science to better understand the speed in which it can spread through different biomes and ecosystems. A larger sample size and the addition of other abiotic factors may be useful to other researchers who would like to better understand the limiting factors of Ampelopsis.

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LEVELS OF INSECT, BIRD, AND MAMMAL ACTIVITY AT SNAG TREES LOCATED IN AREAS WITH VARIABLE AMOUNTS OF HUMAN ACTIVITY AND URBANIZATION

Aly Briere, Kennah Taylor, and Toby Rabten

ABSTRACT

Snag trees are a lesser known important part of a healthy forest ecosystem. Vertebrates such as birds and mammals, and invertebrates such as insects utilize them as habitat, and a place to forage for food. We studied the effects urbanization has on the activity level of invertebrates and vertebrates at snag trees by surveying the abundance of mammals, birds, and insects at three locations at SUNY Purchase College. Our first observational site we called our edge site, had the highest amount of human activity, our second location, our intermediate site had an intermediate amount of human activity, and our final observational site, our forest site had the lowest amount of human activity out of the observational sites. Observational data on vertebrate and invertebrate activity at the three sites was collected over a two-week period. Our findings were that mammal and bird activity was the highest at the forest site and insect (invertebrate) activity was the highest at the edge site. Mammal and bird (vertebrate) activity was the lowest at the edge observational site and insect (invertebrate) activity was the lowest at the forest observational site. Possible reasons for these findings are: many vertebrates such as rodents utilize very degraded snag trees as nesting sites, urbanization decreases the abundance of degraded snag trees due to high rates of snag tree removal in edge habitats vs in less disturbed habitats. Edge habitats are also more open to weather and human disturbances making them less suitable of a habit for vertebrates due to their susceptibility of being harmed from the effects. Invertebrates are less susceptible and sensitive to the effects of human activity and increased exposure to weather disturbances because of their small size, better burrowing and foraging ability compared to vertebrates. We believe more research needs to be done on the specific species of vertebrates and invertebrates utilizing the snag trees to formulate a plan on how to protect these species by protecting these invaluable snag trees in urban areas.

Keywords. Ecosystem, Snag, edge, forest, urbanization

INTRODUCTION

Sustaining the presence of wildlife within natural systems becomes increasingly difficult with the spread of human developments that disrupt the biosphere. The first forest that was cleared for human agriculture and livestock breeding marks the first modification of the ecosystem by Humans Marchant et. al 2018). Today, this modification takes another form; modern urbanization, where human have altered earth's natural structures to the point where there have been global negative impacts on the function of natural systems (Rongfang et al. 2018.) Urbanization affects global species diversity as well by minimizing habitat sizes and shifting the makeup of the ecological community via the creation of edge space (Brearley et al. 2010). These "edges" that border human development and intact ecosystems, correspond to a decrease in wildlife presence within these ecosystems due to noise, light pollution and general disturbance (Goulart et. al). Human development is also associated with deforestation, which is detrimental to woodland ecosystems, as the density of tree cover has been shown to have a strong positive correlation with species abundance (Goulart et. al). This makes it vital to integrate and preserve features in the increasingly urban landscape that can be supportive to long term diversity, and eco-systemic health.

Within forest ecosystems, snag trees are a vital component of the environment and are classified as standing dead trees that are created through old age, fire, wind, insects, and fungi (Barry et al 2017). A broad spectrum of vertebrates utilize the cavities within snags for shelter such as bats, rodents, and bears (Weiss et al. 2018.) Birds and other vertebrates also utilize snag tree cavities, created from tree rot, for shelter and often feed on insects that also utilize the trees (Weiss et al. 2018). Trees that have begun to die may be cut down because they pose a hazard to human developments but some need to be left undisturbed as they still play a major role in the ecosystem. In urban environments they are usually removed before they can degrade and prevent mammals from persisting that are reliant on their cavities (Edworthy and Martin 2014). These trees also offer nourishment for the forest ecosystem as they decompose by re-juvinating the soil and providing nutrients for organisms such as insects (Barry et al 2017). Snag trees in unmanaged forests have more microhabitats, which are cavities within the tree that support biodiversity and maintain the health of the ecosystem, than trees in managed forests (Paillet et al 2017). Snag tree cavities can take up to three years to develop, therefore snag trees must be left in the ecosystem and not disturbed by forest managers (Zarnoch et al 2013.) Snags are capable of storing carbon, and when left in forests undisturbed, release nutrients back into the soil matrix, further promoting the long-term health of the local biome (Oberle et. al 2018). They can also offer important data on tree ring chronologies which are useful in ecological studies (Weiss et al. 2018).

The Purchase college campus has many patches of forests that house different abundances of species depending on location. In this study, we investigate how the activity of animals on snag trees changes in different habitats that have a variation of disturbance levels. We investigated trees in forest, intermediate, and edge habitats We hypothesized that snag trees located in areas with low levels of human activity and urbanization would have a higher visitation rate for insects, mammals, and birds compared to snag trees located in areas with high levels of human activity and urbanization.

METHODS

To begin our study, we surveyed areas on campus to find snag trees in locations that had different amounts of disturbance from human activity and urbanization. For our first location, we looked for an area with an intact forest interior, small amounts of fragmentation and low levels of human activity. The second location we chose has moderate human presence and is closer to a main dorm so we used this area as our intermediate site. The third location is the most fragmented and has the highest amounts of human activity and urbanization. The observational site we choose with low amounts of human activity and urbanization is located 1 mile from the main campus and a half of a mile in all directions from all human developments. We labeled this observational site our "Forest" site. The observational site we chose with intermediate levels of human activity and urbanization is located a quarter of a mile from alumni and all other human developments which we labeled "Alumni". The observational site we choose with high amounts of human activity and urbanization is located less than a 10th of a mile from human developments in very close proximity to the dance building and a concrete road and walkway, we classified this as our "Edge" site.

The Forest site was found at the South-West corner of the campus, and bordered the South West edge of the loop. The intermediate observational site was found at the North-Eastern corner of Purchase Campus and was located in between the Alumni and the Commons. The Edge observational site was found near the Western Edge of Purchase campus and was directly West of the Garden in front of the Dance Building and directly North of the West 2 parking Lot.

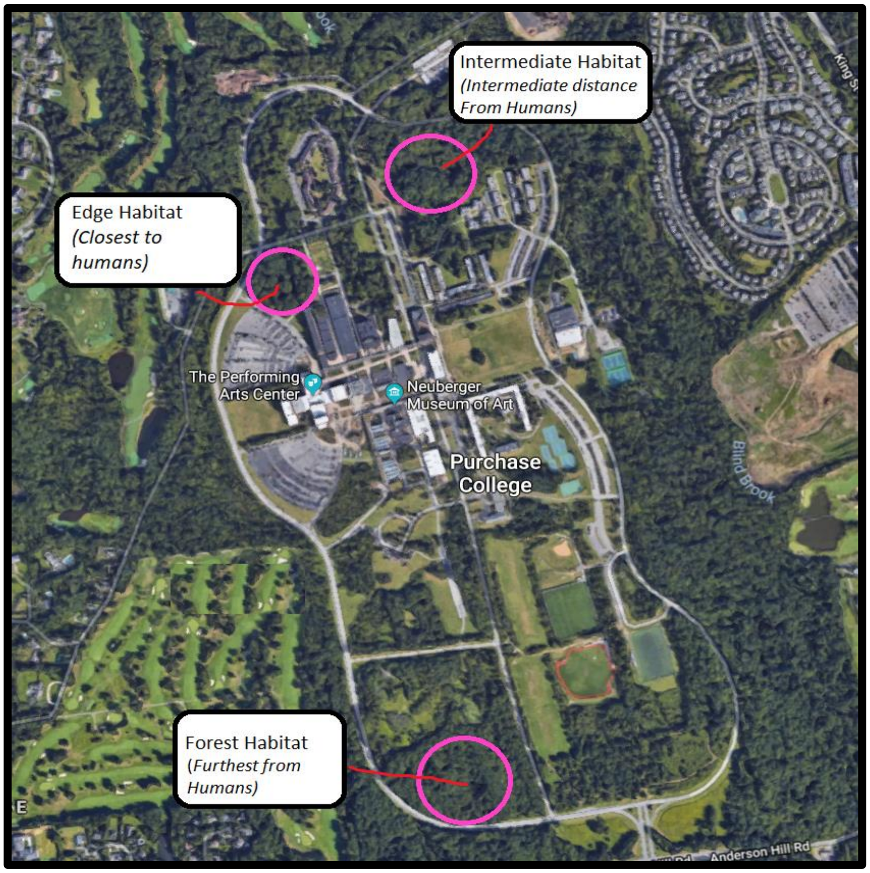


Figure 1. Map of our three sites

At each site, we chose three snag trees to observe within a 40 foot proximity from each other, this ensures that all the trees have the relative distance from human activities and other distances. For the purposes of our study we focused on the presence of birds, squirrels, chipmunks and insects that were visible with the naked eye. We defined activity of these organisms as foraging, climbing, perching, nesting, or breeding on the snag trees. To record our data, each group member (in our three-person group) was assigned one site and recorded their observations of snag tree utilizations for each organism type.

Each group member went to their designated site twice per week and observed each tree at the observational site for an hour over a period of two weeks. The length of time we chose, seemed to be optimal for minimizing the effects of our presence on how the animals were acting. We first observed the insects, as that required getting very close to the trees and counting as many as we could see without any equipment. We then watched the trees from a distance of approximately 15 feet. This allowed us to keep a close eye, while also being far enough away to not alter "normal" animal habits. While performing these observations we used iNaturalist to identify unknown organisms as well as our built in Phone cameras to keep track of the snags that we were observing and to photographically capture any organisms of interest.

RESULTS

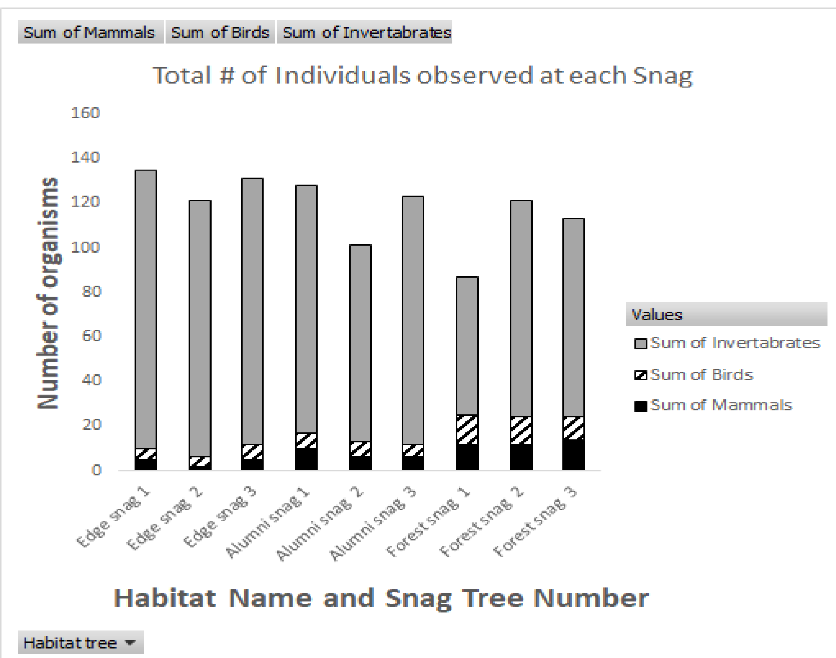
Figure 1 below is a graph of our raw data which display's the number of birds, mammals, and vertebrates we observed in total at each tree in each observational site over the two-week data collection period.

At the "Edge" site (high level of human activity) 93% of snag activity recorded was caused by invertebrates (percentages of organismal activity per habitat are found in figure 3 below), and an average of 14.1 invertebrate individuals were observed (average organismal activity for each site found below in table 1, and figure 2). 5% of snag activity was caused by birds at this site with an average of 0.6 individual birds. Lastly, 2% of activity was caused by mammals, and an average of 0.5 individual mammals were recorded.

At the "Alumni" site (intermediate level of human activity) 88% of snag activity recorded was caused by invertebrates, and an average of 12.9 individual invertebrates were recorded. At this site birds were responsible for 5% of activity and had an average of 0.8 individuals. Finally, 7% of activity was caused by mammals, and an average of 0.9 individuals were recorded at this site.

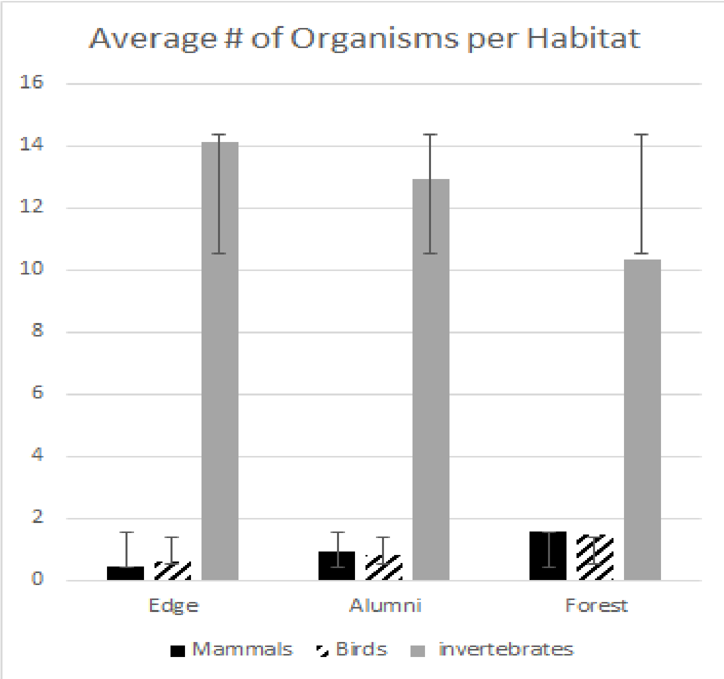
Lastly, the "forest" site (lowest level of human activity) 78% of snag activity recorded was caused by invertebrates, and an average of 10.3 individuals were recorded. 10% of activity at this site was caused by birds, and an average of 0.5 individuals were recorded. Lastly mammals were responsible for 12% of activity, and an average of 1.6 individual mammals were recorded.

The standard deviation for our habitat sites below in table 2 displays that the "edge" site had a standard deviation of 42, the "alumni" site had a standard deviation of 39, and the "forest" site a standard deviation of 31.



Levels of human activity
Edge: High
Alumni: Medium
Forest: Low

Figure 1. Total recordings for each Snag. Each bar in the graph above represents the total activity collected for an individual snag).



Levels of human activity
Edge: High
Alumni: Medium
Forest: Low

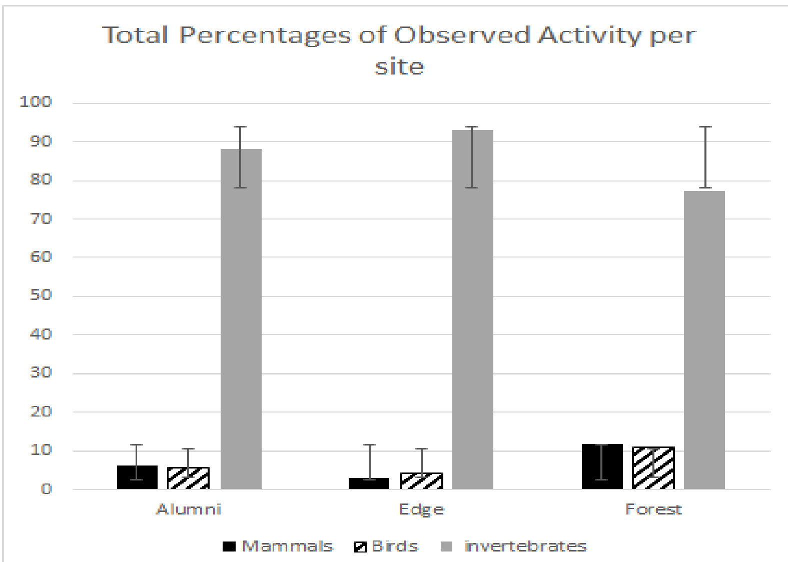
Figure 2. Average number of invertebrates, mammals, and birds per habitat. The graph above shows the average number of individual mammals, birds, and invertebrates observed per habitat site .

Table 1. Average number of individuals observed for each site. This table below lists the numerical averages for individuals of mammals, birds, and invertebrates involved in snag activity over the course of the two-week study

Habitat	Mammals (average)	Birds (average)	Invertebrates (average)
Edge	0.5	0.6	14.1
Alumni	0.9	0.8	12.9
Forest	1.6	.5	10.3

Table 2. Standard deviation for each habitat type. Illustrates the diversion from the average of total organismal activity for each habitat site

Habitat	Standard Dev for each Habitat
Edge	42
Alumni	39
Forest	31



Levels of human activity
Edge: High
Alumni: Medium
Forest: Low

Figure 3. Total Percentages of organism activity recorded over 2 weeks.

The Figure above illustrates the total percentages of the organism types found at each site. At all sites, invertebrates were the most commonly found organism percentage wise. The total percentage of Birds and Mammals observed at each site made up only a small proportion of the organisms observed as invertebrate findings were far more abundant than Bird and Mammal findings.

DISCUSSION

Based on the data we collected, we found that organism activity in snags seems to be affected by proximity and intensity of human activity and that the abundance of invertebrate activity in an area is affected by the abundance of nearby bird and mammal activity. We hypothesized that insect, mammal, and bird activity would be the lowest at the "edge" site, our observational site with the highest amount of human activity and urbanization, and insect mammal, and bird activity would be the highest at the "forest" site our findings partially supported our hypothesis. In the "forest" observational site with low levels of human activity, Invertebrate activity was the lowest compared to the other sites but mammal and bird activity was the highest. This may be because the birds and rodents were acting as predators to the insects and decreased their presence in this area. In particular, birds may be chiefly responsible for this shortage in insects as they have a heavy preference for insects as their main food source above all other sources in woodland areas (Nyfeller et al. 2014). In the Edge habitat the presence of birds and mammals was the lowest, which may be a factor that allowed for Invertebrate colonies to flourish and hold dominance over this Edge site. The higher abundance of Birds and mammals seen in the forest is supported by other studies that have been done around the world. In a study conducted on snag density and abundance of cavity nesting birds in western coniferous forests areas with higher densities of snags also had higher abundances of certain cavity-nesting bird species (Spiering and Knight 2005). In Australia, scientists had a 3.9% success rate at capturing squirrel gliders in deep forest compared to only 1% catch rate in areas within edge habitat (Brearley et. al)

Out of all of the habitats, the edge space promoted invertebrate species richness the most but was the least supportive to birds and mammals such as chipmunks and squirrels. This would make sense as other research has shown that edge habitats allow for more access to wind, light, and sound which can cause huge disturbances to the ecosystem and habits of Birds and Mammals *(*McGabe et al 2018). Along with this overexposure of wind, light, and sound, the Edge habitat we chose was also lined with pathways used by humans daily and this high amount of Human activity also seemed to have a clear impact on the presence of Birds and Mammals for the snags at this Edge site.

Urbanization has also been seen to have had a negative effect on local populations of Mammals and Birds mainly due to the destruction of common food sources (insects and nuts) and prime habitation spots such as snags and healthy trees (Seress and Liker, 2015). In a study conducted on the abundance of snag trees in relation to urbanization, forest patches with no prior history of forest disturbance have 19 times the density of snags than patches of forest that have been disturbed by complete timber harvest in the past, and 3 times the density of snags of forest areas that have been moderately disturbed from timber harvest (Spiering and Knight 2005). This study shows how urbanization directly affects snag abundance which also affects snag activity levels and biodiversity. In one study, an increased amount of edge space was shown to drive the presence of squirrel gliders significantly downward as these animals are deterred from areas that have been disrupted. Squirrel gliders select for densely forested areas opposed to choosing denning sites close to human developments (Brearley et al. 2010). This type of habitat select is most likely a driving factor for the trends we observed in chipmunks, squirrels and possibly birds as well.

Habitats that are closer to Human sites but not within direct human traffic (Edge site) have been shown in recent studies to be prime spots for Insect habitation. This may be due to the fact that these “edge” habitats provide both sufficient nutrition from human sources (trash and waste) while not being outright exterminated by being in the direct path of human traffic (Lindenmayer and David et al. 2014).

In our study we decided that whether the animal we were observing was an invertebrate or vertebrate was more important than the specific species since vertebrates and invertebrates have similar resource and habitat requirements pertaining to each group. To continue expanding on this study, research would have to be conducted on the specific vertebrates and invertebrates that utilize snag trees in different areas.

Sources of error that could have muddled our findings include not taking enough sightings at each of our snag sites and leaving out other factors that can affect visible organism activity such as temperature, time of day, and precipitation.

To further investigate and support these findings, we would definitely need to spend a longer period of time working with these different sites. Adding more plots to each habitat and sampling more frequently would also help to give our data the accuracy we need to further expand this body of research.

CONCLUSION

Our findings are important because they suggest that urbanization has an effect on vertebrate and invertebrate activity within snags. Understanding how to conserve and manage forests through proper snag management and more carefully scaled urbanization is vital as allows us to prioritize and preserve the denning sites and breeding grounds that serve as vital habitats for many animals and prevent disruptions of local ecosystems. In some areas of the world, birds depend on standing dead trees for reproduction even more than live ones (Davis and Miller 2018). In certain cases snag trees have even been artificially created by forest managers to restore ecosystems and provide shelter for birds, mammals, and invertebrates (Zarnoch et al. 2013). Therefore, the importance of snag trees for the health of woodland ecosystems everywhere is not to be overlooked (Weiss et al 2018). The impacts of converting green space into urban areas differ depending on the level of development. As biota continue to become more vulnerable because of the imposing changes, it's important that animals are able to sustain themselves in the built world.

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IMPACT OF PINE ALLELOPATHY ON SEED GERMINATION

Robert Bertolacci, Germain Meza, Sean Sandell

ABSTRACT

Allelopathy is an environmental augmentation by an organism in which it produces a biochemical agent that influences germination, growth, survival, and reproduction of other organisms. This experiment was designed to test the effects of soil allelopathy on various types of seeds. This was tested with five different types of soil and four different types of seeds keeping temperature, humidity, light, and amount of water constant. The results yielded that the seeds did poorly in the red pine soil (allelopathic soil) compared to the other soil types. The data also shows that seeds grown in the forest floor soil had the highest seed germination. Independent of seed species, the red pine soil on campus was shown to have the biggest impact on seed germination.

Keywords: Allelopathy, Germination, Invasive Species, Red pines, White pines

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INTRODUCTION

Growth and development of flora in any environment is important to the overall health of that area. Without proper development of a variety of trees, grasses, and shrubs, other organisms could not sustain themselves (Tilman and Downing 1994). These are the primary producers of an ecosystem; therefore, they provide their environment with the first level of energy needed to support every other organism. Plants also support animals by providing habitat. Before plants can begin to take root, one major factor has to be accounted for, which is soil. These groups need a suitable location to grow, meaning they need adequate soil to have a chance to grow to maturity. Inadequate soil could lead to a decrease in plant growth and germination (Gong et al. 2001). The quality of soil can be altered because of some factors, including salinity, acidity, the ability to retain water, and nutrient content. Soil health is a very important factor in determining how many seeds will germinate, how tall the plant will grow, and what types of species can grow there. Changes in acidity, in particular, can have some positive and negative impacts on seed germination and seedling growth (Redmann and Abouguendia 1979).

The acidity of soil can be affected by many features near the soil, one of which is pine trees, specifically Red and White Pines. These trees will drop their needle-shaped leaves on the ground around them which can acidify the soil around the tree. This is known as an allelopathic effect, an effect by an organism in which it produces a biochemical agent that influences germination, growth, survival, and reproduction of other organisms. The allelopathic effect from the Timor white gum (*Eucalyptus urophylla*) plant has a restraining factor on native woody communities (Qin et al. 2018). In this case, the pine needles have acidic properties that change the pH of the soil near the tree making it harder for other plants to grow there. This adaptation can be observed visually; as the plant life under large groups of pine trees is often more sparsely located than in open fields.

Both Red and White Pine are native to North America (Cook et al. 1952), so native species have had a long evolutionary history of dealing with the allelopathic effects of pine needles. This may give these native species more adaptations that make it better suited than other species to germinate in pine needle soil. However, in the past two centuries, human movement has led to an increase in invasive species. This has introduced an array of species to our forests, and many have become dominant. On the Purchase College campus, we can find a long list of invasives, such as Multiflora Rose, Tree of Heaven, Norway Maple, and Porcelain Berry. Successful removal of these species, especially those that take over the undergrowth of our wooded areas, would require long and tenuous effort. The most effective method for removal is to go in and cut back all of the invasive undergrowth, then to repeat the process constantly for several years. If this is not done constantly the area is likely to return to how it was before by the next year (Flory and Clay 2009).

Another method of removal is to introduce a species that is a natural predator of the first species. In this case, this would mean introducing Asian species that naturally predate on Porcelain Berry and the Multiflora Rose. However, past efforts to use this method of population control have had low success, with the possibility of making the situation worse (Baldwin et al. 1952). Some other methods to control these invasive species would also look at chemicals to help the situation, but the side effects of these chemicals are not completely known. One potential method of controlling invasive species without introducing a new species or using new chemicals is to reintroduce a native species that is known for using chemicals for its benefit.

We looked at how different soil samples from different locations, two pine soils and two non-pine soils, around the Purchase College campus would cause different species of seeds to germinate or not to germinate. Our hypothesis is that fewer seeds, independent of species, will germinate in the pine soils than in any other soil.

METHODS

Field site. The site we studied from was SUNY Purchase College. Purchase College has different types of biomes located on the campus. First, we collected soil samples from a forest biome; two soil samples from the forest edge and two soil samples from the center of the forest. Second, we collected soil samples from an open grassland biome; called the “Great Lawn”. We collected soil samples from the center area, the northern area, the western area, and the eastern area of the Great Lawn. Third, we collected soil samples from a semi-urbanized biome; next to a road and a walkway where white pine trees are planted. Soil samples were collected next to four different white pine trees. Fourth, we collected soil samples from a heavily urbanized biome; located in front of the Big Haus dorm on the campus and next to a parking lot. Four soil samples were collected next to four different red pine trees.

We used a hand trowel to collect our soil samples on October 12th, 2018 and stored them in labeled ziplock bags. In total, we collected 16 bags of soil samples. These sample locations are marked on the map below (Figure 1). We took four samples from each location. These soil samples were left in the Ecology Lab over a weekend to dry out.

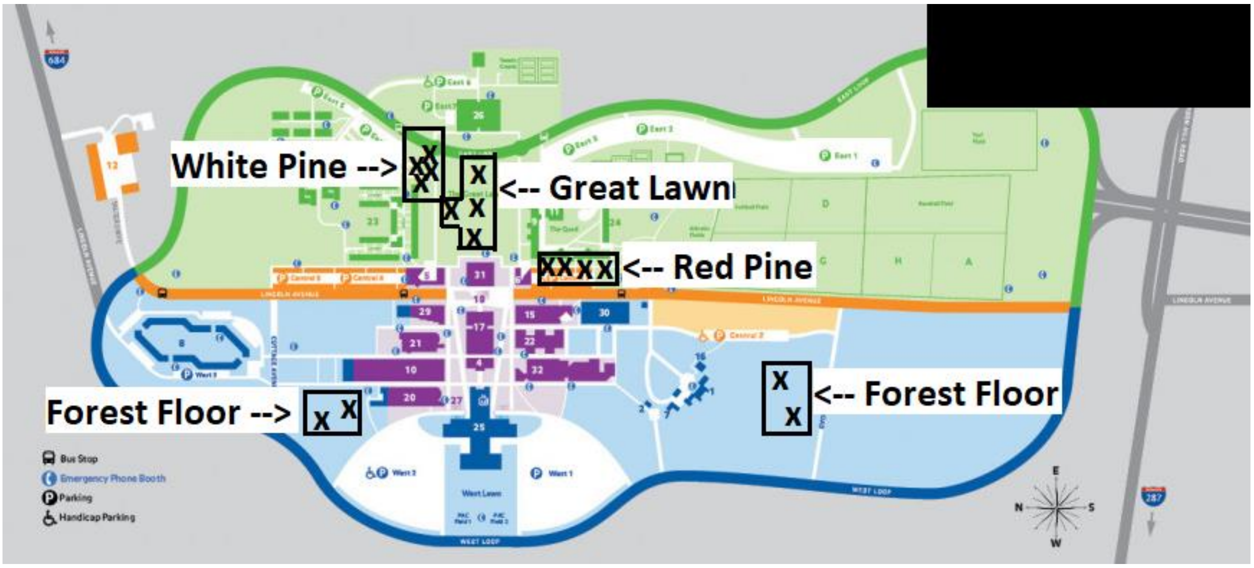

Figure 1. Soil Collection Sites on SUNY Purchase College Campus (X indicates each collection site).

We selected 4 different types of seeds to plant in our soil samples. The seeds were: Sweet Peas, Basil, Cosmos, and Catnip. We put our dry soil in pots and planted one type of seed in each pot. Four pots filled with potting soil were added as a control. We labeled each pot according to seed type and soil type. The potting array is shown below (Figure 2). These pots were then watered to saturation and placed in an incubator at 80 degrees Fahrenheit.

8 Sweet Pea Seeds Red Pine Soil	8 Sweet Pea Seeds White Pine Soil	8 Sweet Pea Seeds Forest Floor Soil	8 Sweet Pea Seeds Great Lawn Soil	8 Sweet Pea Seeds Potting Soil
10 Basil Seeds Red Pine Soil	10 Basil Seeds White Pine Soil	10 Basil Seeds Forest Floor Soil	10 Basil Seeds Great Lawn Soil	10 Basil Seeds Potting Soil
10 Cosmo Seeds Red Pine Soil	10 Cosmo Seeds White Pine Soil	10 Cosmo Seeds Forest Floor Soil	10 Cosmo Seeds Great Lawn Soil	10 Cosmo Seeds Potting Soil
10 Catnip Seeds Red Pine Soil	10 Catnip Seeds White Pine Soil	10 Catnip Seeds Forest Floor Soil	10 Catnip Seeds Great Lawn Soil	10 Catnip Seeds Potting Soil

Figure 2. Potting Matrix. Number of seeds placed in each soil type.

RESULTS

We checked on our plants every day for 17 days. The plants were watered every day and the number of seeds germinated per pot per day was recorded (Figure 3).

8 Sweet Pea Seeds (6 germinated) Red Pine Soil	8 Sweet Pea Seeds (8 germinated) White Pine Soil	8 Sweet Pea Seeds (7 germinated) Forest Floor Soil	8 Sweet Pea Seeds (6 germinated) Great Lawn Soil	8 Sweet Pea Seeds (8 germinated) Potting Soil
10 Basil Seeds (6 germinated) Red Pine Soil	10 Basil Seeds (8 germinated) White Pine Soil	10 Basil Seeds (8 germinated) Forest Floor Soil	10 Basil Seeds (8 germinated) Great Lawn Soil	10 Basil Seeds (8 germinated) Potting Soil
10 Cosmo Seeds (4 germinated) Red Pine Soil	10 Cosmo Seeds (3 germinated) White Pine Soil	10 Cosmo Seeds (3 germinated) Forest Floor Soil	10 Cosmo Seeds (3 germinated) Great Lawn Soil	10 Cosmo Seeds (2 germinated) Potting Soil
10 Catnip Seeds (1 germinated) Red Pine Soil	10 Catnip Seeds (2 germinated) White Pine Soil	10 Catnip Seeds (4 germinated) Forest Floor Soil	10 Catnip Seeds (0 germinated) Great Lawn Soil	10 Catnip Seeds (0 germinated) Potting Soil

Figure 3. Total number of seeds germinated in each soil type.

The soil found under the red pine trees yielded lower germination rates than almost all other soil types. The forest floor soil yielded the highest germination rate out of all other types- even higher than the control. The different amounts of seeds grown per soil type can be seen in (Figure 4).

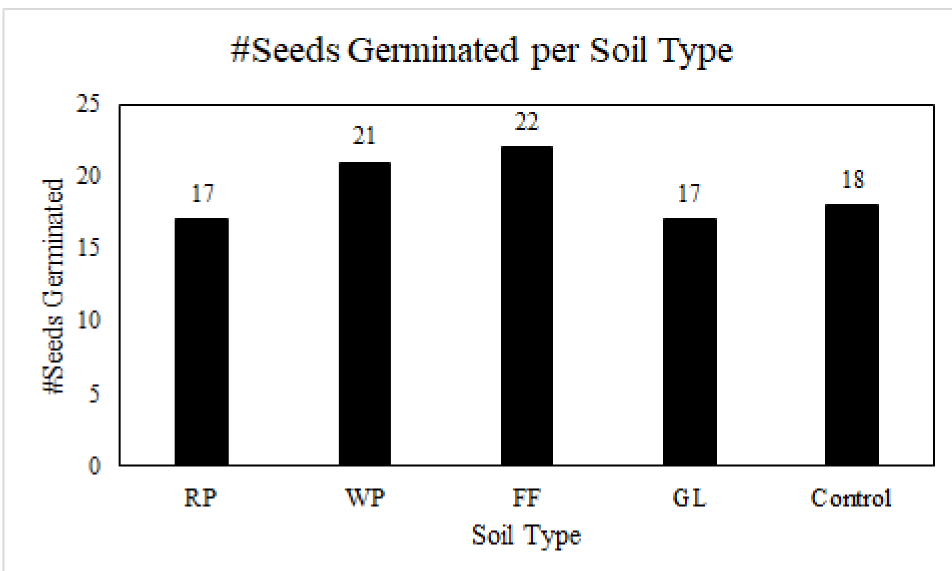

Figure 4. Total number of seeds germinated in each soil type. RP=red pine, WP=white pine, FF=forest floor, GL=great lawn

The seed growth array can be further broken down into a "per pot" view (Figure 5). This data is good for showing that not all seeds grew equally throughout the soil types. The Sweet Peas preferred the WP and Control soil and did worse in the RP and GL samples. The Basil did poorly in the RP soil, but did equally well throughout the other four samples. The cosmos preferred the RP soil and did poorly in the control. The catnip only did well in the FF sample and suffered everywhere else; so much so that it didn't even grow in the GL or Control samples.

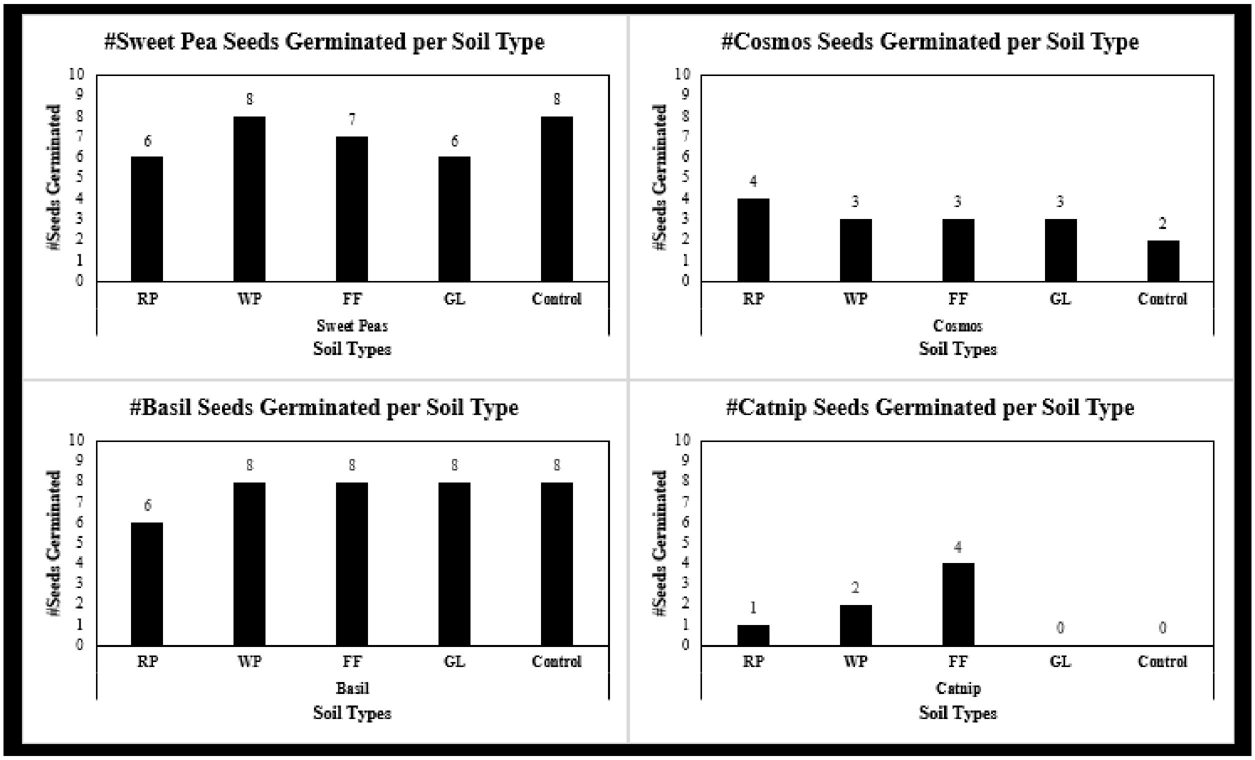

Figure 5. Total number of Sweet Pea, Basil, Catnip, and Cosmos seeds grown per pot.

DISCUSSION

In this study, we found that the soils collected from under the red pine trees had less seed germination than the soils that were collected at the other sites. The dropped needles of red pine trees inhibit the growth of plants (Kato-Noguchi et al. 2009). While we were collecting our pine soil samples, we observed that there was very little grass growth under the red pine trees. The allelopathy of red pine forests is involved in forming sparse understory vegetation (Kato-Noguchi et al. 2017). In the case of our pine soil samples, this would be tested for in the seeds ability to germinate compared to other soil types. A clear pattern can be noted as the red pine soil samples produced fewer seedlings than most other soil types (Figure 5).

Some seed types preferred specific soils over others. Pine needles, through defoliation and the breakdown of resin acids, alter the pH of soils by making them more acidic (Kato-Noguchi et al. 2017). It was listed on the seed packet that Cosmos can grow in a slightly acidic soil which is atypical of flowering plants. Sweet peas, the other type of flowering plant that we tested with, have the opposite preference- basic soil. This explains why the Sweet Peas didn’t grow well in the acidic RP soil and why the Cosmos grew the best in this soil type. This may explain why the cosmos were the only seed type to show good growth in the RP soils- all other seed types grew poorly. The other soil type that we saw poor growth for was the GL soil. Grasses typically require a slightly acidic pH to thrive which is likely what the grounds crew for SUNY Purchase has been keeping the Great Lawn around. This slight acidity would yield similar results to the RP soil. This is evident with the Sweet Pea seeds, as their worst soil types are both RP and GL.

Analyzing environmental factors for the sample sites may yield additional hypotheses for why some plants did better than others. If we were to redo this experiment, it might be worth taking salinity values for the soil samples to test the osmotic stress values of the soil that we’re about to plant in. If a soil is too salinated it may not allow for any seed germination as is the case for 7% of the earth’s soils

(Flowers et al. 1997). Soil salinity has two likely effects on seeds: it can decrease the ease at which a seed gets water (osmotic stress) or it can facilitate the entry of ions into the seed which can be fatal in large doses to the fragile seedlings (ionization) (Ayers 1952).

Soil salinity as a whole is a major abiotic stress factor for already established plants (Zhu 2001). The same aforementioned stress factors (osmotic stress and ionization) can occur to a plant's root systems while the plant is fully developed as well as while it's still developing or in germination. This can be a major problem when it comes to agriculture worldwide. High soil salinities tend to yield poor crop qualities (Chinnusamy et al. 2004). This can be used as a tool to make certain soils unfavorable for certain plants to grow in. This may be useful in formatting a plan to combat invasive species.

There are many different ways that we could have approached this project or could re-approach it in the future. If we increased our sample size from 20 pots to 100, it would certainly yield more concrete results. In addition, if we ran the project for longer than 17 days, we may be able to test the allelopathic effects of pine needles on already established plants and not just seedlings. This might prove effective if we were to test the pine needle allelopathy as a method of eradicating the campus' invasive plant species. Our current experiment, if done with invasive plant seeds, may be good for determining whether or not said seeds would be inhibited by the pine allelopathy.

CONCLUSIONS

The red pine soil samples had the least amount of seedlings than the other soil types we tested. Soil allelopathy can hinder plant health, this can allow invasive plant species to move in and push out all of the native plants. With landscapes changing due to urbanization, the health of our native forests are being put under stress and are more vulnerable to allelopathy.

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WATER TEMPERATURE VARIATIONS THROUGHOUT THE DAY ARE NOT CORRELATED WITH DISSOLVED OXYGEN IN BLIND BROOK

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ABSTRACT

Blind Brook is a brook that runs through Westchester County in Southeastern New York and runs into Long Island sound by the Marshland Conservancy in Rye, NY. The focus of this experiment was to determine if there are any correlations between dissolved oxygen (DO) and variation in water temperatures at different times of day in Blind Brook. There were two parts to this experiment, an in lab portion where we heated water from the various locations we tested at Blind Brook and a control group. The data collected from this experiment showed that there is an inverse correlation (In that as water temperature increases DO decreases) between water temperature in a controlled setting and DO. The second part of the experiment was an infield study in which we collected water temperature and dissolved oxygen at three different times throughout the day (9 a.m., 12 p.m., and 6 p.m.), and at three different locations along Blind Brook within the Purchase College campus. The data we collected did not suggest that there is any correlation between water temperature and dissolved oxygen. Although the pH was not tested every day, a pH meter was used on the last day of data collection and the data suggest that there a direct correlation between DO and pH (as pH increases DO increases), compared to water temperature and dissolved oxygen where no correlation is observed.

Keywords: Blind Brook, dissolved oxygen, Temperature, pH, Correlation

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INTRODUCTION

The effects of climate change on marine ecosystems are of great importance, as the earth is made of mostly water and play a key role in regulating temperatures which are most susceptible to changes in the environment. Carbonate chemistry, salinity, and temperature are some of the main stressors of interest regarding global climate change in marine environments. Studying the effects of these stressors on physiological processes can serve as a tool to resource managers and policymakers in making decisions addressing climate change (Somero et al. 2016). Temperature and dissolved oxygen (DO) are informative measurements in determining water quality. Studies regarding the effect of climate change on these two factors suggest that as climate change progresses temperature increases and dissolved oxygen decrease, which has profound effect on cool water fish which are pushed closer to lethal habitats (Shahram et al. 2017). DO is the amount of oxygen suspended in water and is determined by physiochemical factors especially temperature, pH, and salinity (Jack et al. 2009). Carbon dioxide (CO_2) the most notorious greenhouse gas also effects dissolved oxygen. Models that double the amount of CO_2 have shown that time of lake anoxia (the absence of oxygen) will be shortened decreasing fish winterkill but there is also projected lengthier summer anoxia (Fang and Stefan 2009). The effects of climate change is also seen in other aquatic ecosystem, increasing oxygen stratification in deep subtopic reservoirs (Zhang et al. 2014).

The alteration of DO by climate change has many projected impacts both worldwide and in local ecosystems (Missaghi et al. 2017). Dissolved oxygen plays a critical role in many aquatic ecosystems, having an effect on animal behavior such as predator/prey dynamics. Low oxygen levels cause prey species to spend more time closer to the surface causing an increase in predation. (Moore et al. 1998). Habitat selection for fish is heavily influenced by the relation of DO and temperature. Alterations to either has caused fish to settle in environments that were either too anoxic or too warm to breed or survive (Creaser 1930). In White Perch (*Morone Americana*) hypoxic environments reduce capacity for development growth and activity which decreases nursery production (Hanks and Secor 2010). Dissolved oxygen also has an effect on human impact, an example of that is the role it plays in the release and absorption of metals from storm sewer sediments (Jack et al. 2009) and runoff (Li et al. 2013) into aquatic environments.

The goal of this study is to determine how temperature and dissolved oxygen interact in Blind Brook throughout the day. Our hypothesis predicts a morning high for dissolved oxygen, a mid-day decrease as temperature rises and an increase in DO as temperature decreases in the evening. Therefore, we expect to see an inverse correlation between temperature and dissolved oxygen.

MATERIALS AND METHODS

Field Study. We chose three locations on Blind Brook to enable us to study Blind Brook as a general ecosystem. We also decided to choose locations within the boundaries of Purchase College because further down it becomes an estuary and salinity effects dissolved oxygen. We accounted for velocity by picking sites with similar velocity, averaging at 16.5 feet per minute. We determined the velocity of the sites by using a ping pong ball dropped into the water and measuring how far it traveled in 30 seconds. We chose 9:00 a.m., 12:00 p.m. and 6:00 p.m. as times to sample. This would allow us to see the trend in dissolved oxygen at different times of day and in turn water temperature variations.

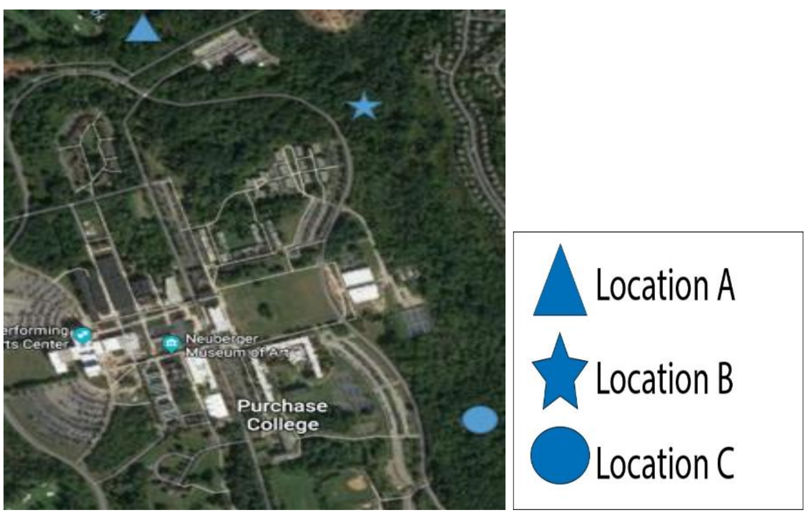

Figure 1: A map of the three locations; the triangle being Location A (located near the intersection of Lincoln Ave and East Rd), the star Location B (located near alumni village parking lot on East Rd), and the circle location C (located near the east 2 parking lot where the painted Rocks are found).

The two data sets that we collected are water temperature and DO. We did this by using the EX-Tech Model DO210, which is a DO meter that also records water temperature. When collecting the data at the different sites we first turned it on a couple of minutes before submerging it into the water this allowed the readings to stabilize. After the readings settled we submerged the probe in the water and stirred it, removing any air bubbles or surface layers from forming on the probe. We allowed the readings to level out and took down the readings. Sadly, we could not organize a pH meter for the duration of the experiment but we were able to organize one on the last day of data collection which was on 10/31/18. To collect the pH reading we used the Oakton WD-35634-30 pHTestr 30 Waterproof pH Test. The pH meter requires 2 points of calibrations to carry out the calibrations we used Oakton pH Calibration Buffer Pouches of pH 7 and 10. After calibrating the pH meter we then submerged the probe into the water and recorded the readings, after we allowed it a couple of minutes for the readings to level out.

Lab Experiment:

We tested the correlation between temperature and DO in lab. We did this by collecting 500ml samples of water from all three locations and used 500ml of tap water as the control group. We then gathered four 500ml beakers and labeled them Location A, B, C, and control. We placed the four beakers on a hot plate (not yet turned on) and poured in the samples of waters into the beakers accordingly. We then took thermometers and placed them in each beaker and powered on the hot plate. The base reading for the four samples was 17 (C°) and every 2 (C°) using the EX-Tech Model DO210 DO meter collected DO until we reached 31 (C°).

RESULTS

Our results show that there is no correlation between water temperature and dissolved oxygen at all three sites. Location A showed a max peak in the afternoon for water temperature 7/10 days, compared to dissolved oxygen showed a max peak at mid-day for 8/10 days (Figure 2). Location B showed a max peak in the afternoon for water temperature 6/10 days, compared to dissolved oxygen which showed a max peak at mid-day 8/10 days (Figure 3). Location C showed a max peak in the afternoon for water temperature 6/10 days, compared to dissolved oxygen in which showed a max peak at mid-day 6/10 days (Figure 4). The results collected on the same day, indicate that there is a correlation between dissolved oxygen and pH with both showing max peaks at mid-day for all 3 locations. This compares to only 1 max peak in the afternoon for location A with temperature and DO (Figure 5, 6, and 7). However the lab data suggests that there is a correlation dissolved oxygen and temperature when the two factors are isolated (Figure 8).

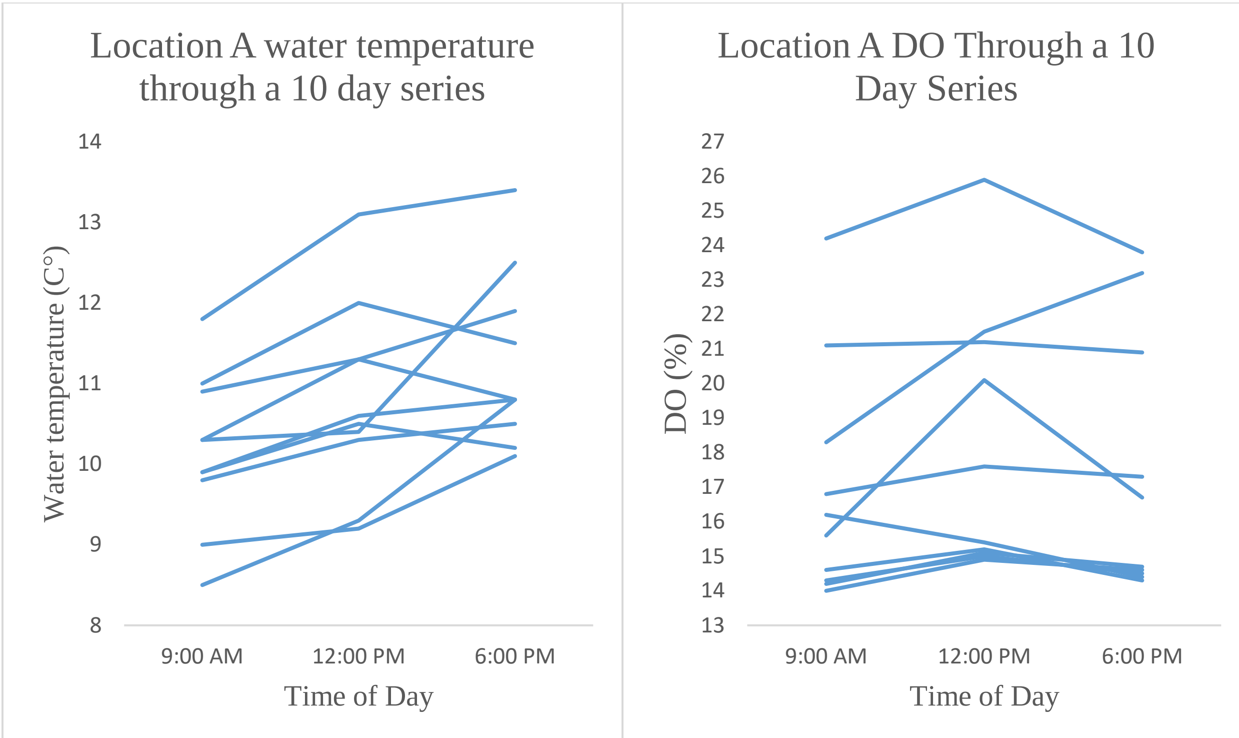

Figure 2: Illustrates water temperature at location A through a 10-day data series and DO at location A through a 10-day series with each line on the graph being a different day.

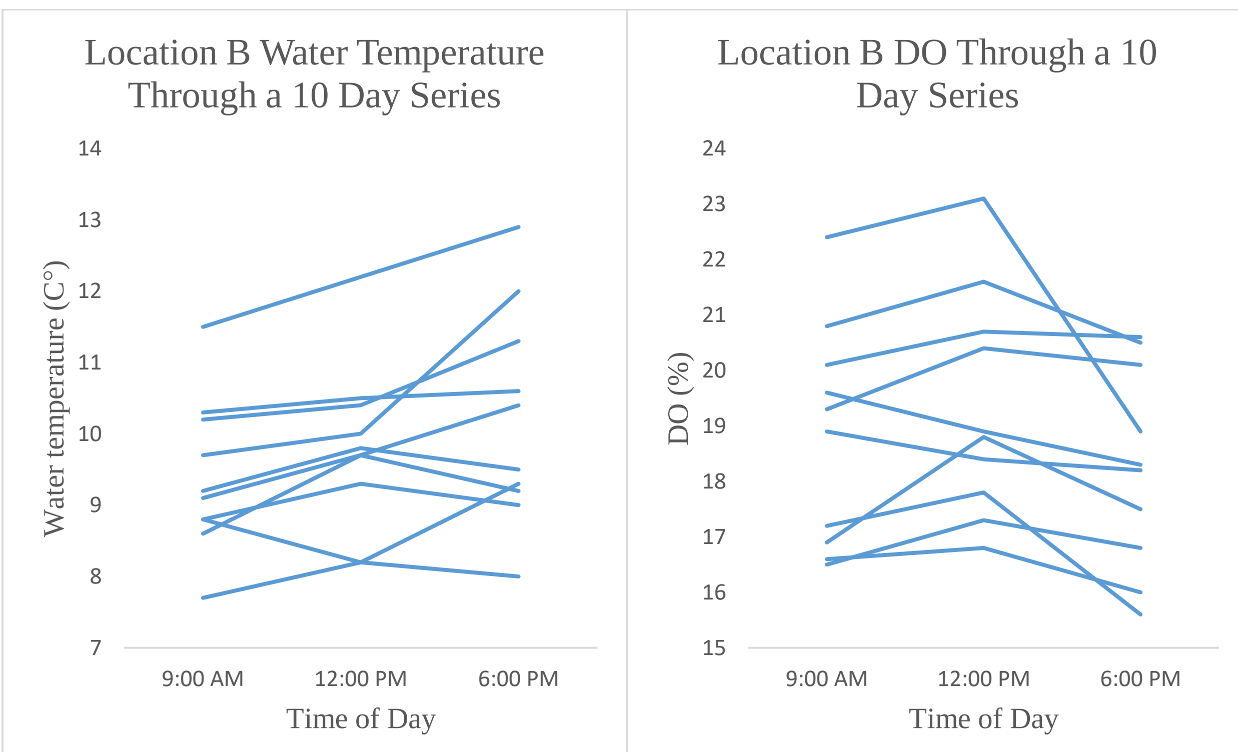

Figure 3: Illustrates water temperature and DO at location B through a 10-day data series and DO at location B through a 10-day series each line on the graph being a different day.

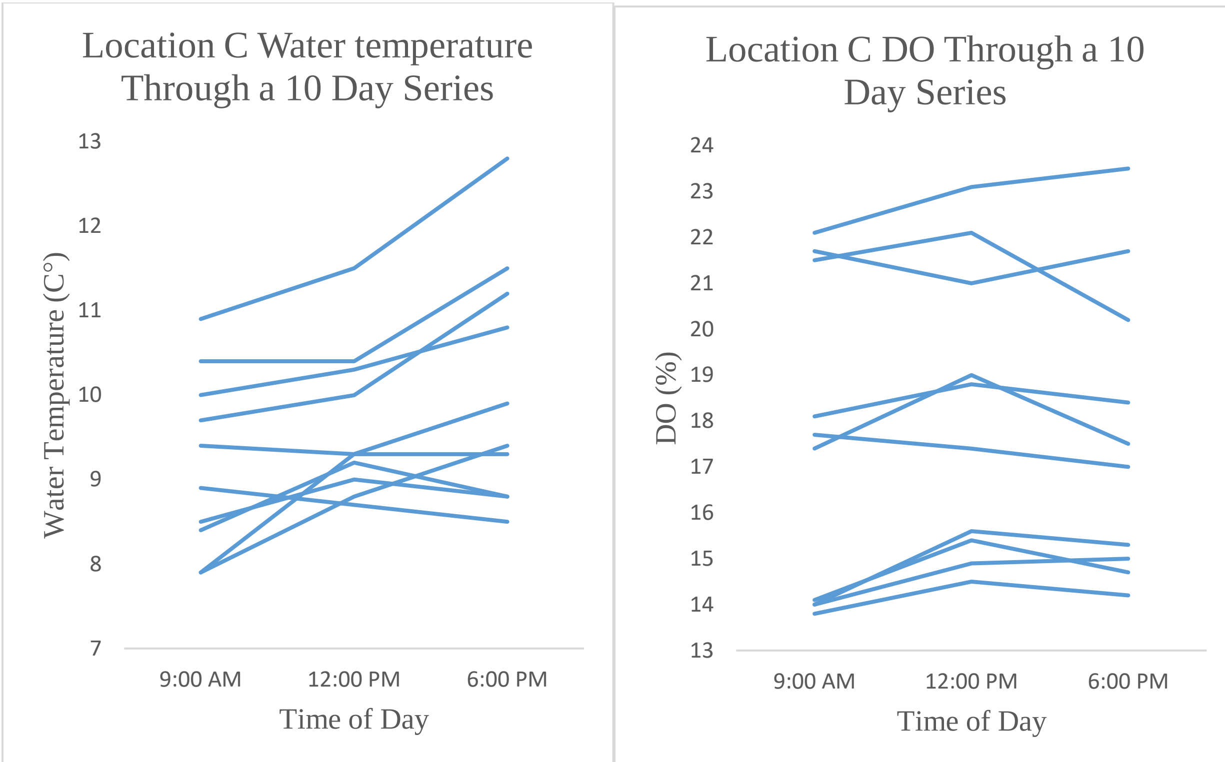

Figure 4: Illustrates water temperature at location C through a 10-day data series and dissolved oxygen at location C through a 10-day series with each line on the graph being a different day.

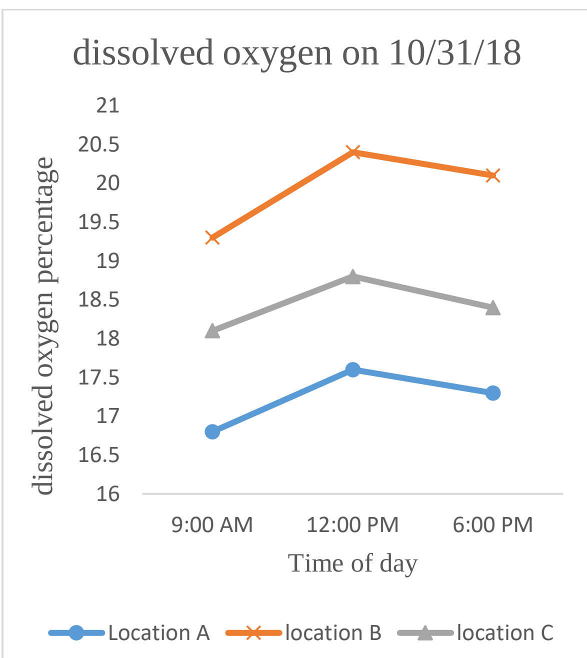

Figure 5: Graph showing the DO at location A (bottom plot), location B (top plot), and location C (middle plot)

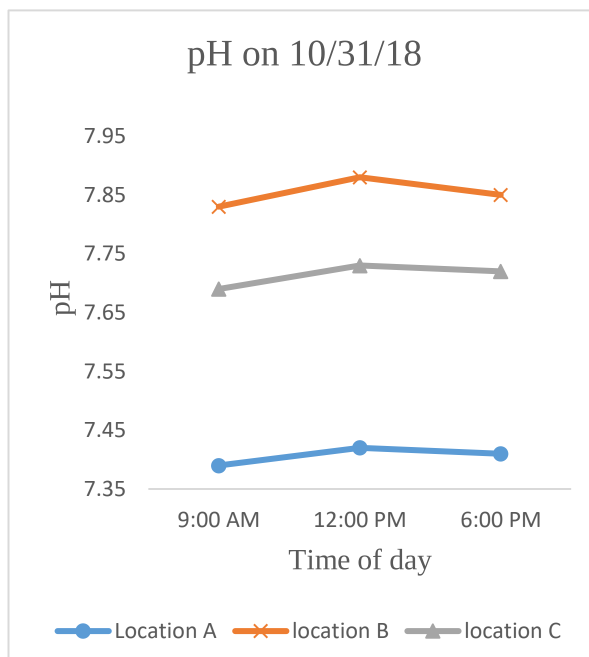

Figure 6: Graph showing the pH at location A (bottom plot), location B (top plot), and location C (middle plot)

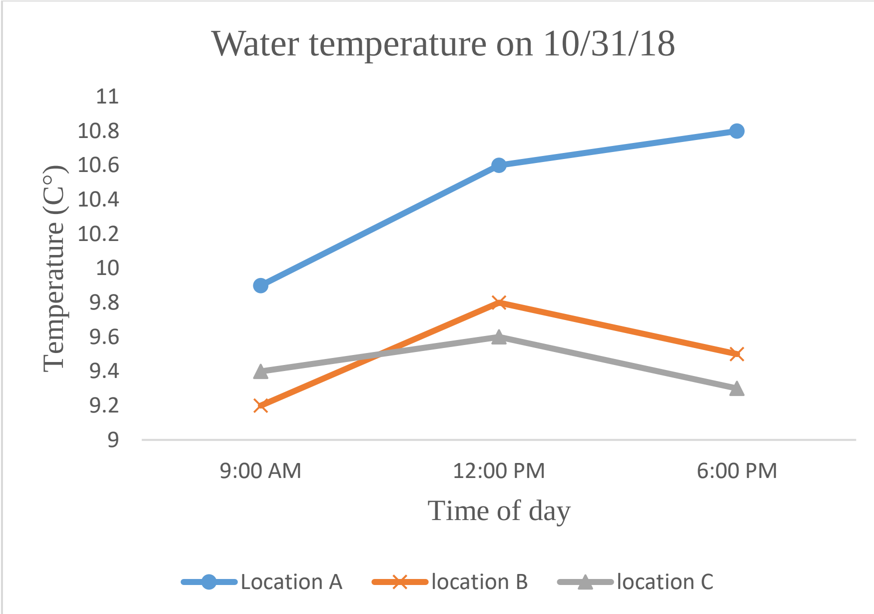

Figure 7: Graph showing the water temp at location A (Top plot), location B (Middle plot), and location C (Bottom plot).
Only data for October 31st is present due to the lack of access to a pH meter

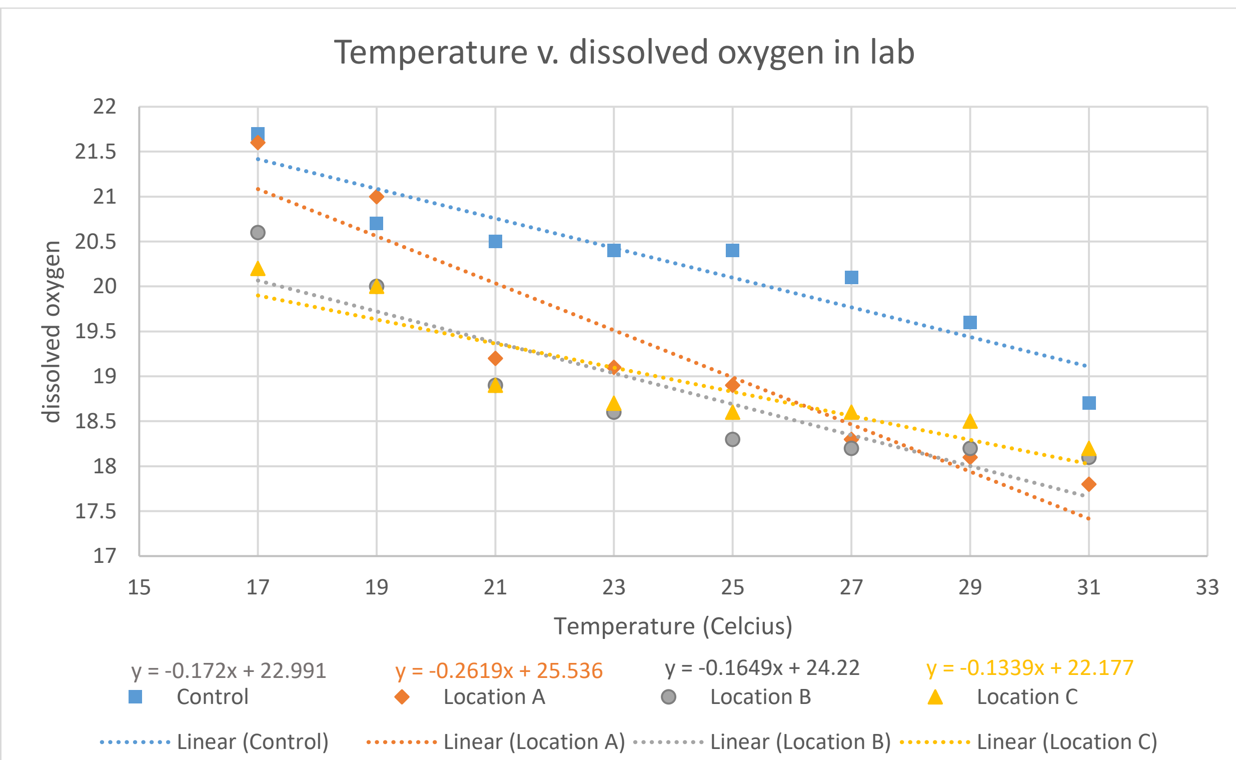

Figure 8: Graph showing the relationship between dissolved oxygen and Water temperatures in a laboratory setting each plot illustrating the different locations and the control

DISCUSSION

Water temperature and DO discussion. Although we predicted that DO would be the lowest at mid-day when the temperature was the highest, we actually found that in all 3 locations the majority of the data series collected showed that the DO was the highest at mid-day, despite water temperature not being the highest at mid-day in all 3 locations like we predicted. The majority of the data series for water temperature showed that it was the highest in the afternoon suggesting that there is no correlation between water temperatures and DO (Figures 2-4). This is despite a strong inverse correlation between water temperature and DO in a lab setting (Figure 8)

Correlation between DO, pH, and water temperature discussion. Due to limited access to the pH meter we were only able to sample pH one day. We would have preferred to use it for every data series collected because pH is a physiochemical factor that affects DO (Joel et al. 2009). The data collected on 10/31 suggest that there is a correlation between pH and DO all three locations showing a max peak at mid-day for both pH and DO. The order of which the three locations are organized is also the same with location B being the highest and location A being the lowest with no data series intersecting one another (Figures 5 and 6). The data regarding the same day for water temperature and dissolved oxygen suggests that there is no correlation with DO, max peak for all three locations being at mid-day and one of three locations showing a max peak in the afternoon while two of three showing a mid-day peak. Whereas for water temperature location A is the highest and the data series for location B and C intersect (Figures 5 and 7). Contrary, to correlation that is seen between pH and DO for that specific day with having the same order and no intersecting data series.

Sources of error. A possible source of error for this study could be that we didn't take into consideration tree cover in the locations we sampled. Studies have shown that an increase in tree cover leads to an increase in stream health (Gotez et al. 2003) and that shade from tree cover has a greater effect on the gross primary production and ecosystem respiration in a stream than agricultural intensity (Burrell et al. 2014). Tree cover could affect the water temperature and in response the DO, specifically in location A where there was less tree cover and had the least amount of DO compared to the other two locations being an indicator for an unhealthy marine ecosystem (Shahram et al. 2017). Our results could also have been influenced by the fact that we only sampled pH on the last day of sampling. Considering this experiment was carried out during the fall season the falling foliage and decomposition of the organic matter could be an influence in pH, therefor influencing DO. This is similar to what is seen after algae blooms begin to die being detrimental to aquatic species due to a decrease in DO and a decrease in pH.

Improvements for future studies. The accuracy of this study could be greatly improved by the sampling of pH values over the course of the sampling period, an option that was not available to us due to technical limitations. Rainfall events and changes in stream velocity could also be incorporated into the study in order to increase the validity of the data. Tree cover and the rate of photosynthesis of aquatic plants present in the brook could have also been tested for which might explain why DO is the greatest for the majority of the days sampled at mid-day as the sun's rays became strong it provides aquatic plants with the light needed to carry out photosynthesis. The interaction between pH and photosynthetic activity warrants further study due to photosynthesis effect on increasing dissolved oxygen in marine environments.

CONCLUSION

Our findings show that there is no correlation between water temperature and DO in Blind Brook in contrast to the results from the in lab study. Our results also show that there is a possible correlation between pH and DO, however further experimentation should be done. Considering Blind Brook is surrounded by human development such as golf courses, airports, and other industrial complex further research should be done in order to protect this important aquatic ecosystem. The well-being of this ecosystem can have profound effects on the distribution and abundance of fish, amphibian, invertebrate, and plant species who call Blind Brook their home.

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