The effect of parasitic mistletoe (Arceuthobium pusillum)on black spruce (Picea mariana) invertebrate populations

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Abstract

Black spruce (*Picea mariana*) are found frequently within forests of the Upper Peninsula of Michigan, where they are commonly infected by eastern dwarf mistletoe (*Arceuthobium pusillum*). The species richness and evenness of native invertebrate populations was studied to determine if *A. pusillum* had an impact on their presence within the ecosystem. Branch beating was the method used to collect samples of native insects from both affected and unaffected *P. mariana*. There was no significant difference in the species richness or evenness of native invertebrate populations found between the affected and unaffected trees. Though a significant difference was found between the invertebrate populations and the three bog ecosystems they were collected from. All of the sampling locations were within a 10-mile radius of each other, but had varying species richness levels when compared to one another. This could be possible because of the difference in predator densities among the three bogs, pH differences, or differences in plant diversity between the three different locations. Overall, it was concluded that more research should be done to determine why this newly discovered trend exists.

Introduction

In the northeast United States, spruce trees (*Picea*) are an important asset to the health and diversity of the forest and provide habitats for many native insect and animal species. However, they are susceptible to a large number of pathogens and parasites that may cause injury or death. Some of the parasites that affect the northeastern spruce forests are spruce budworm, spruce sawflies, gall-forming adelgids, and dwarf mistletoe (Natural Resources Canada 2015). Dwarf mistletoe (*Arceuthobium*) is one of the most widely prevalent tree pathogens in the United States (Hoffman 2004). It is found throughout the entire continental United States and has 34 species in the New World (USDA Forest Service 1996). This widespread parasite only affects coniferous hosts and many species of the *Arceuthobium* genus have adapted to infect a few specific conifer species. Dwarf mistletoe has extremely limited photosynthetic abilities, so most of their nutrients are taken from their host's xylem and phloem. (Logan et al. 2013). The infection causes vascular damage, reduces needle size, lowers chlorophyll levels and possibly results in tree death (Logan and Reblin 2017). The decline in overall tree health of the tree may reduce the prevalence of organisms that inhabit the tree. Lower species richness and evenness within the tree would indicate that *Arceuthobium* is not only causing tree damage but is harming populations of other native organisms.

This study focused on infection by eastern spruce dwarf mistletoe (*Arceuthobium pusillum*) because it was easily identified and prevalent at the study site. Black spruce (*Picea mariana*) was chosen for observation and testing because it is the species most severely affected by *A. pusillum* (Baker et al. 2006). The effect of *A. pusillum* on *P. mariana* has been extensively studied; however, there is little information on how *A. pusillum* affects the invertebrate communities that inhabit *P. mariana*. This research examined the richness and diversity of the invertebrate communities of trees infected with *A. pusillum* compared to trees without *A. pusillum*. The initial hypothesis is that infection of *A. pusillum* in *P. mariana* would cause decreased species richness and evenness in native invertebrates that inhabit the trees.

Materials and Methods

Study area- Before conducting this study, I surveyed the bog areas located on the University of Notre Dame Environmental Research Center Property. This property is around 7500 acres of forests, wetlands, lakes and bogs. The land is located adjacent to the Ottawa National Forest in the Upper Peninsula of Michigan, near the Wisconsin state line. Three locations, Cranberry Bog, Tenderfoot Bog, and North Gate Bog (Figure 3) that showed sufficient evidence of *Arceuthobium pusillum* infestation in the *Picea mariana* population for study.

Experimental Procedure: Tree Selection- In each of these sites 10 affected and 10 unaffected trees were identified and numbered. The trees had to be at least 10 feet tall with a living branch that was at least one-meter long. Affected trees had to have *A. pusillum* present, while the unaffected trees could not have any presence of *A. pusillum* on any part of the tree. Seven affected trees and seven unaffected trees from each of the three sites were chosen at random through a random number generator. A total of 21 affected and 21 unaffected trees were sampled across the three sampling locations.

Experimental Procedure: Invertebrate Collection- The branch beating method was conducted to obtain an insect sample from the affected and unaffected *P. mariana*. To conduct the branch beating, a branch, of at least one meter in length and at approximately breast height (1.3m), was chosen from each sample tree. A 70 by 125 centimeter cotton sheet was held taut under the selected branch by two individuals. The branch was swiftly hit with a wooden pole for approximately 15 seconds allowing for the insect sample, as well as other debris, to be collected on the sheet. The entire sample was shaken to the center of the sheet and funneled into a kill jar that was charged with a cotton ball soaked in acetone. Two jars were used in each location, one for the affected samples and another for the unaffected samples. The jars were brought back to the lab where the organic debris was separated from the insect samples. The invertebrates were then classified by order and then recorded.

Statistical Analysis- This data was analyzed using the Shannon diversity index to compare the order richness of the affected and unaffected species as well as to compare the difference in order richness across the different locations. The data was also tested using stronger statistical tests. After confirming normality, the data was analyzed using a one-way ANOVA in order to test for significant differences between the affected and unaffected trees. Another ANOVA was run to test the diversity of invertebrate orders among the three test sites.

Results

The data (Figure 1) comparing the diversity of invertebrate orders sampled of the affected and unaffected tree samples resulted in a normal distribution. This normalcy indicated that the data could be evaluated using parametric measures. There was not a significant difference in the diversity of invertebrate order richness between affected and unaffected tree samples (1-way ANOVA, $F_{1,2}$= .062, p= 0.815). The data comparing the order diversity of the three different locations initially was not normally distributed. This data was squared in order to transform and normalize the data. There was a significant difference in insect order richness among study sites (1-way ANOVA, $F_{2,3}$= 9.667, p= 0.0492). The data was also analyzed using the Shannon diversity test to test for species richness and evenness (Figure 2). The paired unaffected and affected tree samples in Cranberry both resulted in a 0.74 Shannon value. The paired unaffected and affected tree samples in Tenderfoot resulted in 0.51 and 0.53, respectively, for Shannon values. The paired unaffected and affected tree samples from North Gate resulted 0.45 and 0.55 respectively, for Shannon values.

Discussion

The initial test of Shannon diversity showed little difference between the order richness and evenness between affected and unaffected trees at each site (Figure 2). This indicated that even before using strong statistical tests, that there was not likely to be statistical significance of the order richness when comparing affected and unaffected tree statuses. This was confirmed with a one-way ANOVA of the data that showed that this data was not significant. This fails to reject the null hypothesis that the infection status of a tree would have an affect on the invertebrate population.

Comparing the Shannon diversity values of the different locations, there is a visible difference between the three bogs. The Cranberry bog sample showed the greatest order richness and diversity for both unaffected and affected tree species. This qualitative data suggests that stronger statistical tests may be significant. This was confirmed with a one-way ANOVA that significant differences of order diversity between the sites. This significant result showed that the invertebrate order diversities are not the same at each bog location.

This result is fascinating considering that all of these bog ecosystems were located within 10 miles of each other and appeared to have similar plant populations. Possible differences could include different predators at each location, different pH levels, or general plant composition. Change in predator prevalence causes a top-down reaction changing the prevalence of all of the species related to that food chain (Gross 2006). The pH levels of the bog can also affect invertebrate reproduction. Many bog invertebrates rely on a water source during their larval growth, notably the Insecta orders Emphemeroptera, Hemiptera, Coleoptera and Diptera, all observed in this study (Judd 1961). Collembola are also highly affected by water quality due to their semi-aquatic nature (DeWalt et al 2010). The plant composition may also affect the invertebrate population especially in bogs, because of the uniqueness of many plant species. Pitcher plants are both predators and food resources for different types of invertebrates. These plants trap and kill insects which are then a food source for invertebrate detritivores (Hamilton 2010). Different densities and species of these carnivorous plants are able to impact the invertebrate population of the area.

Even though the data failed to reject the null hypothesis, this study created the possibility for further studies of what causes order differences between bogs in similar areas. Even though the initial hypothesis was rejected, this study suggests the need for future study about what causes differences in invertebrate communities among bogs in similar areas. Bogs are an important and sensitive ecosystem therefore more knowledge about this habitat provides further information about how bog damage may be affecting a variety of native species.

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Figures

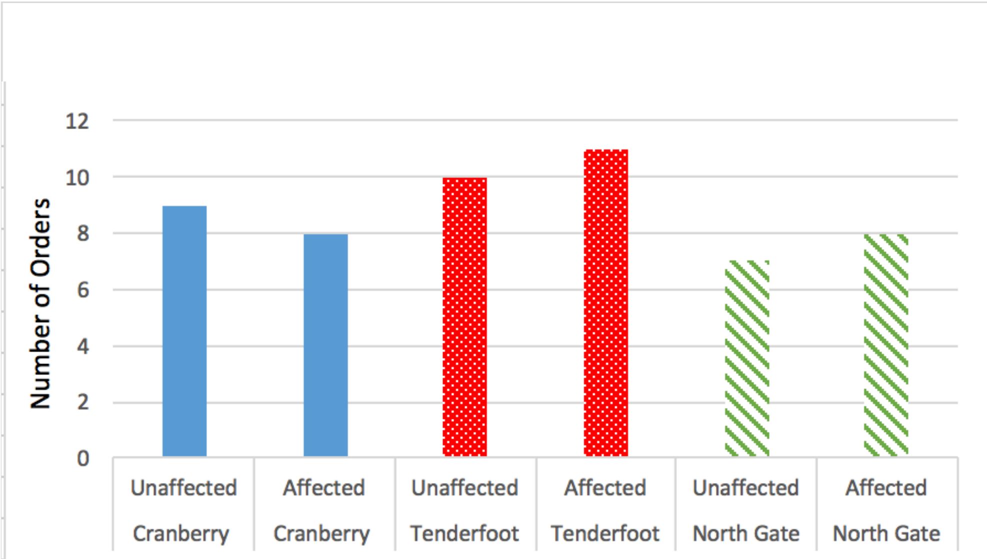

Figure 1: Number of Orders from each area and status of tree tested

ANOVA test of affected vs. unaffected p= 0.815

ANOVA test of Location (Cranberry-Tenderfoot-North Gate) p=0.0492

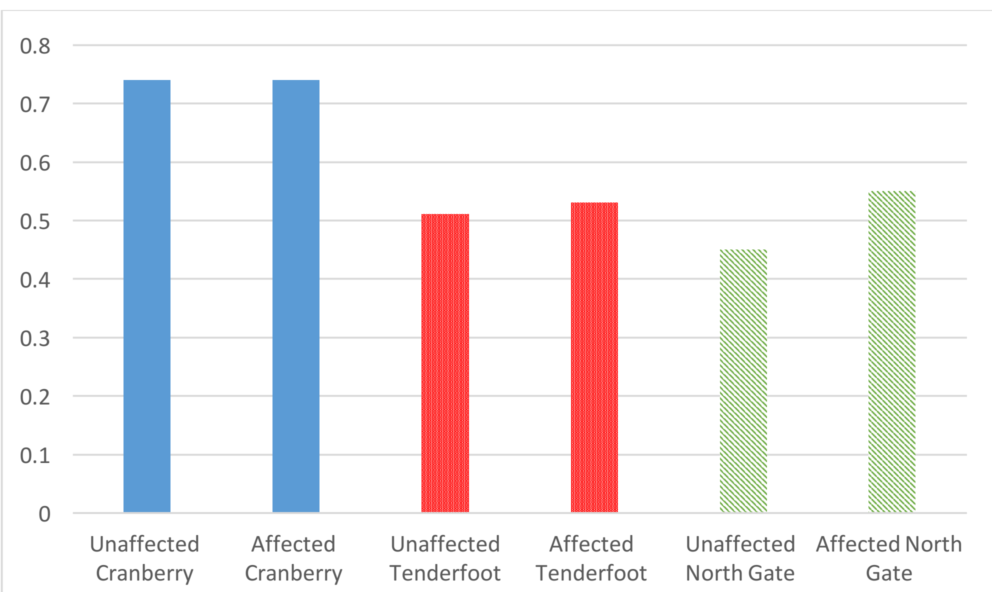

Figure 2: Differences of Shannon diversity value for each area and status of tree tested

Shannon values from left to right (0.74, 0.74, 0.51, 0.53, 0.45, 0.55)

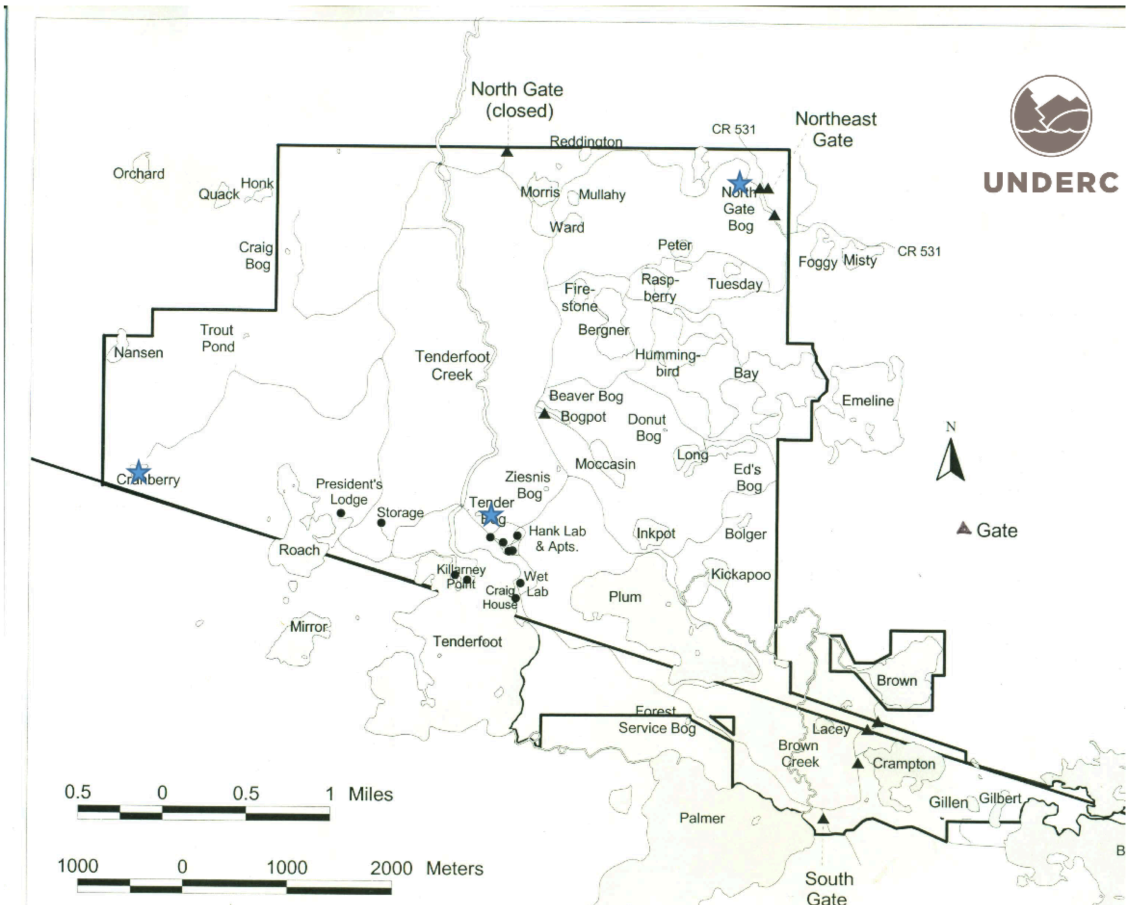

Figure 3: Three test bogs marked on the UNDERC property

North Gate Bog, Cranberry and Tender(foot) Bog designated with a blue star