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Abstract

Across the United States, land managers are struggling to cope with a relatively new invasive species, Callery pear (Pyrus calleryana). Callery pear is currently one of the most important invasive species threatening prairies and early successional habitats in Ohio and the Midwest, and yet, no viable means of control exists for this species. This species is relatively resistant to herbicides and resilient against prescribed cutting and burning. One potential management of invasive species is biocontrol, or the intentional introduction of natural enemies to control the growth and propagation of a target organism. Previous experiments with Callery Pear have examined herbivory by large animals, thus, an important knowledge gap exists in the interactions between native insect herbivores and the woody plant. We conducted a month-long field enclosure experiment where we manipulated the species richness of native orthopterans in enclosures with either a Callery Pear sapling or a similar native tree sapling, American Basswood, and destructively measured the biomass of each tree and the vegetation in each enclosure. We then calculated the percent change in biomass between the treatments and controls to determine if varying the orthopteran species richness had any effect on plant growth. We found that in treatments where there was a high species richness of orthopterans, Callery Pears were over 100% bigger relative to controls. This result was opposite to our prediction that a higher diversity of herbivores would lead to an increase in herbivory and thus a decrease in biomass. This phenomenon should be studied further in order to understand how intentional reinstatement of insect diversity to early successional areas by environmentalists may actually be helping invasive species to grow more rapidly.

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Background

Humans have been moving plants, animals and other organisms out of their native ranges and introducing them into new areas for thousands of years (Dunn 2011). A species can be introduced to an area unintentionally (e.g. as a by-product of global travel and trade) or intentionally (e.g. for medicinal or horticultural practice) (Mejerson et al. 2007). This movement of species from their native ranges on its own does not necessarily cause a problem. However, an introduced species may be classified as invasive if it generates a negative impact on local biodiversity and ecosystem structure (Vitousek et al. 1997). In recent years, the rate of this movement of species out of their native ranges has grown rapidly as a result of globalization, especially between two of the major forces in the world economy, the United States and China (Culley et al. 2011). Callery pear (Pyrus calleryana) is one species which was intentionally brought to the United States from regions around China, Taiwan, Korea and Japan, and has since become invasive.

Collected in the early 1900s by USDA plant explorer, Frank Meyer and plant breeder Frank Reimer, Callery pear was originally imported as a potential agent to combat a pathogenic fungus (fire blight) in the common pear (Pyrus communis) (Culley et al. 2008). Due to its self-incompatibility, vegetative propagation, and rare fruit production, Callery pear was originally considered to be safe from potential invasional success via escape from cultivation (Vincent et al. 2005). However, since its original introduction, this woody plant has become a menace to management agencies across the eastern United States. Not only is Callery pear tolerant of a wide range of living conditions, rapid in growth, able to reach sexual maturity at a young age, and selected by many species of birds for seed dispersal throughout its range of influence, it has also found great success in urbanized areas due to the reputation it holds as an aesthetically pleasing tree, with beautiful white blossoms found in early spring and leaves that turn bright red in the fall (Culley et al. 2008).

There are very few documented effective management strategies for Callery pear. The tried-and-true approaches to controlling woody invasive plants (e.g., herbicides, controlled burning, and physical uprooting) have proven insufficient to contain this resilient species. Thus far, the most successful means of control for the large varieties of these wild trees has been complete mechanical removal followed by the application of an herbicide such as concentrated glyphosate or triclopyr (Culley et al. 2008). An expensive and labor-heavy means of extermination, mechanical removal is not a sustainable management practice. Further, as it costs a significant amount of money for management agencies to control its growth and spread, Callery pear has the potential to become a dominant species in the native ecosystems which it invades, creating a problem as large and complex as that of the highly invasive Japanese Honeysuckle (Lonicera japonica). Thus, additional research is needed to determine cost-effective and environmentally-friendly solutions for the control of this species. One potential control method is a form of biocontrol via insect herbivory.

Herbivorous insects have many noteworthy effects on ecosystems globally, including in the control of weedy plants (Prather et al. 2013). Though it is known that certain invasive plants may be prevented from further propagation if they are palatable to the native herbivore community, there is a lack of research which directly assesses the effects of herbivore diversity on plants, particularly on invasive plant species (Tellamy et al. 2004). Looking at this issue from the larger organismal scale, there has been some limited documentation of feeding on Callery Pear by large herbivores such as white-tailed deer and reintroduced elk, however, its susceptibility to both small herbivores, such as insects, is mostly unknown (Lankau et al. 2004). There are some hypotheses on this topic, though. One states that native herbivores which feed on many plant species may be effective at biocontrol of invasive species (Rogers et al. 2008). Therefore, it is possible that the manipulation of native orthopteran species richness, or the relative abundance of individuals in a certain community, could be manipulated to serve as a control agent for this invasive plant (Culley et al. 2007).

We hypothesized that altering the species richness of native insect herbivores would negatively affect the success of Callery Pear, as measured by biomass. Further, we predicted that the maintenance of a diverse community of native insect herbivores may help to control this species, yielding a negative percent change in biomass as compared to the control treatments. This prediction is based off of the fact that one of the primary causes which is believed to contribute to the successful invasion of introduced plants is escape from native insect herbivores (Rogers et al. 2008). Orthopterans have been known to limit the growth of woody species in other areas (Law et al. 2018). Thus, we inferred that if invasive species rely on escape from this herbivory in order to grow and propagate more rapidly, then perhaps a high species richness of many different insect herbivores with varied diets and feeding habits would limit the success of the plant.

Materials and Methods

We worked in the Environmental Research Area (UD-ERA; 39°43'56.9"N 84°11'26.7"W) at the University of Dayton's River Campus. In Dayton, Ohio, around 1044 mm of rain falls throughout the year, and the average temperature is 11 °C. The UD-ERA shares the characteristics of an early successional forest, containing a wide range of saplings, adult trees, shrubs, grasses, and many varieties of herbivores. Aside from occasional mowing in a few patches and the removal of large dead trees, it has not been managed since 2009.

To test our hypothesis, we used a mesocosm experiment in an area where the density of Callery Pear saplings was very high. In the fall of 2017, herbivory was observed on Callery pear seedlings from orthopterans, a diverse generalist herbivore community (Prather and McEwan, personal observation). This observation indicated that not only are insect herbivores alive and active in this area, but also that there is an abundance of herbivores which have the capability to feed on many different species of plants, including the woody invasive species in question. To understand insect herbivory on Callery Pear, we chose to compare it to that of a native woody plant, American Basswood (Tilia Americana). Traditionally in studies which are aimed at better understanding the effects of herbivory on invasive plant species, the introduced species of interest is paired with a native species which has similar characteristics. This pairing system generally provides a better understanding of why the herbivory may or may not have a certain effect on the invasive in question, and what the mechanisms for invasion are for that plant

(Barrett et al. 1986). American Basswood was chosen as the native species of comparison as it is abundant at the UD-ERA and has similar properties to the young Callery Pear, such as broad, flat, simple leaves, a similar size and stature, and the production of seasonal fruit.

We used orthoptera because they are a relatively large insect species which are easy to identify to species and have been observed on Callery Pear at the UD-ERA. We specifically made an effort to choose those which were known to be a mixed feeding species. In the summer of 2018, an observational approach was used to determine the most abundant orthoptera in the area. The species chosen from these observations to be used for the experiment in descending order of abundance were Melanoplus femurrubrum, Conocephalus strictus, Melanoplus differentialis and a Neoconocephalus species (unidentifiable at juvenile stages).

During the first five weeks of this study, we conducted a field survey of orthopteran biomass at graminoid-dominated areas in order to determine a range of insect herbivores which would be natural to use in the enclosure experiment. On the first week of surveying, hoops of about 25 cm in diameter were haphazardly placed about 1 yd apart from each other. For the following five weeks, orthopteran seen jumping in the span of about 30 seconds were visually counted and recorded. Based off of this data, the density was set to be six orthopterans per experimental unit, or, per enclosure. Next, the species richness was set at four ranges: 0, 1, 2, 3 or 4 species. This resulted in a total of 10 treatments, each with six replicates containing either a Callery Pear or American Basswood seedling, resulting in a total of 51 enclosures. Treatments were randomly assigned to cages throughout the research area via a random number generator.

In June 2018, 60x60x100cm enclosures were built within the UD-ERA in the same area which initial orthopteran surveying was performed. To build the enclosures, metal stakes were hammered into the ground at four points around a tree in the experiment and PVC pipe was used to build a shell upon which a pre-sewed mesh casing with a zipper for access into the cage was placed. To secure the mesh to the ground, keeping the orthopterans in and other predators, both insects and larger mammals, out, sandbags were placed at each corner flush to the edge of the enclosure on top of the mesh. Each enclosure contained either a Callery Pear or American Basswood seedling and surrounding vegetation, usually a mixture of wild strawberry, Fragaria vesca, and a variety of grasses. Criteria for selection of each seedling was a uniform height (between 60cm and 90cm) and an abundance of leaves (seedlings with no leaves or extreme herbivory via deer were not chosen). The enclosures were placed at least one yard apart. In September 2018, the enclosures were stocked with orthopterans, caught via sweep-net in the UD-ERA. Upon the start of the experiment, orthopterans were monitored for survival every seven days, at which point all living individuals were counted and identified to species. This weekly monitoring went on until the end of the experiment, which lasted one month, at which point adult mortality of the orthoptera began to rapidly increase due to decreasing temperatures with the impending fall.

At the end of the experimental period, orthopteran were released and visual leaf counts were performed by counting each leaf present on the saplings with attention on which showed signs of herbivory and which did not. Next, plant biomass was destructively sampled from all cages via clipping and placed into labeled paper bags. In each case, the seedling of interest was kept separate from the surrounding plant matter in the cage. After collection, all vegetation was dried in an oven for 48 hours in order to account for potential variations in water weight between the treatments. Next, the seedling and surrounding vegetation for each treatment were separately weighed in order to calculate percent change in biomass as compared to the controls. To compare plant responses to the treatments, the difference in plant biomass at the end of the experiment between control treatments with no grasshoppers and species richness (with low richness combining treatments 1 and 2 and high richness combining treatments 3 and 4) was calculated. In addition, the change in other biomass and total aboveground biomass was calculated and compared to species richness level.

For the species richness values, we chose to use the orthopteran counts from the second week of the experiment, September 19th, 2018. This data was chosen due to the fact that it allowed for all the cages to be stocked completely for one week and accounted for early death of orthopteran due to handling, age, or other causes. We then reclassified the species richness data so that a richness of 1 and 2 were grouped together as low richness and a richness of 3 and 4 were grouped as high richness. We then went through and spot checked the final 2 weeks of data collection to determine if species richness values were indeed highest on the September 19th date or if we missed any orthoptera on that specific counting day. It was found that the September 19th day of counting showed the highest species richness in each case (aside from the initial data) and thus, these numbers were used. Next, the percent change of each dependent variable (tree biomass, total aboveground biomass, and leaf counts) was calculated for both the Callery Pear and American Basswood in both low and high richness as compared to the control treatments. Box plots of this data were then made comparing the species richness to the tree biomass. General linear models with plant or total biomass as the dependent variable and species richness as the independent variable were run (which included two treatments- high or low species richness).

Results

We found that species richness does have an effect on the biomass of Callery Pear. However, this effect was based on which plant species we were using, and the direction was contrary to what we expected. High species richness tended to increase the biomass of Callery Pear (p=.07). Richness treatment had no effect on the biomass of Basswood. In addition, orthopterans negatively affected plant biomass overall, aside from the positive effect of high species richness on Callery Pear (*Figure 1*).

The high species richness treatments on Callery Pear were correlated with a larger positive percent change in total aboveground biomass, that is, the combined biomass of both the Callery Pear sapling and the surrounding vegetation. Richness treatments had no effect on Basswood biomass. As follows a similar trend from the above data, the all of the mean percent changes in total aboveground biomass here were negative, besides the positive effect of the high species richness treatment on Callery Pear (p=0.01, *Figure 2*).

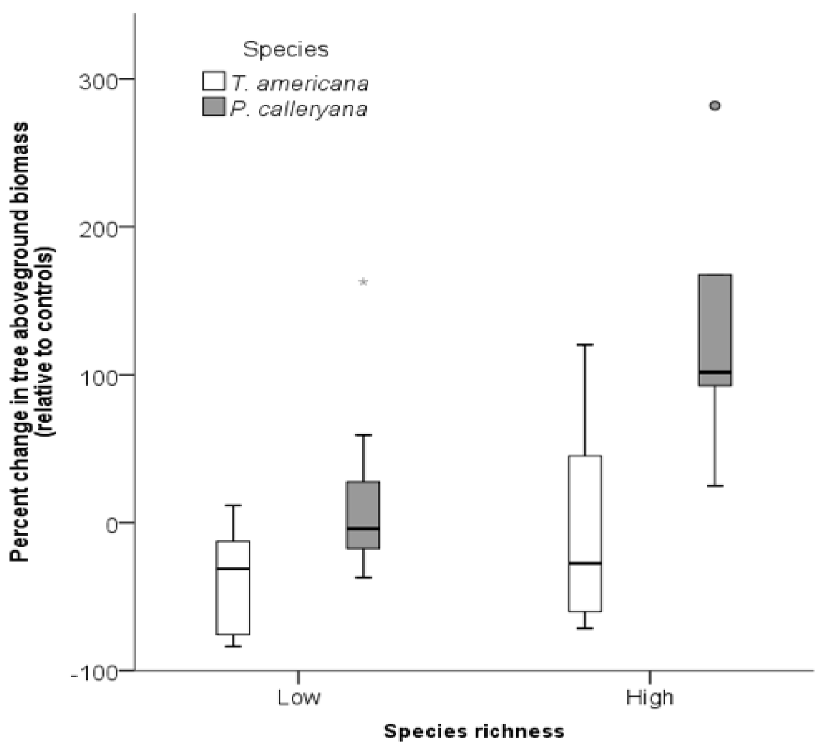

Figure 1: Percent Change in Tree Biomass

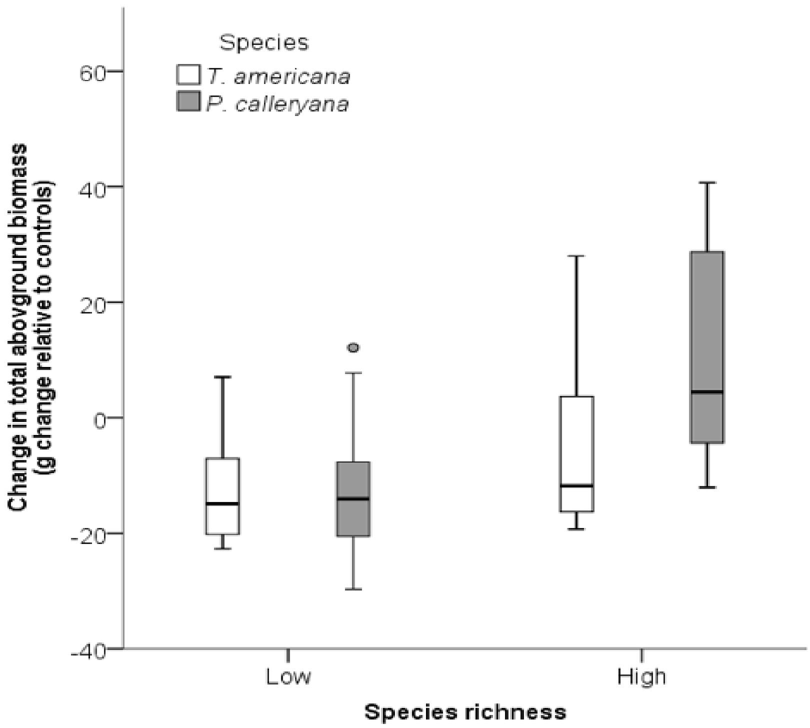

Figure 2: Percent Change of Total Aboveground Biomass

Discussion

At the start of this project, we predicted that a higher species richness would lead to a higher negative percent change, thus indicating that a higher diversity level of orthopteran would negatively affect the success of Callery Pear. However, the results of this experiment suggested exactly the opposite. We found that a higher species richness produced a higher positive percent change in Pear biomass, thus indicating that a higher diversity level of herbivores positively affected the success of Callery Pear.

Though this result was not predicted, one potential mechanism which could have occurred is that a higher species richness of insect herbivores led to an increase in overall herbivory. Though it may seem counterintuitive, it may be the case that the increased level of herbivory actually triggered a response mechanism in the Callery Pear specifically, causing it to grow more rapidly (i.e., compensatory growth), thus explaining the positive percent change in biomass in the high richness treatments. There are many previous cases in which this type of feedback mechanism exists between invasive plants and herbivores. The first documented case of this occurring was in 1995 with Bernd Blossey and Rolf Notzold. This study compared the growth of Lythrum salicaria (purple loosestrife) from two locations, one with insect herbivory and one without. With a native range of Eurasia, Purple loosestrife is invasive in North American wetlands, creating a negative impact on both the biodiversity and ecosystem function of these habitats. This study found that in the location with insect herbivores, there resulted an increase in vegetative growth (Blossey et. al 1995). This supported their EICA hypothesis, or, the evolution of increased competitive ability hypothesis. This hypothesis states that an evolutionary mechanism may be responsible for the reallocation of resources in invasive species from defence to growth in response to herbivory (Rogers et al. 2008). This experiment could very well link Callery Pear's mechanism of invasion to the EICA hypothesis, thus giving insight into potential management practices to be explored in the future.

Conclusion

Callery Pear is an emerging invasive species which is threatening the sustainability of early successional habitats and prairies and habitats in the midwestern and eastern United States. Currently, land managers and conservationists alike are searching for environmentally-friendly and cost-effective methods of controlling this species before it launches into a full blown invasional front all across the U.S. and further affects the biodiversity and ecosystem function of these areas. We found that the maintenance of a high species richness of orthopteran in an experimental mesocosm containing a Callery Pear sapling and surrounding graminoid-dominated vegetation actually facilitated the growth of Pear. However, a potential control method for this species which should be investigated further is the maintenance of a high density of one species of orthopteran which is very efficient at eating Callery Pear in order to control the growth and propagation of this species in areas where it is at an early stage of invasion, that is, where it is at a low density. One species which we found in this experiment to be efficient at eating Callery Pear is the Melanoplus femurrubrum. If investigated properly, this could be an efficient means of control for this invasive species which would be both cost-effective and environmentally-friendly.

References

Barrett S.C.H and Richardson, Barry. (1986) Genetic attributes of invading species. Ecology of Biological Invasions. Cambridge University Press, 21–33.

Blossey, B., & Notzold, R. (1995). Evolution of Increased Competitive Ability in Invasive Nonindigenous Plants: A Hypothesis. Journal of Ecology, 83(5), 887-889.

Culley T. M., Hardiman N. A. & Hawks J. (2011) The role of horticulture in plant invasions: how grafting in cultivars of Callery pear (Pyrus calleryana) can facilitate spread into natural areas. Biol. Invasions 13, 739–746.

Culley, Theresa & A. Hardiman, Nicole. (2008). The role of intraspecific hybridization in the evolution of invasiveness: A case study of the ornamental pear tree Pyrus calleryana. Biological Invasions

Dunn, Margery G. (Editor). (1989, 1993). "Exploring Your World: The Adventure of Geography." Washington, D.C.: National Geographic Society.

Lankau, R. A., Rogers, W. E. and Siemann, E. (2004), Constraints on the utilization of the invasive Chinese tallow tree Sapium sebiferum by generalist native herbivores in coastal prairies. Ecological Entomology.

Laws, AN, Prather, CM, Branson, DH, Pennings, SC. Effects of grasshoppers on prairies: Herbivore composition matters more than richness in three grassland ecosystems. J Anim Ecol. 2018; 87: 1727– 1737.

Meyerson L. A. & Mooney H. A. (2007) Invasive alien species in an era of globalization. Front. Ecol. Environ. 5, 199–208.

Prather, C.M., Pelini, S.L., Laws, A., Rivest, E., Woltz, M., Block, C.P., Del Toro, I., Ho, C.K., Kominoski, J., Newbold, T.A. Parsons, S., 2013. Invertebrates, ecosystem services and climate change. Biol. Reviews 88: 327-348.

Rogers, W.E., & Siemann, E.H. (2008). The Role of Insect Herbivores in Exotic Plant Invasions: Insights Using a Combination of Methods to Enhance or Reduce Herbivory. Ecological Studies, Volume 173.

Tellamy, D.W., 2004. Do alien plants reduce insect biomass? Conservation Biology, 18: 1689-1692. 7. Schneider, J., Maehr, D.S., Alexy, K.J., Cox, J.J., Larkin, J.L. and Reeder, B.C., 2006. Food habits of reintroduced elk in southeastern Kentucky. Southeastern Naturalist, 5 (3), pp.535-546.

Theresa M. Culley, Nicole A. Hardiman; The Beginning of a New Invasive Plant: A History of the Ornamental Callery Pear in the United States, BioScience, Volume 57, Issue 11, 1 December 2007, pp. 956–64.

Vincent, Michael A. “On the Spread and Current Distribution of Pyrus Calleryana in the United States.” Castanea, vol. 70, no. 1, 2005, pp. 20–31. JSTOR, JSTOR.

Vitousek PM, Dantonio CM, Loope LL, Rejmanek M, Westbrooks R. 1997. Introduced species: a significant component of human-caused global change. N. Z. J. Ecol.