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Acknowledgements

Footnotes (1) While microarthropods inhabit coarse woody debris, here “habitat” refers to the more diverse communities within the leaves themselves. ACKNOWLEDGEMENTS Funding for this research was provided by DePaul University Environmental Science & Studies Department. Thank you to advisor Dr. Liam Heneghan and to peers Ashlyn Royce, Bailey Didier, and Aarti Mistry for their assistance in transportation and sample collection and processing.

Interspersed Denuded Zone (IDZ): How patchy leaf litter dynamics in a buckthorn-invaded urban woodland can affect microarthropod species richness

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ABSTRACT Biodiversity loss may serve as a key diagnostic of the Anthropocene. Invasive species are an important driver of this loss. In this study of a forest preserve in Chicago, Illinois we examined Interspersed Denuded Zones (IDZs for short), which are areas of patchy leaf litter in invaded forests caused in this case by the rapid decomposition of litter from buckthorn (*Rhamnus cathartica)*. We characterized the leaf litter mass in IDZs and enumerated litter-inhabiting microarthropod populations. We found that plots of high buckthorn density are associated with IDZs: there was significantly less leaf litter mass in these invaded areas. Litter in IDZs also hosted fewer microarthropods compared to plots with little to no buckthorn invasion. We therefore caution that our results may signal potential microfaunal biodiversity loss as a result of buckthorn invasion.

INTRODUCTION

Anthropogenic influences have been implicated in a Holocene extinction event – the so-called sixth mass extinction in Earth's history (Kolbert, 2014). Though more charismatic species such as polar bears and leopards garner the most media attention, arguably most biodiversity loss is not happening at this macroscopic scale. Much of the Earth's animal diversity resides in a spot many often tread over—the forest floor. The top five inches of the soil of any given North American forest contains most of the biodiversity in that entire forest ecosystem (Giller, 1996). Animal biodiversity of the forest floor is characterized by diverse populations of microarthropods (e.g., mites and Collembola–of which only 10% of species have been described (André et al., 2002).

Though many factors contribute to biodiversity loss on a global scale–habitat loss and fragmentation, air and water pollution, and

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changing climate–a key driver of extinction in local communities is invasive species (Dirzo, Raven, 2003). In this study we looked specifically at how invasive shrubs such as *Rhamnus cathartica* (European Buckthorn) can affect the community of organisms in the leaf litter of midwestern woodlands. Though the threat to plant diversity from shrubby invasives is well-characterized, we focused here on the implications of buckthorn on soil faunal communities. Microarthropods, in particular those that live in leaf litter comprise a very biodiverse component of the litter habitat and are essential to litter decomposition dynamics (Santorufo et al., 2012). We conject that, through the disruption of some aspect of ecosystem structure and function, buckthorn can erode the basis of these communities.

Heneghan et al., 2002 found that buckthorn and other woody invasive species decompose more rapidly than their native counterparts due to their high nitrogen content. Based on this research, we proposed that rapid decomposition leads to patchy areas of leaf litter on forest floors, where, in buckthorn-dense areas, litter decomposes quickly, leaving areas of sparse litter. Here we introduce the term *Interspersed Denuded Zone* (IDZ for short) to describe these sparsely littered areas below thickets of buckthorn. Though IDZs are readily apparent in invaded woodlands, no previous studies have characterized them adequately.

While Boudreau and Wilson (1992) found that buckthorn could decrease species richness of trees in a forest ecosystem over time, no study has documented its effect on microarthropod communites. We therefore wish to describe IDZs in terms of microfaunal abundance. Leaf litter is an essential habitat for microarthropods—mites, collembola and others—which are incredibly taxonomically diverse, as well as gravely under-researched (Brussaard, 1997). We propose that the disruption in decomposition dynamics that leads to IDZs could decrease habitat for microfaunal populations.

Heneghan et al. (2002) also proposed that dense thickets of buckthorn may function as an "ecological trap" for soil fauna. Here, we further evaluate this hypothesis that hyper-nitrogenous leaf litter attracts microbes, followed by microarthropods, and then rapidly decomposes, leaving patches of diminished habitat (IDZs) for microfauna. Habitat reduction even at such a small scale could implicate biodiversity collapse, as these critters are a foundational link in forest ecosystems (Santorufo et al., 2012).

In order to examine this phenomenon of patchy forest floor dynamics, we examined differences in leaf litter mass of quadrats between high-buckthorn and low-buckthorn plots in LaBagh woods, a buckthorn-invaded forest preserve in Northwest Chicago, IL. We then characterized the IDZs (buckthorn-dense plots) through examining microfaunal abundance within the leaf litter between IDZs and open areas. With this study we hope to contribute to the growing literature on the links between invasive species and biodiversity loss and spur further research on Interspersed Denuded Zones.

METHODS

Site

We chose LaBagh as a representative Midwestern invaded urban forest for the purposes of this study. LaBagh Woods (41.9796° N, 87.7438° W) is a 200 acre forest preserve managed by the Forest Preserves of Cook County that borders densely populated areas and heavily trafficked roads. The site is dominated by low-lying wetlands, open woodlands, and savanna ecosystems. The southern start of the North Branch trail along the Chicago river can be found in LaBagh woods. Like most forested areas in Illinois and throughout the Midwest, this system has been invaded by buckthorn (Kurylo et al., 2007).

Litter Collection

We selected six plots from which to collect litter samples: three of these plots were located in high-density buckthorn areas (proposed IDZs), and three were located in low-density buckthorn areas, which we will refer to as open areas (Figure 1). We collected dead organic matter from all plots on October 4, 2019.

Within each plot, we took three random samples by blindly throwing a 0.25 m^2 quadrat made from PVC pipe. All of organic material within the quadrat was collected and placed in a garbage bag. Adjacent to the area where the litter was collected, we filled a 1-quart Ziploc bag with litter for microarthropod analysis.

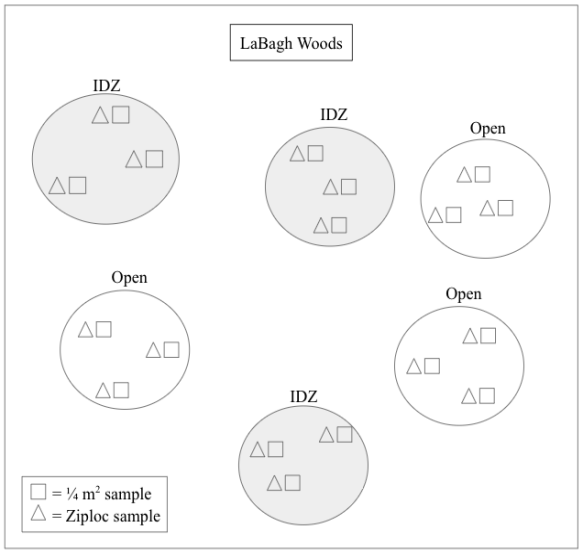

Figure 1. Diagram of sampling process. Six samples were taken from each IDZ (shaded), and six samples were taken from each open plot (not shaded): three ¼ m^2 samples (squares), and three quart Ziploc bag samples (triangles). The diagram is not to scale.

Sample Processing

After litter samples were air-dried, we separated out the components of the sample into leaf litter, coarse woody debris (e.g., twigs) and a catch-all category we labeled "other" (eg. acorns, hickory nuts). Each component was weighted using a standard lab scale.

Litter samples from the Ziploc bags were placed into a Tullgren Funnel extractor and soil fauna was collected into alcohol-filled cups below. The samples were emptied into dishes, and sorted, and identified into the following categories: mites, predatory mites, Collembola, and other arthropod. The sorted samples were placed in glass vials filled with alcohol.

Data Analysis

Means (and standard errors) of organic matter from the quadrats were calculated. Differences between masses of organic matter in IDZ versus open areas were evaluated using t-tests. The average number of arthropods per gram in each plot, were also compare using t-tests to determine if there was a significant difference in arthropod abundance between the types of plots.

RESULTS

Our analysis found a significant difference in leaf litter mass between IDZ and open plots, and a significant difference in microarthropods per plot between the IDZ and open plots.

Litter Analysis

While there was a significant difference in the separated leaf litter between the IDZs (M= 17.96, SE = 5.07), and the open plots (M = 39.32, SE = 9.62); t(16) = -1.96, p = 0.035, we found no significant difference in the mass of coarse woody debris between the IDZs (M = 166.3, SE = 28.77), and open plots (M = 167.3, SE = 50.30); t(16) = -0.02, p = 0.493, nor was there a significant difference in the total amount of litter (leaves, sticks and twigs, and acorns), between IDZ plots (M= 184.2, SE = 29.34), and open plots (M = 206.64, SE = 53.84); t(16) = -0.37, p = 0.372.

Figure 2 shows the differences in mass per quadrat between the two types of plots, and includes data sorted into leaf litter, coarse woody debris, and the total differences.

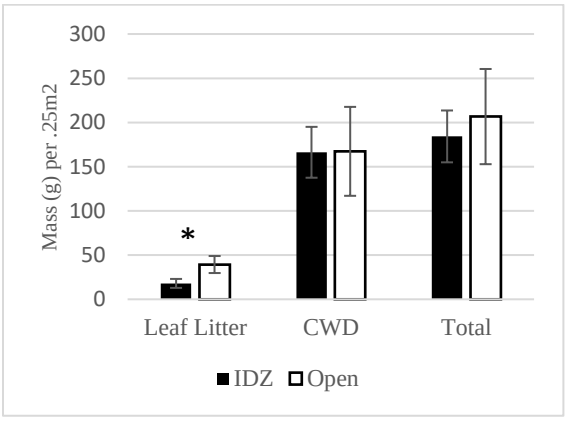

Figure 2. Differences between leaf litter, coarse woody debris and total organic matter from quadrats collected at LaBagh woods (Oct 2019). * Indicates significance at the level of $p < 0.05$.

As shown by our statistical tests, out of these comparisons, the only significant difference was that of the leaves, the category excluding coarse woody debris.

Microfaunal Analysis

Our analysis of microfaunal counts between the different types of plots found a significant difference in the number of microarthropods per plot between IDZs (M = 625.3, SE = 385.3), and open plots (M = 1611, SE = 255.1); $t(4) = 2.13$, $p = 0.0499$.

Figure 3 shows differences in the total number of counted microarthropods as a sum of the averages between the three plots for each type of plot. Our analysis shows that this difference is significant between the two types of plots.

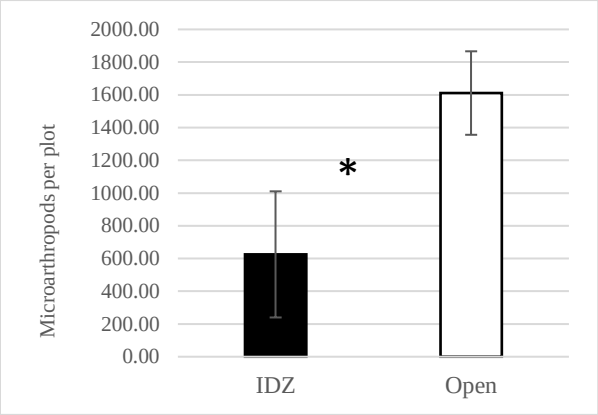

Figure 3. Differences in microarthropod counts between IDZ and Open plots. (Oct 2019). * Indicates significance at the level of $p < 0.05$.

DISCUSSION

Our results revealed a significant difference in average leaf litter mass per 0.25 m^2 area between the three IDZ plots, and the three open plots. The result was significant only when comparing the leaf category of the sorted litter, and not significant overall mass input nor in the coarse woody debris category. We imagine that coarse woody debris and total mass input is not significantly different because, as nitrogen increases in the litter as a result of buckthorn the leaf litter decomposes, and the woody debris remains.

Difference in litter volume on the forest floor accords with previous literature that shows a relationship between buckthorn's high nitrogen content and increased litter decomposition rates, (indeed buckthorn seems to accelerate decomposition of the surrounding litter (Heneghan et al., 2002). We postulate then that buckthorn's rapid decomposition changes leaf litter dynamics to a critical point at which a near collapse of the litter habitat occurs, making it less suitable to maintain microfaunal populations. We argue that this collapse is responsible for our second significant finding that there were fewer microarthropods on average in the IDZ plots.

A near collapse of the litter habitat also explains why buckthorn could be considered an ecological trap: buckthorn litter with its high concentrations of nitrogen is attractive to microarthropods (which feed on microbial biomass growing in the litter), it then decomposes rapidly, and leaves little habitat (litter) left for microarthropods.[1]

Based on an amalgamation of our two significant results, we conclude that Interspersed Denuded Zones exist, and that they are defined as thickets of buckthorn atop barren litter, which contains fewer microfauna compared to buckthorn-free or low-buckthorn plots.

While the scope of this particular study is relatively small, and further research must be done to comprehensively characterize IDZs, we believe that our results have biodiversity and conservation implications for any invaded forest ecosystem. Microarthropods are imperative to nutrient cycling, decomposition dynamics and soil health, and our results show that their habitat may be diminishing as a result of the proliferation of buckthorn within LaBagh (Santorufo, et al., 2012). The effects of a collapse in their richness would begin with alterations of decomposition and nutrient dynamics but could eventually cause large scale impacts on floral and faunal diversity within invaded forest ecosystems.

As buckthorn and other woody invasive species continue to permeate forests of North America, their previously researched impacts, as well as those studied here, will accumulate to disrupt

longstanding ecosystem processes of native flora and fauna. Our results show that these impacts could extend to disrupt and potentially collapse ecological relationships between forest floor organisms, and eventually lead to impacts higher up in the tropic levels of the forest ecosystem.

Studies on biodiversity are increasingly important in light of the current mass extinction event, we would argue especially those at a microfaunal level. We therefore recommend further research on the impact of woody invasive species on macrofaunal communities and how these impacts affect biodiversity on the ecosystem level in order to underscore the importance of mitigating deleterious impacts of invasive species.

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