# Invertebrate resource consumption across successional stages of a Northern temperate forest

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Abstract

Prescribed burns are a convenient means to measure forest succession and its effects on species diversity and ecosystem functions. The purpose of this study is to examine invertebrate resource consumption across various stages of forest succession. We placed different resource types, including butter-coated, salt-coated, sugarcoated, and uncoated grains of rice in four segments of neighboring forest. These forest segments underwent natural and prescribed burns in 1911, 1936, 1954, 1980, and 1998. We measured average units of rice removed over two twenty-four hour periods. We found that forest age was a significant predictor of resource removal, with the 1936, 1980, and 1998 plots having the greatest resource removal. We found that rice treatment was not a significant predictor of resource removal. We also found that the type of resource removed did not vary across the various burn plots. An increase in resource consumption in 1936, 1980, and 1998 burn plots indicates that forest succession and its related changes in ecosystem functions do not always follow a prescribed linear, or logistic model. Further research should explore the relationship between biodiversity and resource removal as a function of forest age.

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## Introduction

The human population is projected to increase by 2 to 4 billion by 2050 (Cohen, 2003). With an increase in the human population also comes an increased demand for food and housing (Moore *et al.*, 2003). Habitat fragmentation, particularly in the form of deforestation, has been a common solution to limited agricultural and housing space (Holdren, 1974; Meyer, 1992). Similarly, with an increase in human population also comes a greater risk of accidental habitat destruction, such as in the event of fire or invasive species introduction (Barnes, 1998). One particular area of interest is concerned with how habitat fragmentation, and its associated loss in biodiversity, is linked to a change in ecosystem services. Ecosystem services provided by forest habitats that are not only at risk when biodiversity is destroyed, but that are also a particular concern to humans include carbon sequestration, water regulation, and pollination (Ciccarese, 2012).

Forest succession, often times the outcome of severe habitat destruction, is a useful tool for understanding the influence of changing biodiversity on ecosystem services. Biodiversity tends to increase logistically across successional stages of a forest (Lichter, 1998). Mid-to-late successional forests are likely to have greater biodiversity relative to their early-successional counterpart (Lichter, 1998). For this study, we are fortunate to have access to the University of Michigan Biological System (UMBS) “Burn Plots”, a naturally and experimentally designed burn chronosequence. These “space-for-time” substitution plots were both naturally and experimentally burned periodically over the past 100 years to demonstrate the effects of secondary succession. Because these plots possess the ability to demonstrate both the effects of habitat destruction long term, and its associated changes in biodiversity, they prove critical to the research design.

One particular ecosystem service of interest is invertebrate contribution to nutrient cycling within forest stands. To further our understanding of this service, we plan to study how invertebrate resource preference and consumption varies across successional stages of the UMBS burn plots. We assess resource acquisition by placing known amounts of powdered sugarcoated, salt-coated, butter-coated, and un-coated rice in varying ages of the UMBS “Burn Plots”.

Because mid-to-late successional forests have greater biodiversity, harboring greater interspecies competition, we hypothesize that older plots will also have a greater proportion of resources consumed (Youngsteadt *et al.*, 2014). Because powdered sugar is a readily accessible form of simple carbohydrates and energy, we hypothesize that the powdered-sugarcoated rice will have greater removal compared to the other treatment types. Lastly, because younger forests have limited soil nutrient availability, we hypothesize that the treatment type removed will be more selective in younger plots (White, 2004).

**Methods**

We sampled mesofauna resource consumption across UMBS "Burn Plots". We designed 100 chicken wire cages with the following dimensions—6" X 5" X 1". We cooked 1,000 grains of long-grain white rice in two cups of boiling water for 30 minutes. We coated 250 grains of cooked white, long-grain rice in 60 mL powdered sugar, 250 grains in 60 mL butter, and 250 grains in 60 mL table salt. We left 250 grains uncoated for a control.

We used the following UMBS "Burn Plots" for sampling—1911, 1936, 1954, 1980, and 1998. Within each plot, we placed five chicken wire cages two meters apart from one another. Within each cage, we placed four petri dishes. The four petri dishes contained one of the following—10 grains of butter-coated rice, 10 grains of powdered sugarcoated rice, 10 grains of salt-coated rice, or 10 grains of uncoated rice. We performed this process for two separate 24-hour periods, for a total of 200 replicates.

We placed bates at 8 a.m., on the mornings of August 4$^{th}$, 2015 and August 9$^{th}$, 2015. We measured number of grains removed at 8 a.m. the following day.

We used the initial and final count of rice grains to determine proportion of resource removed. We used a one-way ANOVA to compare the mean units of rice removed across the different UMBS “Burn Plots”. We used a one-way ANOVA to compare the mean units of rice removed across different treatment types. We used a two-way ANOVA to compare the mean units of rice removed across different UMBS “Burn Plots” and different treatment types.

**Results**

We used a one-way ANOVA to compare the average units of rice removed across the different burn plots—1911, 1936, 1954, 1980, and 1998. There was a significant difference in average units of rice removed across the different burn plots ($F_{4, 199}$ =9.403, $p < .01$; Fig. 1). Post hoc comparisons using the Fisher LSD test revealed that the 1936, 1980, and 1998 burn plots had significantly more units of rice removed compared to the 1954 and 1911 plots. Post hoc comparisons using the Fisher LSD test revealed that there was not a significant difference in average units of rice removed between the 1911 and 1954 plots, or between the 1936, 1980, or 1998 plots.

We used a one-way ANOVA to compare average units of rice removed across the different treatment types—sugar-treated, butter-coated, salt-coated, and uncoated. There was not a significant difference in the average units of rice removed across the different treatment types ($F_{3, 199}$ = 2.340, $p > .05$; Fig. 1). Post hoc comparisons using the Fisher LSD test revealed that butter-treated and sugar-treated rice were removed significantly more than the control. Post hoc comparisons using the Fisher LSD test revealed that there was not a significant difference between the average units of butter-treated and sugar-treated rice removed.

We used a two-way ANOVA to compare average units of rice removed based on treatment type and different aged burn plots. There was not a significant difference in the average units of rice removed across treatment types and burn plot age ($F_{12, 199}$) = 1.605, $p > .05$; Fig 1.).

**Discussion**

We were interested in measuring invertebrate resource removal across the following University of Michigan Biological Station "Burn Plots"—1911, 1936, 1954, 1980, and 1998. We hypothesized that there would be a difference in resource removal across the different aged burn plots. Specifically, we predicted older plots, which harbor greater biodiversity and competition, to have a greater amount of resources consumed. We found that there was a significant difference in resource removal across different aged plots. The 1911 and 1954 plots had significantly fewer resources removed compared to the 1936, 1980, 1998 plots. We hypothesized that out of the resources available, sugarcoated rice, which is energy rich and high in carbohydrates, would have the greatest removal. We did not find a significant difference in resource removal across different treatment types. However, we did find greater removal of sugar and butter-coated rice over the uncoated, control rice. Lastly, we hypothesized that younger plots, with limited nutrient availability, would be more selective towards sugar removal, where as older plots would select a broad range of resources. We did not find any one plot to be significantly more selective towards resource type.

We anticipated that there would be a linear increase in resource consumption with increasing age of plot. What we found was that the youngest two plots, 1980 and 1998, and the 1936 plot had the highest resource removal. 1911, the oldest plot, and 1954 had the lowest resource removal. Leaf area index may explain why resource removal is higher in the 1980 and 1998 plots. These younger plots, with a low surface area index, are likely to have higher albedo (Kirschbaum et al., 2011). High albedo is linked to higher surface area temperatures, which can ultimately lead to increased metabolism, biotic activity, and resource removal (Brown et al., 2004). While there is likely to be a higher leaf area index in 1936, and subsequent drop in albedo and surface area temperatures, it is likely that biodiversity and its influence on rates of interspecies competition are attributed to the high resource removal at this site. We may see a dip in the 1954 plot due to a lack in both albedo and biodiversity. Low resource removal in the 1911 plot is more difficult to explain, for it is likely to contain both low albedo and high biodiversity. Low resource removal in the 1911 plot may be attributed to caveats in our study. Specifically, it rained during the second 24 period that we sampled. Due to 1911's high leaf area index, less rain was able to reach the forest floor. In the younger plots though, rain passed through open canopy gaps and may have increased resource removal by splashing grains of rice out of the petri dishes.

We anticipated finding resource removal to be greater for sugarcoated treatments. We also anticipated that younger plots would be more selective in resource acquisition. There were no significant differences for either of these. While it is possible that all of the forests are lacking in the resources we test, White et al. demonstrates that the UMBS "Burn Plots" have greater nutrient availability with increasing age. We encourage further examination of the link between nutrient availability in different aged forests and invertebrate resource removal.

The UMBS "Burn Plots" provide a unique opportunity to study ecosystem services across different stages of forest succession. This is important to consider, as increasing human population sizes are likely to increase accidental habitat fragmentation, such as in the case of fire or invasive disease introduction. Ecosystem services play an important role in forest recovery following disturbance, especially in the case of invertebrate's contribution to nutrient cycling. Studying invertebrate resource removal in the UMBS "Burn Plots" aids in our understanding of how this ecosystem service varies across different stages of forest succession.

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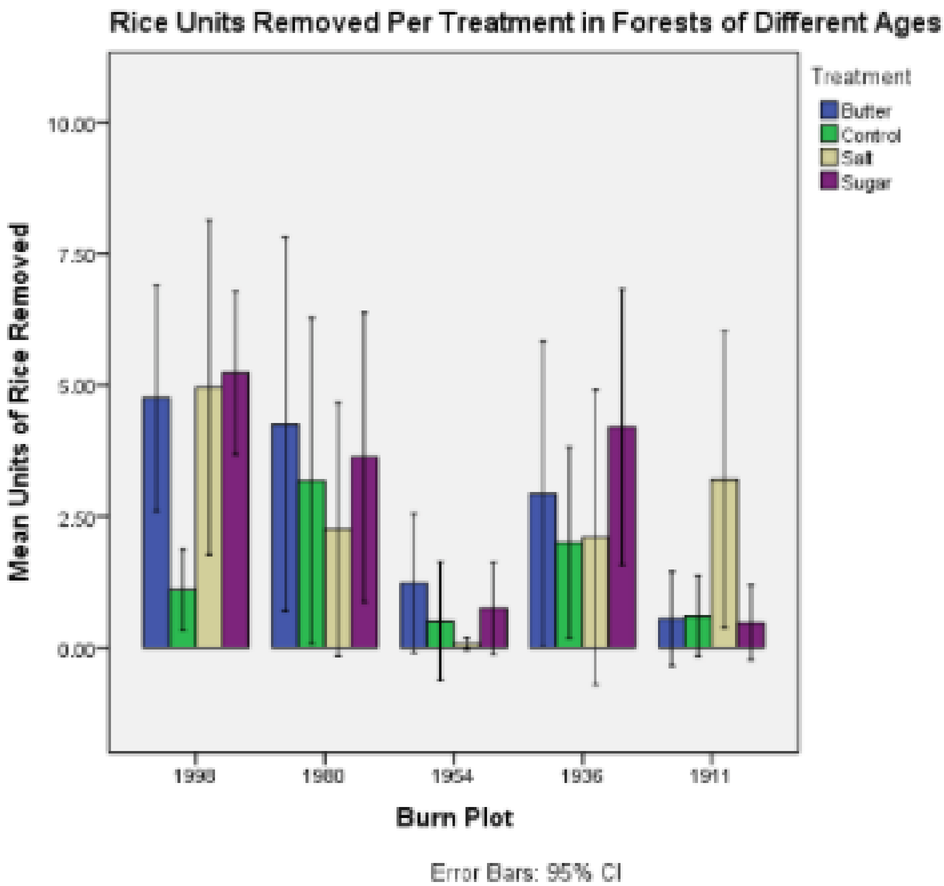


**Figure 1.** Comparing the mean units of rice removed across treatment types and placement within different University of Michigan Biological Station (UMBS) "Burn Plots".