Urban Forests and Global Change

The effect of temperature, soil nitrogen and gastropods on *Thuja plicata* growth and reproduction

Anna O'Brien, Janneke Hille Ris Lambers, & Ailene Kane Ettinger – Department of Biology, University of Washington

Introduction

Humans are changing the environment. For example, nitrogen deposition, rising temperatures, and non-native species are influencing plant communities. These changes have and will continue to affect trees,[1,2,3] thus, understanding the response of species to global change will help conservation agencies and land managers plan for the future. Urban areas already experience higher temperatures, elevated CO_2, greater nitrogen levels, and more non-native species compared to rural areas[4,5]. The response of trees to urban parks therefore be used as a proxy for the net effects of global change on trees (Carreiro and Tripler 2005). We investigate the growth and reproduction of *Thuja plicata* trees, a native Pacific Northwest conifer, in both urban and rural forest fragments to understand global change impacts. After observing extremely low conifer germination rates across sites, we concluded that factors such as herbivory might be important. Gastropods have been shown to impact communities through consumption of plants at the seedling stage[7], and to limit seedling survival of a European conifer[8]. The effects of soil moisture, soil nitrogen, and gastropod herbivory on *Thuja plicata* seedlings was analyzed experimentally to determine the relative effect each might be having on the observed germination rate.

Hypotheses

1) Trees experience higher temperatures and nitrogen levels at urban fragment edges.

2) Adult trees experience increased growth at urban fragment edges. Due to higher nutrients and warmer, longer growing seasons caused by the higher nitrogen levels and increased temperature, trees are able to grow faster.

3) Trees experience decreased reproduction at urban edges. Higher temperatures cause low soil moisture and mortality in sensitive germinants.

4) Gastropods eat tree seedlings. Tree seedlings experience mortality due to gastropod herbivory. Gastropods prefer certain species and nutrient levels of tree seedlings.

Figure 1: Study site locations. Rural sites are in green, urban sites in red.

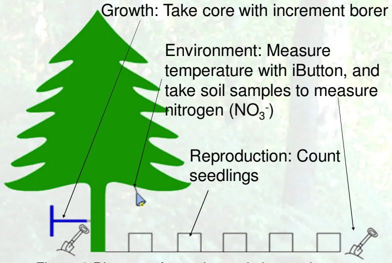


Figure 2:Diagram of samples and observations

Methods

The observational field work occurred at 5 forested urban parks and 3 rural parks (Fig. 2). We located study sites near and far from edges of forest fragments. Each study site was centered around a mature *Thuja plicata* tree. Environmental data collected from sites include hourly temperature, soil NO_3^-. An increment core was taken from the tree to measure growth, and seedlings were counted in $1m^2$ quadrats along a 10m transect from the tree to measure reproduction. (Fig. 1) The data were analyzed for the effect of temperature, nitrogen, and urban edge on growth and reproduction. Tree ringwidths from cores were compared to climatic data available for the region, to further understand the influence of climate on tree growth. Results from the field work led us to design and experiment on gastropod herbivory of tree seedlings.

The experiment was conducted to investigate gastropod herbivory on *Thuja plicata* seedlings, whether gastropods prefer it over other common tree seedlings, and whether soil moisture and nitrogen of the seedling impact herbivory. *Thuja plicata* seedlings were grown in high or low nitrogen levels and high or low moisture levels (Fig. 3). Seedlings of other tree species, *Pseudotsuga menziesii*, *Tsuga heterophylla*, *Acer macrophyllum*, and *Alnus rubra*, were grown with additional *T. plicata*. Seedlings of *T. plicata* and other species (Fig. 4) were exposed to herbivory by common introduced gastropods (Fig. 5) in a terrarium (Fig. 6). *T. plicata* seedlings from nitrogen and moisture treatments were also exposed to gastropod herbivory in terrariums. Slug herbivory was measured after 5 days. Seedling height was measured both before herbivory, directly after 5 day trials, and two weeks later. Analyses assessed if species or treatment affected herbivory levels. All models are linear mixed effects models and selected by AIC.

Figure 3: Moisture treatments. Left: High water treatment. Pots are always moist. Right: Low water treatment. Pots receive water that is pulled upward from the dish by the fabric. These become dry.

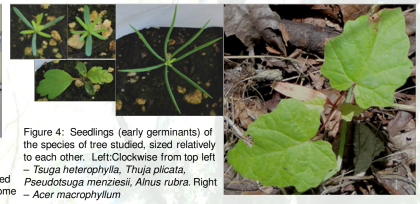


Figure 4: Seedlings (early germinants) of the species of tree studied, sized relatively to each other. Left:Clockwise from top left – *Tsuga heterophylla, Thuja plicata, Pseudotsuga menziesii, Alnus rubra*. Right – *Acer macrophyllum*

Figure 5: Non-native gastropods used in the experiment. Clockwise from top left - *Arion ater/rufus*, *Helix aspersa*, *Arion subfuscus*.

Figure 6: Herbivory trial terrarium. It is divided into two sections. One seedling from each species or treatment is placed on each side. A gastropod is released in only one section.

1. Urban forest edges experience higher nitrate than rural areas and higher temperature than other forest areas. (Figs. 7 & 8)

July-August Mean	Rural Edge	Urban Center	Urban Edge
Difference From Rural Center	+0.37*	+0.49	**+1.25***

Figure 7: Temperature difference from rural forest centers. (Degrees Fahrenheit. *Significant effect of site type (P<.05) Null model AIC is 90.87, selected model is 65.01

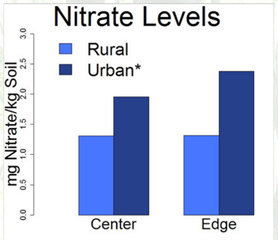


Figure 8: (Right) Soil nitrate levels averaged across site type. *Urban areas have significantly higher nitrate levels than rural areas (P<.1). Null model AIC is 105.78, selected model is 102.37. The model does not include edge and center effects. These are included in the graph as it is probable that nitrate edge and center levels are different, at least in urban areas, though observations did not detect it.

2.Trees grow faster in urban areas, and with increased dormant season precipitation, early growing season precipitation, and late growing season temperature. (Figs. 9,10,11)

The faster growth of urban trees may not be a response to the conditions of urban areas. Urban trees are smaller (p≈0 in a one way ANOVA), and smaller trees may grow faster. The faster growth of urban trees could be due either to better conditions (i.e. warmer temperature) or to their size.

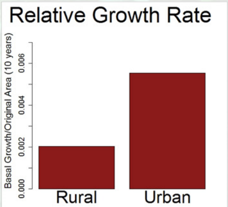


Figure 9: Relative growth rate is change in basal area in the last 10 years, divided by it's basal area 10 years ago.

Model	Null	Dormant Season Precipitation	Early Growing Season Precipitation	Late Growing Season Temperature
AIC	5450.8	5432.1	5425.7	**5418.9**

Final Model	Intercept	Dormant Precipitation	Early Growing Precipitation	Late Growing Precipitation
Coefficient	4.742	0.019	0.106	0.072

Figures 10 & 11: Model selection (Fig. 10-Above) and correlations (Fig.11) of seasonal climate variables and tree growth. Variables are in a linear mixed effects model. Precipitation is cumulative over the season. Dormant season is Oct-Mar, and early growing is Apr-Jun. Late growing season temperature is maximum temperature Nov-Dec. Correlations are weak, and may not be biologically significant.

3. Trees reproduction is less at urban edges, but overall reproduction is so low that other factors besides temperature and nitrogen may be important (Fig. 12)

We observed low conifer seedling density(<1 seedling/m^2) in urban and rural forest fragments (Fig. 12). Conifer germinant counts were much lower than observed at Mt. Rainier, a less disturbed location, where counts were 55.5 seedlings/m2 in 2008 and 4.97 seedlings/m2 in 2009[9].

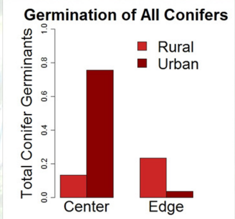


Figure 12: Germinants per transect ($10m^2$) of all conifer species present, averaged by site type. Null model AIC is 144.83, selected model is 62.91.

4.Tree seedlings are eaten by gastropods. Gastropod species and tree species affects amount of seedling eaten. Nitrogen or water treatments do not. (Figs. 13,14,15)

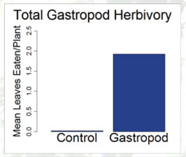
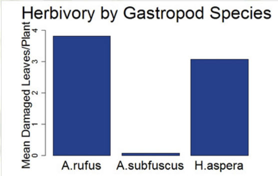
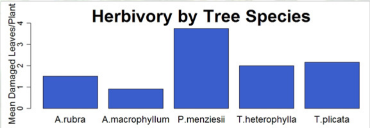


Figure 13: Mean leaves eaten on all experimental seedlings. Null model AIC is 1330.18, selected model is 648.24.





Figures 14 & 15: Mean leaves eaten out of plants exposed to gastropods, averaged across species of gastropod (Fig.14, Left) and averaged across species of seedling (Fig 15, Right). Both are selected by AIC in linear mixed effects models. Null model AIC is 754.9, gastropods species model is 340.00, and including tree species model is 190.01.

Conclusions

Our results suggest that urban forest edges resemble future global change conditions of higher temperature and nitrogen. These global change factors appear to be positively influencing tree growth, suggesting that Thuja plicata will benefit from future conditions. However, low seedling recruitment may be a concern, because it appears that urban and rural forests are currently failing to regenerate on their own. Introduced gastropods could play a role, as they have the ability to reduce seedling biomass significantly. The relative impacts of invasive slug herbivory and other global change factors on native conifer recruitment should be prioritized in future study.

Work Cited

1) Fritts 1974 2) Handa, Korner, Hattenschwiler 2006 3) Yin, Liu, Lai 2008 4) Carreiro and Tripler 2005 6) Gaffin and others 2008 7) Strauss et al, 2009 8) Nystrand & Granstrom, 2000 9) Hille Ris Lambers, Janneke, 2010. Personal Communication

Acknowledgments

In no particular order: Sara Eshe, Melissa Winstanley, Irene Weber, and the Hille Ris Lambers lab; Mary Gates Endowment; Washington NASA Space Grant Program; Frye-Hotson-Rigg Botany Memorial Fund; May Garrett Hayes; UW Botany Greenhouse; Alan Kohn; Michael Kennedy; Laurie Bowman; Bob Paine; UW Department of Biology; Seattle Parks; Cedar River Watershed; King County Parks; Washington State Parks; Silvaseed; Brian Buchwitz, HHMI Integrative Research Internship Program; Aaron Tilley; UW Biology 472 class of fall 2009 and fall 2010.