Using Western Hemlock Regeneration to Explore Potential Climate Responses in Old-Growth Forests of the Pacific Northwest

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Introduction and Background

A complex combination of physical and biological processes determines the distribution of species across landscapes. Global climate change is a major factor accelerating shifts in species distributions. Simulated studies predict that future climactic conditions will result in significant impacts to forest ecosystems of the Pacific Northwest, including range changes for *Abies amabilis*, *Tsuga heterophylla,* and *Pseudotsuga menziesii* (Shafer et al. 2001). While many species will move upward and poleward in response to a warmer climate, other species may remain static or shift in the opposite direction due to physical or biotic variables such as available moisture and increasing biotic interaction (Ettinger 2011). Our study closely examines *Tsuga heterophylla* in order to determine whether the species has shifted upward or downward along a forest ecotone, and, if in fact a shift is occurring, what variables are most responsible for this shift. Understanding the variables driving both species distribution and composition changes is crucial to understanding the future of all ecosystems.

Figure 1. Photo of a Western Hemlock seedling (height class 2) taking advantage of a nurse log near Packwood Lake, WA. Over 99% of Western Hemlock seedlings recorded in this study were found on nurse logs. Nurse logs are essential to hemlock regeneration. Photo credit - Jonathan Ley, www.phlumf.com/gallery.

H.J. Andrews Experimental Forest

The HJ Andrews Experimental Forest (HJA) is a 6400 ha research forest located in the Willamette National Forest. The forest is one of 25 Long-Term Ecological Research (LTER) sites in the United States, and is comprised of 40% old-growth forest. The elevation range within the Lookout Creek drainage basin is 410 m to 1630 m above sea level. The lower elevation forests are dominated by Douglas-Fir (*Pseudotsuga menziesii*), Western Hemlock (*Tsuga heterophylla*), and Western Red Cedar (*Thuja plicata*), while the higher elevation forests are dominated by Pacific Silver Fir (*Abies amabilis*), Noble Fir (*Abies procera*), and Mountain Hemlock (*Tsuga mertensiana*).

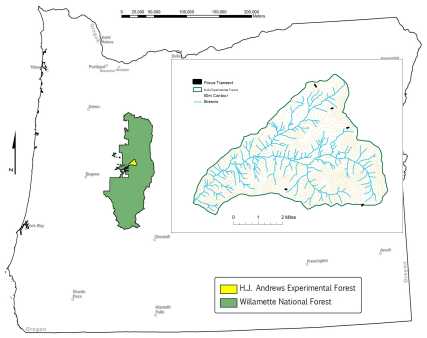

Figure 2. The location of the Willamette National Forest and the H.J. Andrews Experimental Forest within the state of Oregon. Map Inset: The locations of the five focus transects within the HJA, along with the site's boundaries, 50 m contour lines, and streams.

Methods

Figure 3. Photo taken in transect 4. The transect, the highest in elevation and most heavily disturbed, is dominated by true firs.

- Focused on Western Hemlock (*T. heterophylla)* because of its ecological importance to the forests of the Pacific Northwest. Also sampled three species of true fir (*Abies spp.*) and Douglas Fir (*Pseudotsuga menziesii*).
- Resampled five transects located at the ecotone between lower elevation forest dominated by Western Hemlock, Douglas Fir, and Western Red Cedar, and higher elevation forest dominated by true firs. Original sample in 2001.
  - Sampled every seedling (0 – 137 cm in height) within one meter of the center line of each transect.
  - Recorded the height where lichen begins to grow on mature trees for 10 random trees per 20m segment of each transect.
- Resampled presence/absence of 10 species of understory herbaceous plants for 43 plots located throughout the entire watershed. Originally sampled in 2001.
- Compared distribution of species in 2001 and 2011.
- Acquired HJA climate data from the LTER online data repository.

Figure 4. The presence of old-growth Douglas Fir and abundant Pacific Silver Fir exemplifies the ecotone between two forest types.

Works Cited

- Shafer, S.L., P.J. Bartlein, and R.S. Thompson. 2001. Potential Changes in the Distributions of Western North America Tree and Shrub Taxa under Future Climate Scenarios. *Ecosystems* 4: 200-215
- Ettinger A.K., K.R. Ford, J. and HilleRisLambers. 2011. Climate Determines Upper, but not Lower, Altitudinal Range Limits of Pacific Northwest Conifers. *Ecology* 92: 1323-1331
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Results

Climate Trends

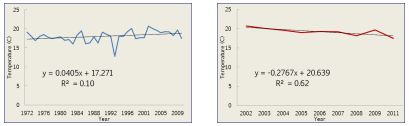

Figure 5. July temperature (Celsius) recorded from the HJA's PRIMET meteorological station (elevation 436 m) over 39 years (left) and 9 years (right). Over longer time spans, temperature has increased by 0.8 °C in the past century in the Pacific Northwest.

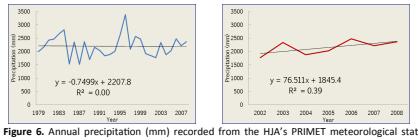

Figure 6. Annual precipitation (mm) recorded from the HJA's PRIMET meteorological station over 31 years (left) and 7 years (right). Precipitation has not changed significantly over the past century in the Pacific Northwest.

Western Hemlock Regeneration

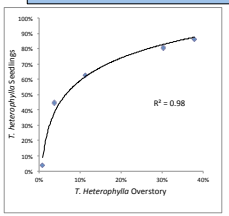

Figure 7. Relationship between the percentage of Western Hemlock seedlings in each transect and the percentage of adult, overstory Western Hemlocks in each transect.

Table 1. Summary of seedling generation on nurse logs. Nurse logs constitute fallen logs that provide a substrate for seedlings.

Species	Total	Percentage on Nurse Logs
Silver Fir (*A. amabilis*)	482	13.5%
Grand Fir (*A. grandis*)	6	0.0%
Noble Fir (*A. procera*)	131	13.0%
Douglas Fir (*P. menziesii*)	87	63.2%
Western Hemlock (*T. heterophylla*)	786	99.49%

Western Hemlock Survival

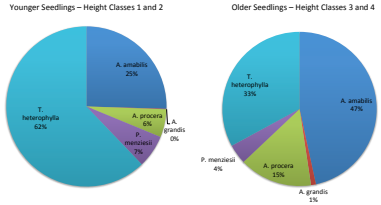

Figure 8. Species composition in different size classes for 2011 sample. The pie chart on the left represents seedlings of height classes 1 and 2 (0-10 cm), while the pie chart on the right represents seedlings of height classes 3 and 4 (10-137 cm). *T. heterophylla* seedlings were much more abundant in younger height classes.

Acknowledgements

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- University of Richmond School of Arts and Sciences
- H.J. Andrews Experimental Forest, Oregon State University, U.S. Forest Service
- Climate and Hydrology Database from Long-Term Ecological Research Program.

Snow Interactions

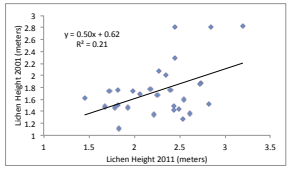

Figure 9. Lichen height measurements from each individual transect plot for both 2001 and 2011. In general, measured lichen heights increased from 2001 to 2011.

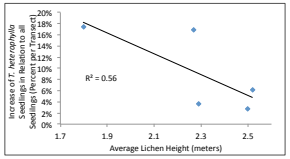

Figure 10. The relationship between measured lichen height (used to quantify winter snowfall) and the relative increase of *T. heterophylla* seedlings within each transect.

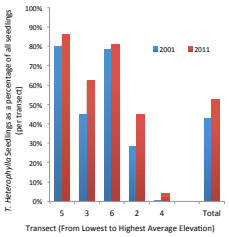

Figure 11. Percentage of all seedlings that were Western Hemlock in each transect for the years 2001 and 2011. The transects are ordered by elevation from lowest to highest.

Table 1. Some understory plant species demonstrated significant downslope shifts in elevation over the 10-year period as shown for the mean elevation at which California blackberry was observed ($p = 0.011$, K-S test).

Species	Mean elevation 2011 (m)	Elevation change (m)
California blackberry (*Rubus ursinus*)	1185.9	-66.9

Figure 12. Photo of forest service access road near transect 2. Bottom, left corner of the photo shows young trees damaged by heavy winter snowfall.

Discussion and Conclusion

Our examination of Western Hemlock seedling regeneration reveals that the spread of seedlings is best explained by the presence and density of Western Hemlock in the forest overstory (Figure 7) and nurse logs on the forest floor (Table 1). This finding is consistent with recent studies that indicate more localized processes and biotic interactions drive the range limits of species in closed-canopy forests (Ettinger 2011). Western Hemlock regenerates very successfully, but also has a higher seedling mortality rate than the true firs it competes with at the studied ecotone (Figure 8). Recent climate data for the H.J. Andrews (Figures 5 and 6) shows a short-term trend of higher precipitation and lower temperatures. This has resulted in large snowpacks that persist into the summer in the past decade (Figure 9). Western Hemlock regeneration appears to be at least somewhat limited by these winter snowpacks (Figure 10) especially at high elevation (Figure 11), which is consistent with general conifer response to snowy winters (Peterson et al. 2002). Data from throughout the entire watershed suggest that herbaceous understory plant species may be even more sensitive to the high snowfall observed and have significantly shifted downslope over the past decade (Table 1). Clearly, species responses to changes in climate are complex and future studies should consider changes in the amount and form of precipitation as well as any changes in temperature.