Predicting understory plant species' elevational migration in response to changing precipitation

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Background

As the Earth's overall temperature continues to rise, plant species are expected to adapt by migrating towards more polar latitudes or towards higher elevations. A recent study, however, contends that species' adaptation may not be so generalizable: plant species may move downhill towards areas of higher precipitation (Crimmins et al. 2011). These contrasting claims prove challenging for conservation efforts since planners may be unsure whether a species will move either up- or downhill.

This study investigated the phenomenon of plant migration to determine if known drought tolerance could predict the direction of species movement. The study hypothesized low drought tolerance would lead to downhill movement as plants sought water, whereas high drought tolerance would lead to uphill movement as plants sought cooler temperatures.

H.J. Andrews Experimental Forest

- 6400 ha site in the Willamette National Forest
- Central Oregon, western slope of the Cascade Range (Fig. 1)
- Plots located in old-growth forest (old-growth is 40% of total watershed area; Fig. 1)
- Dominated by Douglas-fir, western hemlock, Pacific silver fir
- Elevation range: 410 – 1630 m
- High precipitation in winter; low in summer
- One of the 25 Long-Term Ecological Research (LTER) sites in the U.S.

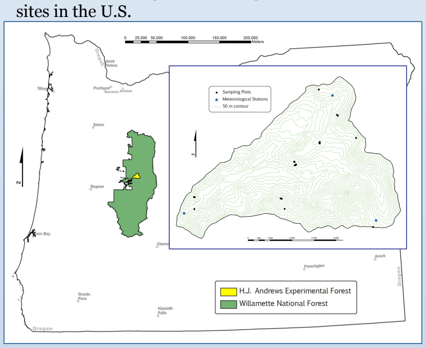


Figure 1. Locations in the state of Oregon of the H.J. Andrews Experimental Forest (HJA) and the Willamette National Forest. Inset: Locations in the HJA of the study sample plots and selected meteorological stations. Elevations of sample plots range from 491 m – 1392 m. *n* = 43 plots

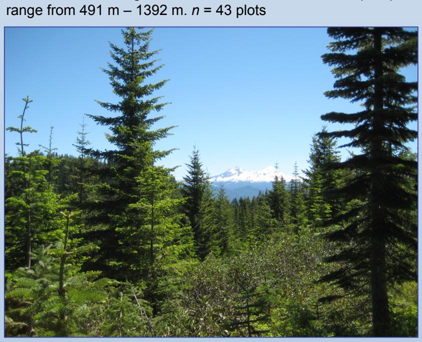


Figure 2. View from upper elevation site.

Methods

- Chose 10 target species previously identified in the HJA; all were perennial herbaceous plants
- Classified target species based on known drought tolerance: five with low, five with medium or high (Table 1)
- Resampled 2002 plots using three 2 x 2 m random quadrats in each 20 x 20 m plot (Fig. 1)
- Compared 2002 and 2011 data: (1) presence / absence at plot level; (2) cumulative frequency distributions of all individuals
- Climate data were acquired from the LTER online data repository

2011

Results

Table 1. Summary of plot presence / absence data. A species was considered present at an elevation if at least one individual was observed at the plot located at that elevation. Change in elevation was quantified by comparison to data collected in 2002 by Lookingbill et al. (2004). *Gaultheria shallon* has no elevation change since it was present at all the same plots and thus the same elevations in both studies.

Species	Drought tolerance	Mean elevation 2011 (m)	Elevation change (m)
salal *Gaultheria shallon*	low	746.8	0
western sword fern *Polystichum munitum*	low	991.5	+68.9
vine maple *Acer circinatum*	low	1134.8	+75.3
bunchberry dogwood *Cornus canadensis*	low	1262.9	+17.0
Oregon bedstraw *Galium oreganum*	low	1285.7	+1.4
dwarf Oregon-grape *Mahonia nervosa*	high	1062.3	+99.9
pipsissewa *Chimaphila umbellata*	medium	1157.5	+70.7
California blackberry *Rubus ursinus*	medium	1185.9	-66.9
snowberry *Symphoricarpos albus*	high	1313.3	+66.0
beargrass *Xerophyllum tenax*	medium	1373.8	-16.4

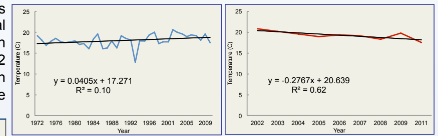


Figure 3. July temperature of the HJA's PRIMET meteorological station (elevation: 436 m) over 39 years (left) and 9 years of the study period (right). Note that data are missing for 2010. Linear trendlines are included.

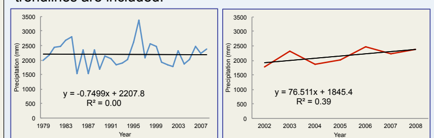
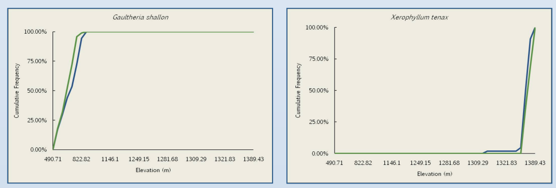


Figure 4. Annual precipitation of the HJA's PRIMET meteorological station (elevation: 436 m) over 31 years (left) and 7 years of the study period (right). Linear trendlines are included.

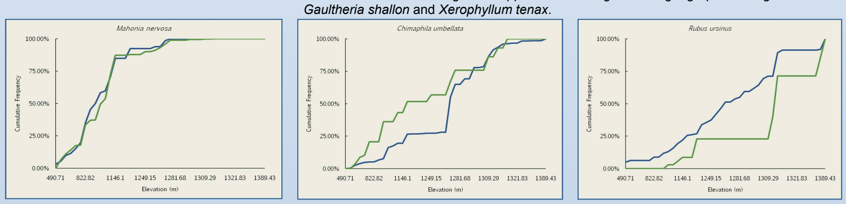
Figure 5. Typical understory of an old-growth stand in the HJA. Photo taken near a study sample site.

Figure 6. Cumulative frequency by elevation of the total number of individuals surveyed of selected target species. Values along the *x*-axis represent respective plot elevations.

2002 2011



The HJA's elevational range overlapped with the edges of the geographical ranges of *Gaultheria shallon* and *Xerophyllum tenax*.



Mahonia nervosa is representative of most surveyed species. Although *Mahonia* was found in three high elevation plots in 2011 where it was not found in 2002, this comprised only 6 of the 549 observed *Mahonia* individuals. The cumulative frequency of individuals does not appear to change over the 9-year period.

Chimaphila umbellata demonstrated a large average uphill shift. *Chimaphila* is much less common at lower elevations in 2011 than in 2002, although its distribution has not changed considerably at higher elevation.

Rubus ursinus was the one species to demonstrate significant elevation change (p = 0.011, K-S test). While *Rubus* shifted downhill, there appears to be a more even elevational distribution compared to 2002 data. The downhill movement of this species does not support the drought-tolerance hypothesis.

Discussion

According to this study, drought tolerance cannot be used as a tool to predict species' movement. However, two notable patterns were observed. First, the general uphill movement of most species as compared to Lookingbill et al. (2004) suggests early "pioneer" individuals are moving uphill but are not yet able to establish larger, healthy populations. *Mahnoia nervosa* exemplifies this trend: while its distribution is similar over the 9-year study period, a few pioneer individuals were beginning an uphill elevational shift by establishing themselves at higher elevations than in the past (Fig. 6). The study period was not long enough to capture the degree of elevation shift present in Crimmins et al. (2011).

Second, the climate data suggest cooler temperatures and increased precipitation over the 9-year period, opposite of expected trends (longer-term trends are weak to absent). These cooler, wetter conditions suggest recent snowfall increases in the HJA. This snowfall appears to force some species downhill by causing disturbances in the forest canopy and lengthening periods of snowpack. *Rubus ursinus*, the only species that demonstrated significant movement and one of two species that moved downhill, seems to follow this pattern. A previous study demonstrated *Rubus*'s strong ability to flourish after forest disturbances (Nesmeth et al. 2006). Increased snowfall in the HJA may have created more disturbances at all elevations; along with long-lasting snowpack at higher elevations, *Rubus* easily could have increased its population downslope.

Works Cited

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