Can we use tree seedling distribution elevation and snow data to estimate the response of tree species to climate change?

A 20-Year Ecotone Study of Pacific Northwest Mountain Forest Vulnerability to Changing Snow Conditions

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How might tree species respond to a changing climate? Is there a natural scenario to study changes in tree populations on smaller spatial scales? In response to climate change species may shift their ranges poleward to remain within preferred climate niches. Similar migrations will occur upslope in mountains on smaller spatial scales. The authors investigated species movement on an elevation gradient using seedling growth patterns with snow cover as a climate change indicator. They determined whether snow cover and melt were associated with elevation, canopy cover, and decadal climate oscillations. The also examined whether tree seedlings were mixed, shifted to higher elevations, and responded to snowmelt patterns.

Did the number of snow days differ among years? Did the elevations differ between areas of western hemlock and Pacific silver fir? And did the number of snow days differ between tree type areas?

- The number of snow days per year averaged 28.6 across all plots and sensors and the snow days per sensor ranged from 13.0 to 44.8. The annual mean last snow day ranged from April 17 to May 18 and the mean across all years was May 2. The last snow date was significantly correlated with the total number of snow days.
- The number of snow days varied greatly among years, with generally more snow in the second half of the study period. The higher snow years were also cold-phase years for the decadal climate oscillations and snow was correlated with the oscillation metric.
- The median elevation of western hemlock, 1285 m, was significantly lower than that of Pacific silver fir, 1337 m, across all years. There was no significantly shift upslope for either species over the study period.
- Data loggers located in western hemlock areas recorded fewer snow days than data loggers in Pacific silver fir areas. Differences in snow days were significant in 6 of the 10 years, generally in years without extreme high or low snow.

Do temperature loggers reliably measure snow cover? Were the snow metrics correlated?

- Temperature data loggers are a reliable tool to measure snow presence and can be used over long periods with little cost or maintenance. Additionally, they can be used to measure under-canopy snow cover and detect variation at fine spatial scales, which complements other types of data collection.
- Although the snow metrics used here are correlated, the correlation is not perfect. The specific metrics used to assess the effects of snow on species across a landscape will depend on the questions being investigated and the sensitivity of the study subject to a given metric.

What other factors might influence tree species dispersal that were not accounted for in this study?

- Changes in distribution ranges of tree species may happen at discreet times because of a disturbance, such as fire, instead of gradually in response to changing climate conditions. Global climate change will not alter conditions uniformly and regional climate oscillations may remain more dominant.
- In the ecotone, site topography may have a larger impact on tree species distributions than elevation. Additionally, neighborhood effects, such as fallen nurse logs, may be important factors for dispersal, especially for western hemlock.

How does this study inform future research on tree dispersal and climate change?

- This study shows the importance of combining data from local plot sampling with data from remote sensing over long time scales to increase our understanding of climate effects on the stability and growth of tree species populations in forests.
- In order to better investigate whether snow metrics are changing with global climate change, if upslope seedling dispersal is occurring, and whether seedling dispersal depends on 'window of opportunity' regeneration events researchers should focus on interannual variation over consecutive years.

Research Approach/Methods

- The researchers monitored changes in seedling populations along 5 20-m by 100-180-m plots in the ecotone, the transitional zone between the western hemlock forest and the higher elevation true fir forest, which they identified using previous data and modeling.
- They surveyed seedlings 3 times at 10-year intervals over a 20-year period recording species, height, distance along the centerline, and offset from the centerline for all western hemlock, Pacific silver fir, noble fir, and grand fir seedlings. The authors grouped the seedlings into size categories by species for analyses.
- The researchers gathered elevation data with a laser survey system during seedling surveys and collected snow cover and snow melt timing using temperature loggers validated with time lapse cameras annually 2013 to 2022.
- To assess snow variability, the authors calculated the number of snow days during the snow depletion season beginning March 21 and the last day of snow for each data logger and examined within- and between-year variability.
- The authors tested whether decadal climate fluctuations drove snow cover variability by comparing snow metric values to an annual metric combining the Pacific Decadal Oscillation and the El Niño- Southern Oscillation using ordinary least squares linear regression.
- For forest regeneration analyses, they focused on western hemlock and Pacific silver fir. They determined whether species were well mixed using a Wilcoxon rank sum test using cumulative frequency distributions and whether species shifted elevations using Kruskal-Wallis tests on abundance distributions in the three sample years.
- Finally, they used Wilcoxon rank sum tests to determine whether average snow cover days or average last snow day predicted differences in the locations of western hemlock and Pacific silver fir seedlings.

Keywords climate change, under-canopy seasonal snow cover, Pacific Decadal Oscillation, El Niño-Southern Oscillation, regeneration niche, western hemlock, Pacific silver fir

Images

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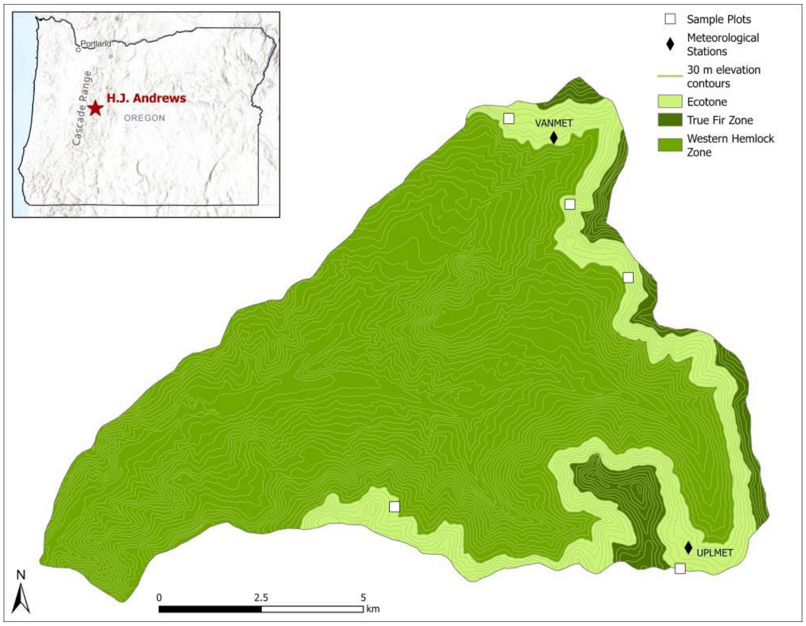

Figure 1 in Lookingbill et al. 2024. The H.J. Andrews Experimental Forest study watershed. The light green band represents an elevation-based approximation (1230–1410 m) of the Western Hemlock–True Fir ecotone. Sample plots are marked by white boxes. Diamonds indicate locations of two benchmark meteorological stations located in the ecotone: Vanilla Leaf (elevation = 1275 m) and Upper Lookout (elevation = 1295 m). Inset: the star identifies the location of H.J. Andrews in Oregon, USA. The map projection is NAD83 UTM Zone 10N.

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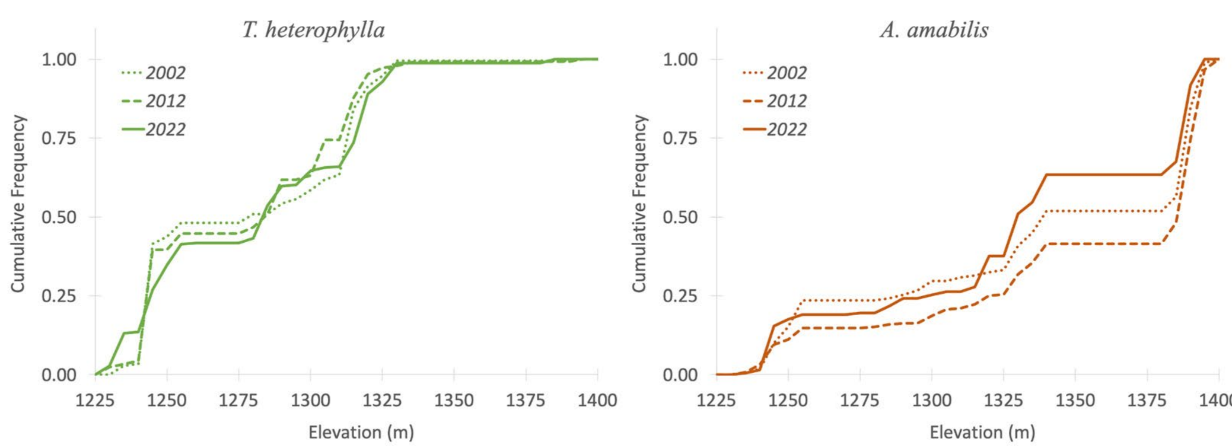

Figure 7 in Lookingbill et al. 2024. No temporal shift in elevation. Cumulative frequency distributions of elevation by species for the three sample years (2002, 2012, 2022) indicate no significant shift for *T.*

heterophylla seedlings or *A. amabilis* seedlings in the ecotone based on the Kruskal-Wallis tests ($p > 0.05$).

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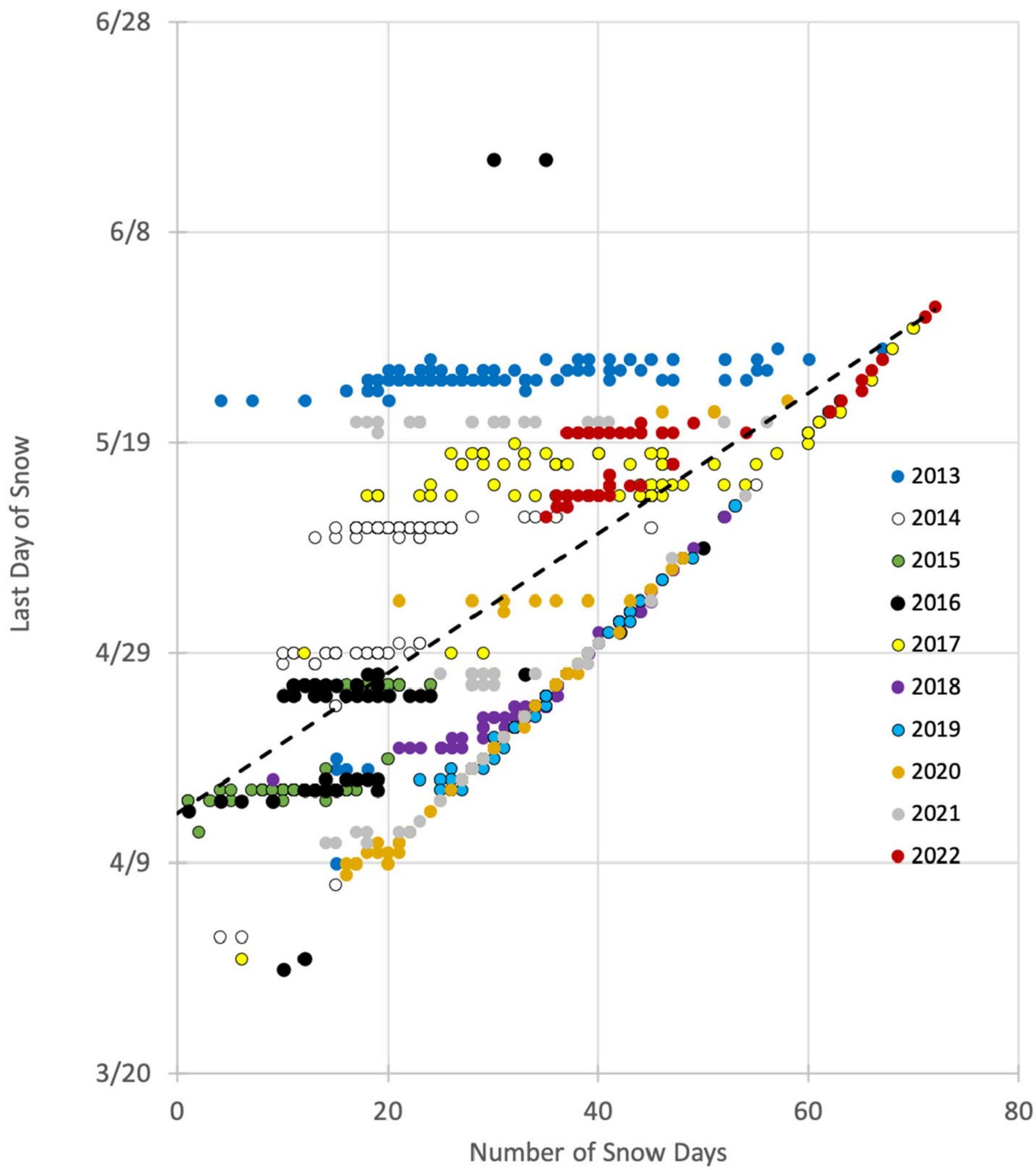

Figure 3 in Lookingbill et al. 2024. Correlation of two snow metrics, last day of snow and total number of snow days during the snow depletion season, as recorded by the forest floor temperature data loggers (2013–2022). The metrics were moderately correlated (r = 0.54; n = 820; p < 0.001), indicating that snow persistence was correlated with overall snow cover during the depletion season.

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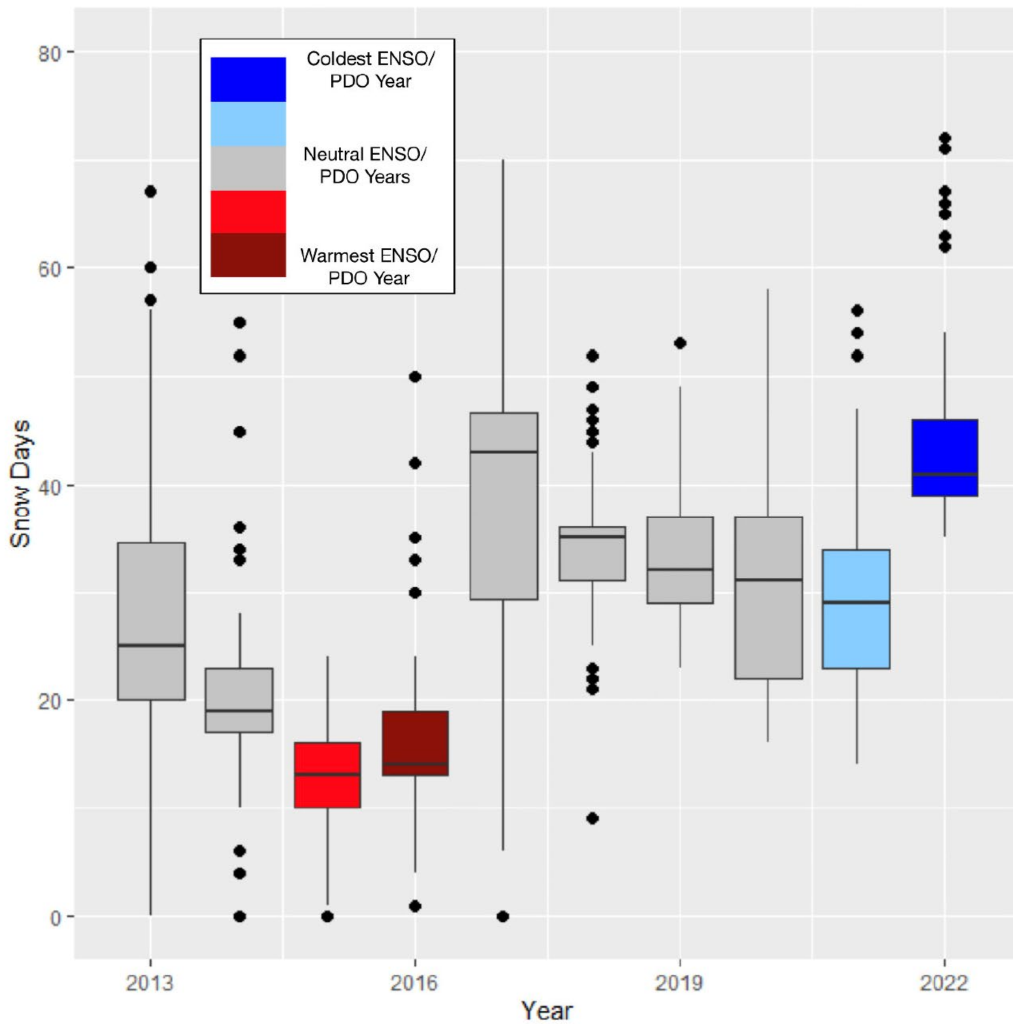

Figure 4 in Lookingbill et al. 2024. Boxplot showing the medians, interquartile ranges, and outliers of the number of snow days metric by year for all data loggers (2013–2022). Years were classified as hot (red), cold (blue), or neutral (gray) based on combined ENSO and PDO rankings. The coldest ENSO/PDO year was 2022, with an ENSO value of −1.067, a PDO value of −2.422, and a median of 41 snow days per data collector. The warmest ENSO/PDO year was 2016, with an ENSO value of 1.867, a PDO value of 0.812, and a median of 14 snow days.