2003 Annual Meeting of the Ecological Society of America, Savannah, GA

Climatic vs. non-climatic control of western hemlock distribution in its coastal and interior ranges

Daniel Gavin and Feng Sheng Hu, Department of Plant Biology, University of Illinois, Urbana IL

Observations:

Western hemlock occurs in two ranges, a coastal range west of the Cascade and Coast Mountains, and an interior range in the Columbia Mountains west of the Continental Divide.

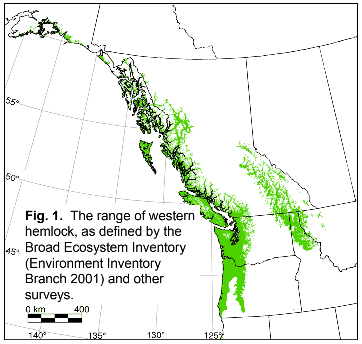


Fig. 1. The range of western hemlock, as defined by the Broad Ecosystem Inventory (Environment Inventory Branch 2001) and other surveys.

The two ranges differ in *general climate*, *forest communities*, and *post-glacial history*.

The coastal range is generally cooler and moister than the interior.

The tree diversity is much greater in the interior than in the coastal range.

The coastal range was colonized much earlier following deglaciation than the coastal range (>9000 vs. <3000 years before present, respectively). Thus, the interior range has had less time to reach a hypothetical climatically-defined potential range.

Predictions:

1. Climatic constraints on hemlock distribution differ between the coastal and interior ranges.
2. The importance of climatic constraints, as determined by the fit of statistical models, differs between the coastal and interior ranges. This would suggest an important role of non-climatic factors.

Approach:

Statistical models are often used to describe the relationship between climate and species' range limits. However, there is little agreement regarding which form of model is the most appropriate. Thus, we first compare the output of three models. We then examine the results the most appropriate model in detail.

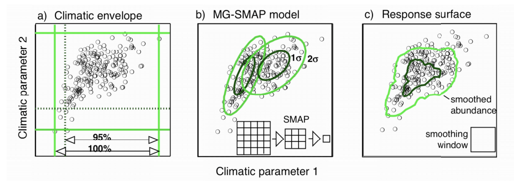
Abstract

The role of climate in determining species distributions at large spatial scales is rarely tested rigorously. We used three bioclimatic models (climatic envelopes, mixed-Gaussian–sequential maximum *a posteriori* classification (MG-SMAP), and response surfaces) to assess climatic vs. non-climatic controls of the range of western hemlock (*Tsuga heterophylla*), a late-successional species that occurs in distinct coastal and interior ranges in northwestern North America. The three bioclimatic models differ in the level of generalization of the species-climate relationship. The MG-SMAP model best predicted the entire range of hemlock, and the formation of this model makes it appealing for bioclimatic modeling. When calibrated using only the coastal range, the MG-SMAP model could accurately predict the coastal range but not the interior range. In contrast, when calibrated on the interior range, the model could only moderately predict both the interior and coastal ranges. Poor predictive capacity of models may be due to different roles of climatic limitation in different parts of its range. The worse fit of the model in the interior range suggests that non-climatic factors affect range limits in the interior to a greater degree than near the coast. Dispersal limitation and/or competition following fire are likely important non-climatic constraints on the distributional limits of hemlock in the interior range.

Methods comparisons:

Which form of statistical bioclimatic model best describes the species–climate relationship?

Models evaluated:



These three common forms of bioclimatic models vary in the degree of generalization of the species–climate relationship.

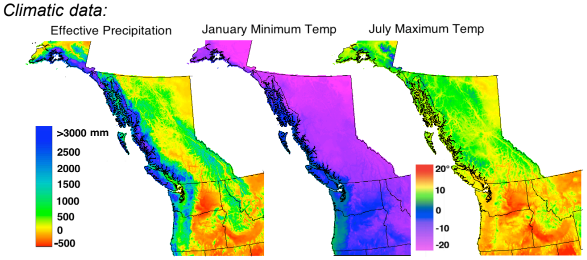
a) The climatic envelope model uses the extreme values (or 95% trimmed values) of grid-cell observations (open circles).

b) The mixed Gaussian-sequential maximum *a posteriori* (MG-SMAP) model fits multivariate Gaussian distributions to clustered subsets of grid cells (usually imagery data; Bouman and Shapiro, 1994). This "climatic signature" is then used to classify cells via a multiscale Bayesian approach that utilizes posterior probabilities at course scales as prior probabilities at finer scales.

c) The response surface method of Shafer et al. (2001) uses a locally-weighted smoother of grid-cell observations.

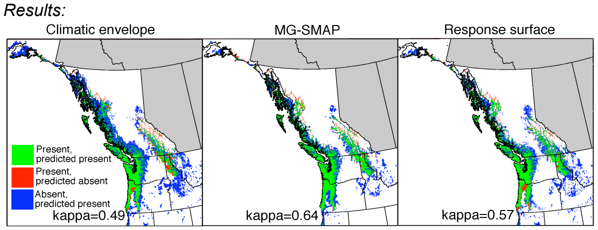
Methods **b** and **c** compare climatic signatures or response surfaces where a species is present vs. where it is absent, while method **a** uses only climatic observations where a species is present.

Climatic data:



Mapped 1960-1990 climatic normals (PRISM climate mapping project; Daly et al. 1994) and estimated effective precipitation (Thornthwaite et al. 1957) at 1-km resolution. Consideration of six other parameters did not improve model accuracy based on these three parameters. Analyses were run using GRASS GIS.

Results:



Observed and predicted ranges of western hemlock for three bioclimatic models. Kappa is a measure of the degree of correspondence of two classifications (0=no difference from chance, 1=perfect correspondence).

Conclusions:

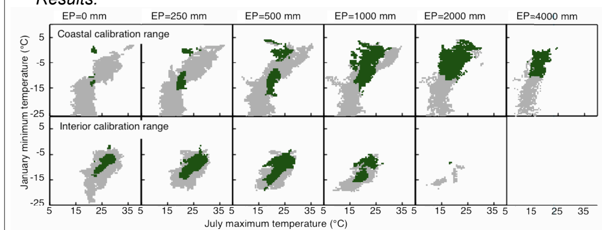
1) The MG-SMAP model results in the best fit of the observed and predicted ranges of hemlock.
2) The mixed Gaussian (MG) method ensures that the most parsimonious climatic "signature" is used. The multiscale (SMAP) method is also appealing for bioclimatic models, as the mean climate at coarse scales is used to influence classifications at finer scales, resulting in realistic, spatially contiguous classifications.

Climatic control of range limits:

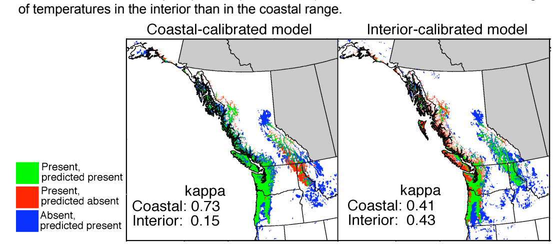
Are the coastal and interior ranges of hemlock in equilibrium with climate?

Methods: Use the coastal range to predict the interior range, and vice versa. Climatic signatures are developed separately for the coastal and interior ranges using the MG-SMAP method.

Results:



Maximum likelihood estimates of the climatic conditions for hemlock presence (dark green) or absence (gray) based on the mixed Gaussian model, applied separately for the coastal range and the interior range. Results are shown for six slices of effective precipitation (EP). At low levels of effective precipitation (EP≤500 mm), hemlock occurs over a broader range of temperatures in the interior than in the coastal range.



Observed and predicted ranges of western hemlock using models calibrated separately for the coastal and interior ranges.

Conclusions:

1) Coastal hemlock occurs in different climate space from interior hemlock. This caused the models to poorly predict the hemlock range outside of the range where the model was calibrated.
2) The coastal-calibrated model could accurately predict the coastal range, but the interior-calibrated model could only moderately predict the interior range. Large areas of overprediction outside of the interior range may be due to unexplored climatic variables or due to non-climatic factors. However, adding additional climatic variables did not improve model performance (not shown). **Thus, this study strongly suggests that non-climatic factors, such as dispersal limitation and competition, may affect range limits at large spatial scales.**

References:

Bouman, C. A. and Shapiro, M. 1994. A multiscale random-field model for Bayesian image segmentation. IEEE Transactions On Image Processing **3**:162-177.

Daly, C., Neilson, R. P. and Phillips, D. L. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology **33**:140-158.

Environment Inventory Branch. 2001. Broad Ecosystem Inventory. British Columbia, Ministry of Sustainable Resource Management. http://srmwww.gov.bc.ca/rib/wis/bei/

Shafer, S. L., Bartlein, P. J. and Thompson, R. S. 2001. Potential changes in the distributions of western North America tree and shrub taxa under future climate scenarios. Ecosystems **4**:200-215.

Thornthwaite, C. W., Mather, J. R. and Carter, D. B. 1957. Instructions and tables for computing potential evapotranspiration and the water balance. Publications in Climatology **10**:181-311.

Funding by: NSF The David and Lucile Packard Foundation University of Illinois