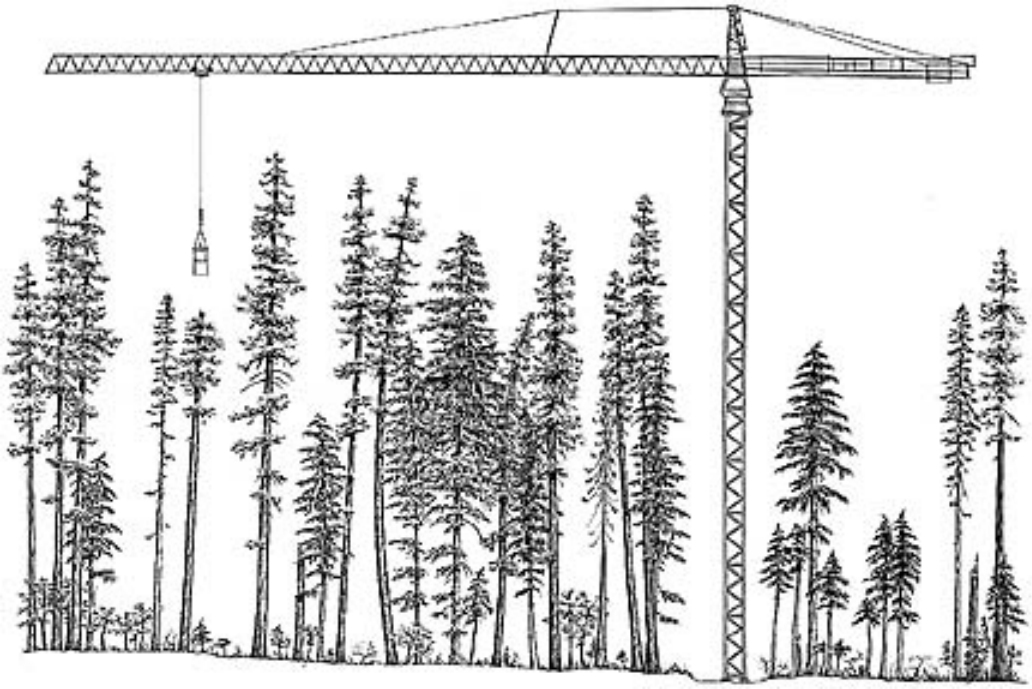
Field Trip Guide

Research in Douglas-fir/Western Hemlock Stands in the Southern Washington Cascade Range

October 9th - October 11th 2009



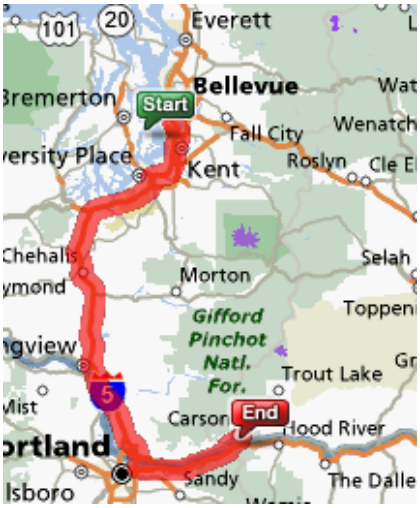
Landscape Ecology Field Trip (2009)

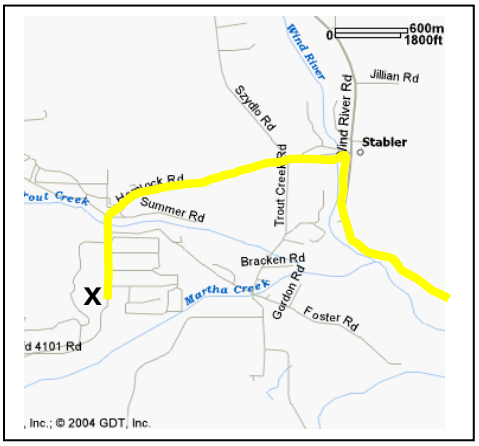
Friday Oct 9:
12:00 pm Leave C-10 parking lot and drive to bunkhouse near Wind River Canopy Crane (WRCCRF)

Directions to the WRCC:

From I-5 near Vancouver WA take I-205 over the Columbia River to I-84. Head east on I-84 to the Cascade Locks exit. At Cascade Locks follow the signs to the Bridge of the Gods—you will need to pay a toll of $1 to cross the bridge—and cross back into Washington. Breath a sigh of relief upon leaving Oregon. Turn right off of the bridge and onto WA State Route 14, quickly reaching the town of Stevenson. From Stevenson continue east on SR 14 about 2 miles and take the well-marked left exit to the town of Carson. From this turn, continue about 6 miles until you enter Stabler (marked by a small country store). Turn left at Stabler onto Hemlock Road, cross over the Wind River, and continue about 1 mile where you will see signs directing you to the WRCC and Canopy Hut. Continue straight past the old Forest Service work center, **cross a small bridge, continue straight ahead for about 150 m (passing two large *Sequoiadendron giganteum* on the right) and turn into the driveway of the last house on right (with big sign = PNW House).**

MAPS:





Quick Preview of Crane Lift:

1) Ascend: Microclimate change from ground level to tree top. Pay attention to temperature, humidity and light changes as the crane lifts. Look at changes in bryophyte communities (moss to lichens). Pg.15.

2) Crown forms (branching patterns and needle displays, top die back): Compare western hemlock, Douglas-fir, grand fir and western redcedar. Pg 10.

3) Gap: Think about the gap maker. Look at change in needle display of grand fir. Look at epicormic branches of Douglas-fir. Note differences in the height of the base-of-live-crown in Douglas-fir vs western hemlock and grand fir (think about light tolerance). Pg. 10.

4) Swing toward south east corner of stand: Look at western redcedar in northwest corner of the plot (low, concave landform). Look at surrounding landscape—even canopy of young stands, uneven canopy of old growth stands and remnant trees of Yacolt Burn.

5) Tree Ecophysiology: Douglas-fir tree used for physiology studies of old-growth trees. Photosynthesis, water potential, sapflow, leaf morphology and display. Pg. 12.

6) Western hemlock mistletoe infection: Mistletoe life cycle, effects on branching, consequences of tree spatial patterns to infection spread, other implications. Pg 17.

7) Descend: same observations as ascend. Pay attention to oblique views of the entire forest canopy. Notice areas with high and low LAI (leaf area index).

Introduction

The Wind River Experimental Forest and Thornton T. Munger Research Natural Area (RNA) are two of the oldest forest research sites in the Pacific Northwest. Falling within the Western Hemlock Zone of the Washington Cascades, these areas contain some of the last remnants of old-growth forest in a highly managed matrix of second growth forest. Research initially focused on forest composition, stand structure, and patterns of mortality. With the installation of the canopy crane, research has expanded to questions about old-growth canopy structure and function (e.g., tree-crown development, water and carbon fluxes).

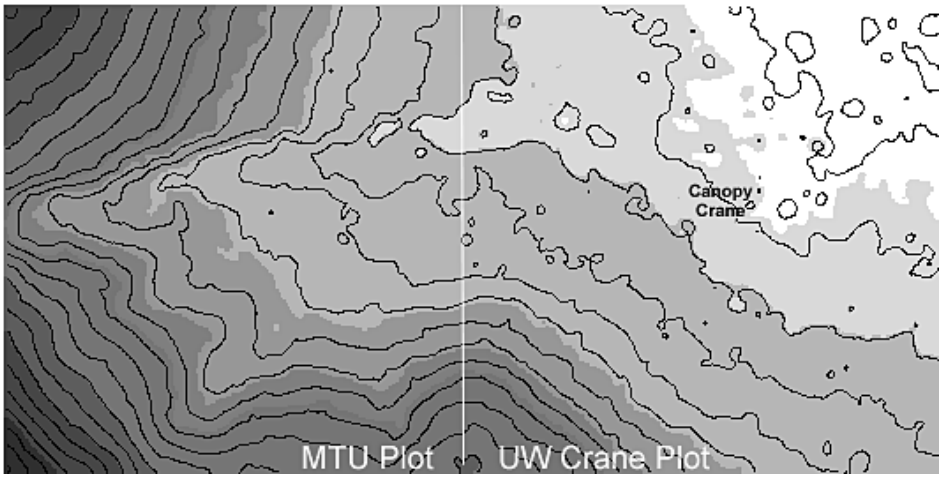
This field trip highlights processes that have complex consequences across a range of space and time scales: space (vertical foliage display, canopy gaps, stand-level disease patterns, landscape fragmentation) and time (diurnal changes in water potential, response to gaps, forest development). We will also examine various research approaches to understand these systems.

Canopy Crane and Munger RNA

The Thornton T. Munger Research Natural Area (RNA) is comprised of a 478 ha tract of old-growth Western Hemlock Zone forest in the Gifford Pinchot National forest in the southern Washington Cascade Range (Kemp and Schuller 1982). This site was established as an RNA in 1934, as an example of old-growth forests that once blanketed the valleys of the Cascade Range of western Washington. The RNA is located on gently undulating topography at the base and lower slopes of the Wind River valley and Trout Creek Hill, an extinct shield volcano (Franklin 1972). The climate of the RNA is is somewhat colder/wetter in winter (average annual snowfall of 233 cm) and warmer/dryer in summer than the Putget Lowland. Coarse-textured soils (inceptisols) have developed in 2-3 m of volcanic ejecta over the basalt bedrock (Franklin 1972). Stands are mostly 350 years or older, with a few small areas dating to the 1902 Yacolt Burn or to "accidental" logging in the 1910s and 1920sThe Wind River Canopy Crane Facility was established at the RNA in 1994 to encourage research on forest canopies in the tall conifer forests of the Pacific Northwest.

General Characteristic of Canopy Crane Site

Topography of Crane Site (1m contours)



Contour map 1 m resolution (200 m x 400 m; North is up)

TREE DISTRIBUTIONS IN THE CANOPY CRANE SITE

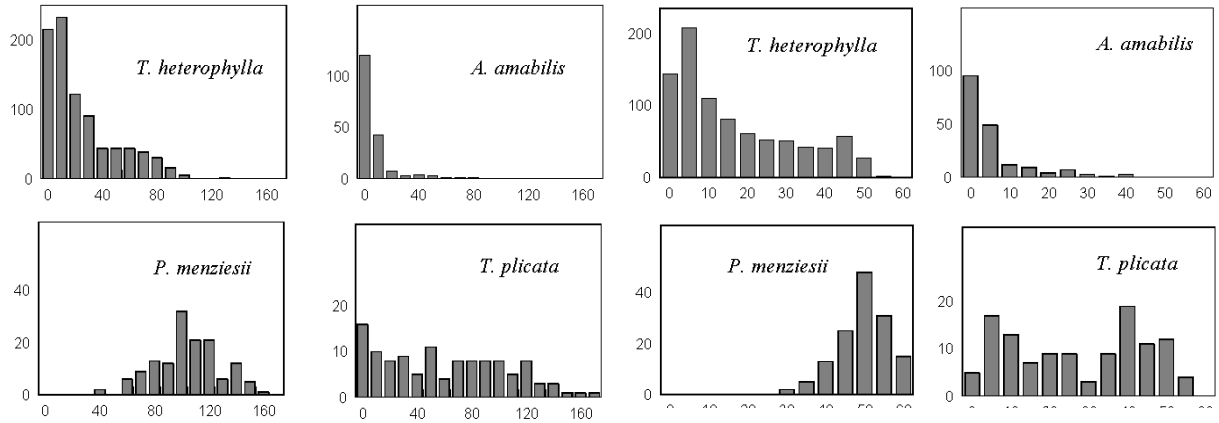
There are nine canopy tree species. The dominants are *Pseudotsuga menziesii*, *Tsuga heterophylla*, and *Thuja plicata*. A detailed stem map of a 4 ha square centered on the crane has been made of all living trees and standing snags over 5 cm DBH. Tree species, DBH and spatial location were recorded and used in the interpretation of stand dynamics. A modified Spearman rank correlation was applied to the stem map. The correlation between *Pseudotsuga menziessi* and the shade-intolerant species, *Abies amabilis* and *Taxus brevifolia*, shifted from positive at large scales to negative at smaller scales. The correlation between *Tsuga heterophylla* and these two shade-intolerant species was negative at several scales.

Abundance. Approximately 18% of all standing trees are dead (table1). The most common canopy trees on the site are western hemlock, Pacific yew, Douglas-fir, and western redcedar. While Pacific silver fir is present in large numbers, most have diameters less than 30 cm and thus contribute little to the upper canopy.

Table 1.

Species		Live	Dead	Total
Tsuga heterophylla	Western hemlock	918	56	974
Taxus brevifolia	Pacific yew	358	29	387
Pseudotsuga menziesii	Douglas-fir	152	207	359
Abies amabilis	Pacific silver fir	193	28	221
Thuja plicata	Western redcedar	121	12	133
Abies grandis	Grand fir	19	20	39
Pinus monticola	Western white pine	2	16	18
Cornus nuttallii	Pacific dogwood	14	1	15
Abies procera	Noble fir	1	0	1
Species	unknown	0	21	21
Total		1778	390	2168

Size Distribution. Shade-tolerant species such as Pacific silver fir and western hemlock are most abundant in the small size classes and form reverse J curves. Shade-intolerant species such as Douglas-fir (and western white pine) are found only in the large size classes and form bell-shaped curves. Western redcedar forms a nearly continuous distribution, suggesting that in this stand it functions at various tolerance levels. These diameter patterns are similar to patterns of tree height, with Douglas-fir dominatng the tallest size classes, western hemlock and Pacific silver fir abundant in low-to-mid levels in the canopy, and western redcedar evenly distributed throughout height categories.



Number of trees by diameter at breast height
(DBH in cm at 1.37 meters above forest floor)

SPATIAL PATTERNS OF TREES AT CRANE SITE:

Freeman and Ford 2002

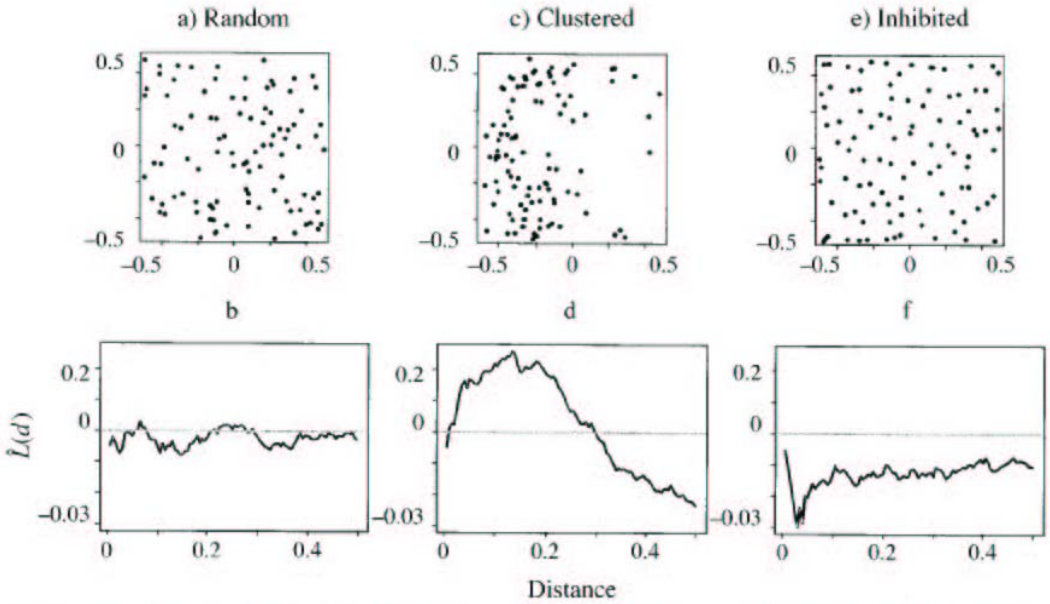
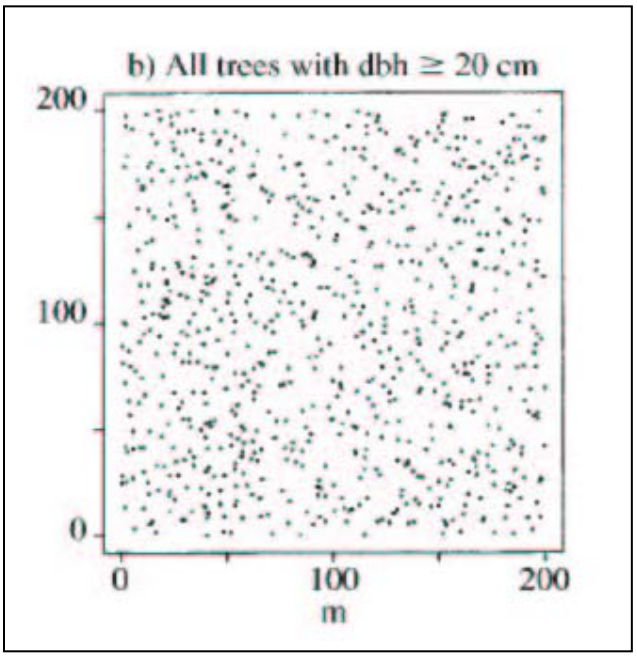
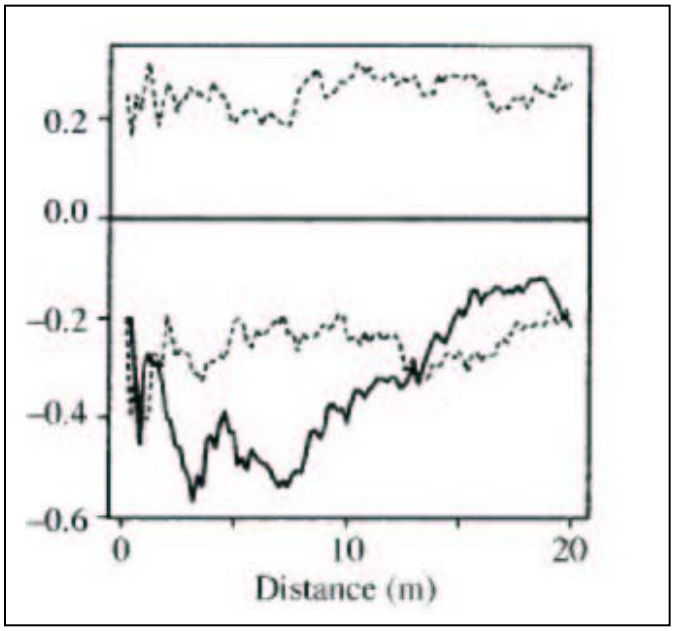


FIG. 1. Examples of simulated point patterns on the unit square and their corresponding calculated $\hat{L}(d)$ functions: (a, b) random, (c, d) clustered, and (e, f) inhibited.





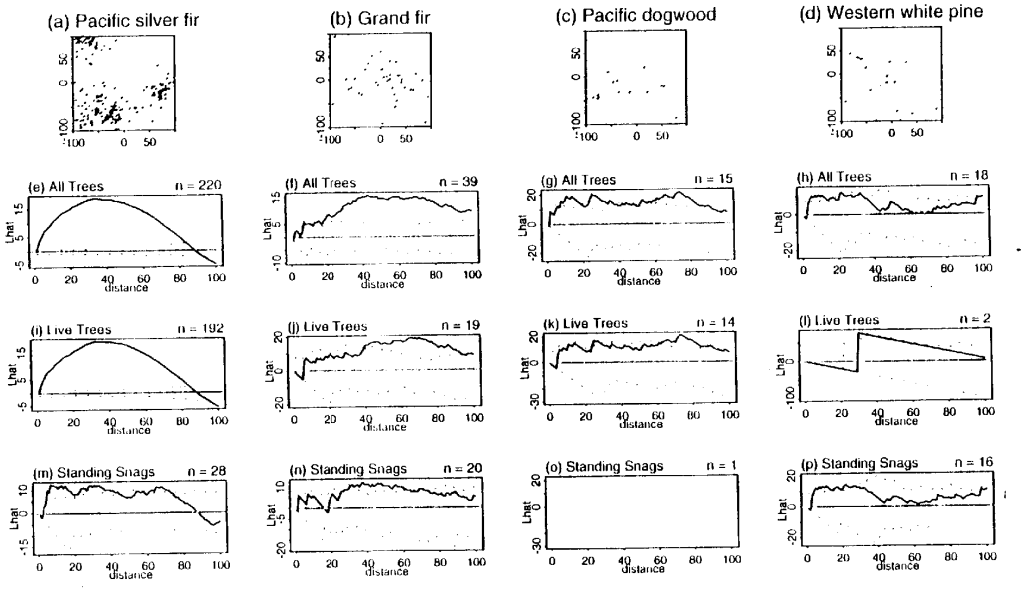


Figure 4.2 Stem maps and $\hat{L}(d)$ with Monte Carlo envelopes for subsets by species.

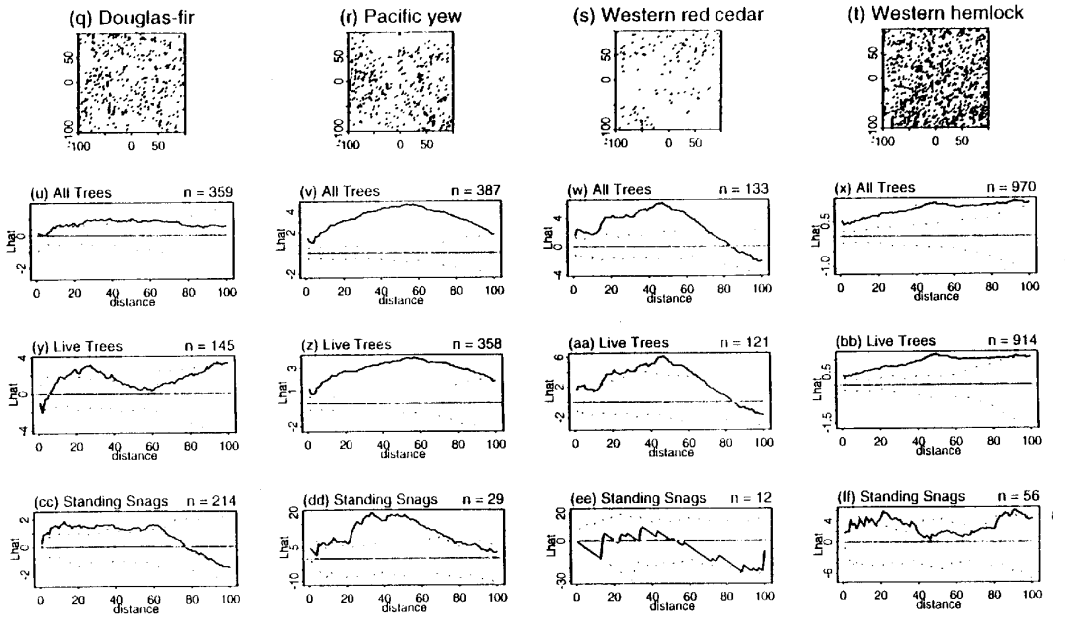
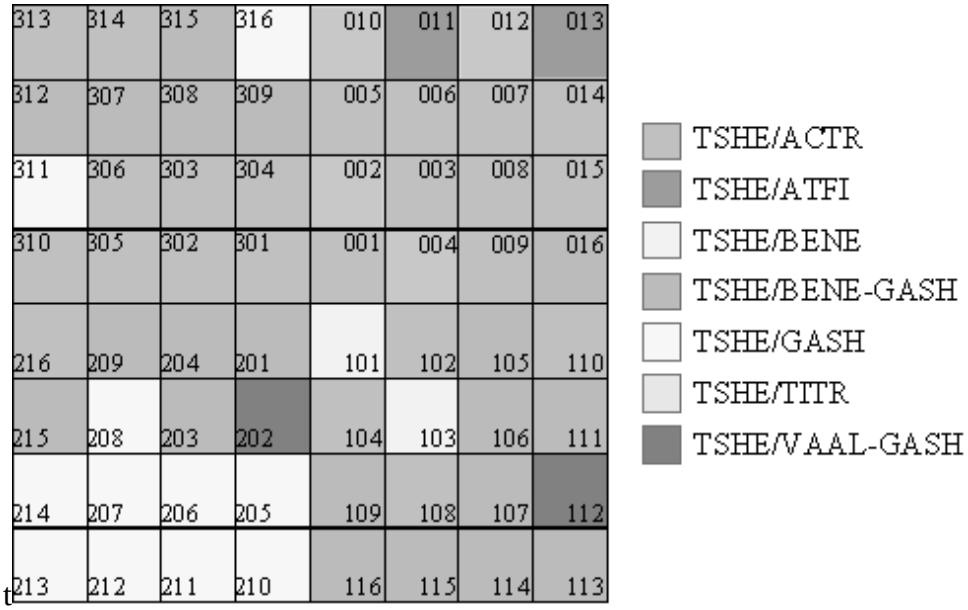
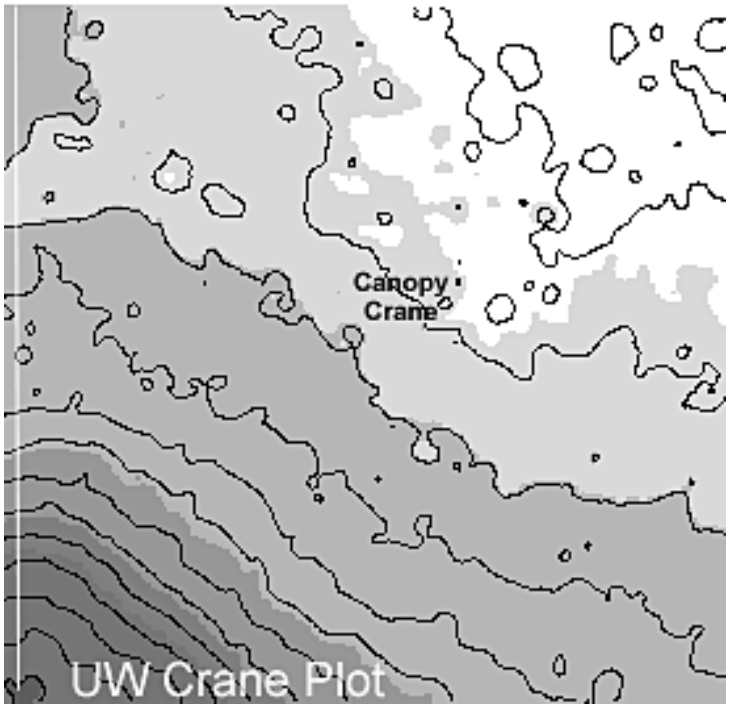


Figure 4.2 (continued)



Species

TSHE = *Tsuga heterophylla* (western hemlock)
ACTR = *Achlyls triphylla* (vanilla-leaf)
ATFI = *Athyrium filix-femina* (lady fern)
BENE = *Berberis nervosa* (Oregon grape)
GASH = *Gaultheria shallon* (salal)
TITR = *Tiarella trifoliata* (foam flower)
VAAL = *Vaccinium alaskaense* (Alaskan blueberry)

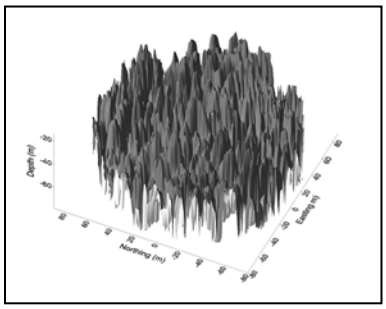


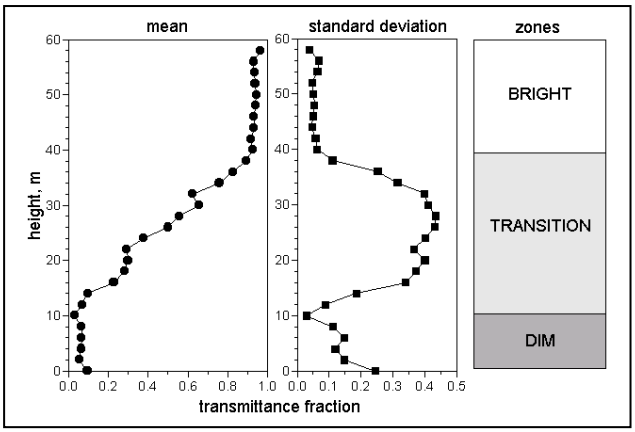
Contour map 1 m resolution (200 m x 400 m; North is

in 1992 established after 1540, originating in the understory where they grew slowly for years to decades before ascending to the canopy through multiple abrupt increases in growth.

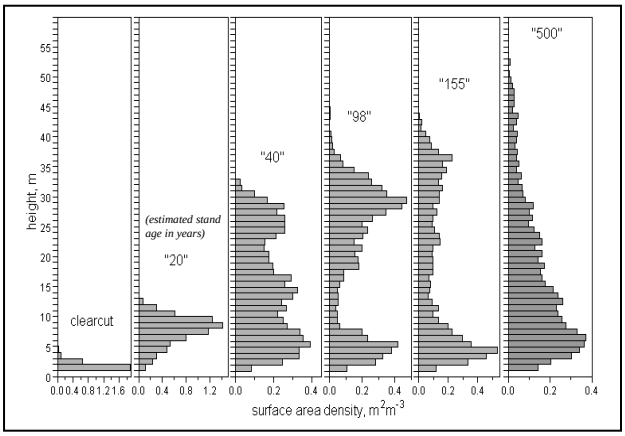
Canopy Structure and Function

The complex canopy structure of old-growth forests affects within-canopy light-transmittance profiles and patterns of illumination. Mariscal et al. (in press) estimated albedo at 7.54% for the WRCCRF forest plot, which is below the lowest published reflectance values for long-term continuous measurements over coniferous forests. The amount and vertical distribution of total radiation is closely related to canopy structure (e.g., tree height and crown depth). Albedo in older stands (>150 years) in the Wind River area was significantly lower than in younger stands. What is the fate of the energy implied by low albedo? What affect does this have on habitat quality, carbon flux, and aerosol exchange?





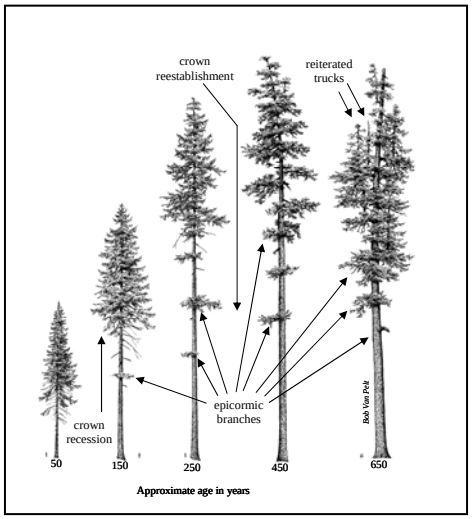
Parker (In press, 2004) defines two measures of whole-canopy scale complexity: Rugosity the standard deviation of local outer canopy height (vertical diversity) and Rumple Index the canopy surface area to ground surface area ratio (horizontal diversity). For the WRCCRF crane plot rugosity = 16.2 m, rumple index = 12.4, indicating that this old-growth Pacific Northwest Douglas-fir/western hemlock forest canopy is extremely complex and multi-layered. The high surface rugosity suggests that external environmental conditions (e.g., radiation, wind speed, relative humidity) might be decoupled from interior conditions. How forests function to alter microclimate is an active area of research.



Canopy complexity changes in a patterned way during stand development: the old-growth condition (500 yr) has a unique structure of "bottom loading" with respect to canopy surface density. This reflects the numerous shade-tolerant species that have repopulated the lower story and the relatively great

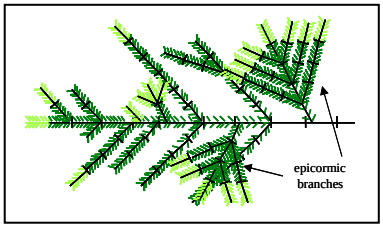
distances between taller Douglas-fir in the upper story. Douglas-fir is a shade-intolerant species and, with mortality spatial distribution, becomes more regular. Maximum surface density indicate areas of potential maximum carbon flux. Structural diversity (including dead material, broken stems or suppressed stems) should be considered in models of forest development and management options (Franklin et al. 2002).

Epicormic branch reiteration of Douglas-fir creates an important structural feature in the WRCCRF old-growth forest. Epicormic branches arise from dormant buds. Continuous production of these branches throughout the mid- and lower-crown and over all seasons suggests that external stimuli (e.g., damage) is not necessary to break bud dormancy. Trunk reiteration occurs mostly on primary and secondary branches.



Ishii (2001) estimated that approximately 10-50% of the total number of Douglas-fir branches in reach of the canopy crane are epicormic in origin producing branch clusters with as many as 10,000 foliated shoots. He suggests further that epicormic branching on mid- and lower-crown primary- and higher-order branches is a persistent process and that epicormic shoot production maintains foliage of old Douglas-fir after height growth and crown expansion have ceased and may contribute to prolonging tree longevity.

Epicormic branches occur toward the proximal end of primary branches and proliferate via daughter buds. Ishii (2002) estimated that a higher percentage of current-year foliage is produced on these epicormic branches. The reiteration of branches works to distribute foliage more uniformly within branches that have reached maximum size. Using growth-ring analysis Ishii estimated that epicormic branching occurs over a large range of branch ages (5-58 years).



<u>Reference</u>

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Franklin, J.F. and R. Van Pelt. 2004. Spatial aspects of structural complexity. *Journal of Forestry* 102: 22-27.
Parker, G. G. 1997. Canopy structure and light environment of an old-growth Douglas-fir/western hemlock forest. *Northwest Science* 71: 261-270.
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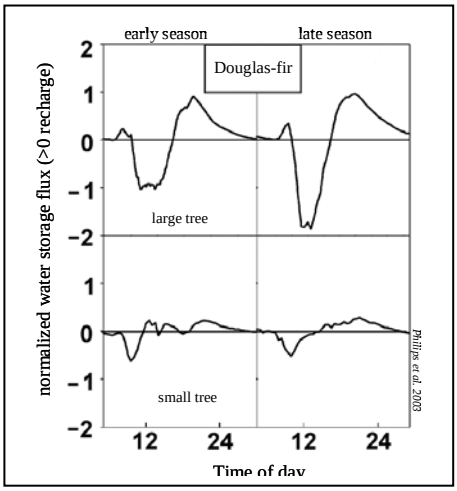
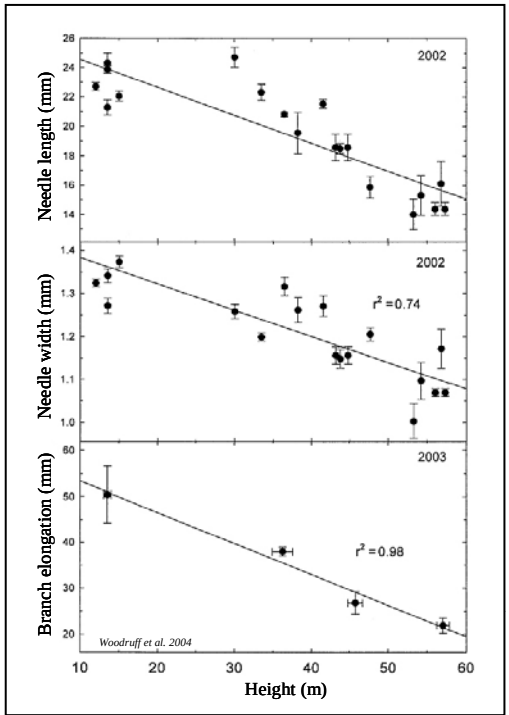
Canopy Crane: Tree Physiology

Is increased use of stored water in large Douglas-fir an adaptation to stave off drought or simply a consequence of growing large? Large Douglas-fir trees on the WRCCRF 4-ha plot use a significantly greater portion of internal water storage in total daily water use (mean 205 kg day^{-1}) than smaller trees (mean 14.3 kg day^{-1}) (Philips et al. 2003). Discharge and recharge of stored water on a diel scale constitutes a significant portion of total daily water uptake. In tall Douglas-fir, the proportion of daily water-use obtained from storage increased 20% in the early season to 25% in the later season. Smaller trees had a more uniform seasonal pattern of around 7.2%. Water storage is probably an adaptation to hydraulic constraints of tree size. Small Douglas-fir have significantly greater ratios of sapwood volume to bole volume than larger individuals. If water storage were simply a byproduct of structural differences between large and small one would expect small trees to have the greater storage capacity. In addition, larger trees have significantly greater ratios of sapwood area to crown leaf area. A reduced sapwood/leaf area ratio in larger trees has been cited as an adaptation to reduce leaf specific hydraulic resistance in tall trees (McDowell *et al.* 2002).

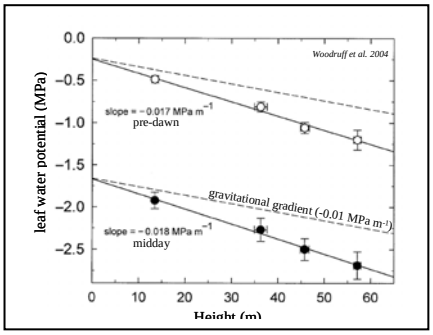


Predawn and midday leaf water potential decrease with increase in height (Woodruff et al. 2004). Vertical gradients of water potential and pressure-volume analyses of Douglas-fir twigs taken at the WRCCRF suggest that turgor decreases with increasing tree height. Vertical trends in leaf characteristics are consistent with the hypothesis that reduced turgor may limit leaf expansion at greater heights. Height-dependent variation in needle length, width, area and branch elongation is consistent with diminished capacity for cell expansion with increasing height



(Woodruff et al. 2004). Trends in leaf morphological and physical characteristics with canopy position have been well documented, but have been typically attributed to light environment (i.e., sun vs. shade leaves); however, recent measurements suggest that these trends are more closely linked to turgor and its variability with tree height.

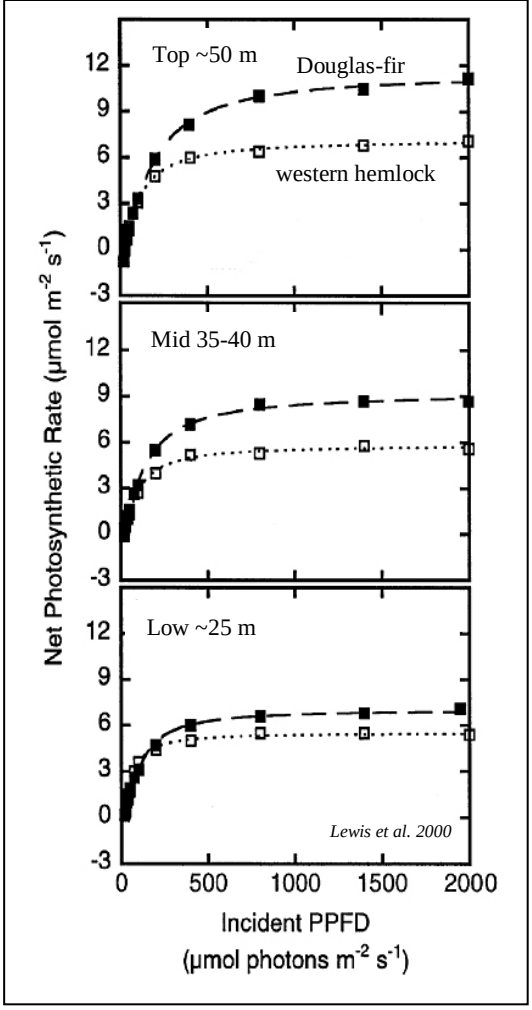
Photosynthesis changes over the seasons for the three dominant confer species on the WRCCRF 4-ha permanent plot. Under conditions of ambient light and CO_2, Douglas-fir typically has the highest absorption followed by western hemlock and western red-cedar. For all three species, *in situ* photosynthesis was higher in June and September in comparison to March and December



	Photosynthesis	
	High light	In situ
	μmol C m^{-2} s^{-1}	μmol C m^{-2} s^{-1}
Douglas-fir		
March	8.4 ± 1.9 (6)	3.5 ± 1.8 (6)
June	12.7 ± 0.7 (11)	9.0 ± 0.8 (11)
September	13.3 ± 1.0 (6)	13.3 ± 1.0 (6)
December	8.1 ± 1.1 (6)	2.8 ± 0.6 (6)
Western hemlock		
March	5.5 ± 0.5 (9)	4.9 ± 0.7 (9)
June	5.8 ± 0.9 (6)	4.7 ± 1.2 (6)
September	8.3 ± 0.6 (9)	8.3 ± 0.6 (9)
December	7.7 ± 0.6 (6)	2.4 ± 0.3 (6)
Western redcedar		
March	1.4 ± 0.3 (6)	1.0 ± 0.3 (6)
June	5.1 ± 0.5 (6)	5.1 ± 0.5 (6)
September	4.4 ± 0.4 (6)	4.3 ± 0.4 (6)
December	4.5 ± 0.8 (6)	1.9 ± 0.4 (6)

when ambient light levels typically limited photosynthesis. Douglas-fir increased absorption under artificial conditions of high light availability in all seasons (PAR = ~1000 μmols m^{-2} s^{-1}) except for September. Western hemlock and western red-cedar increase photosynthesis in response to increases in light, however light responses were marginal during the summer. All species exhibited at least a two-fold increase in absorption with saturating light availability in the winter months.

In the mid to upper canopy light-saturated photosynthesis rate in Douglas-fir is considerably higher than for western hemlock. Douglas-fir in the top canopy position are light saturated for about 55% of the light cycle on midsummer days where western hemlock needles are light saturated for about 70% of daylight hours. In low canopy positions Douglas-fir needles are light saturated about 40% of the time and western hemlock about 55%. Across all crown aspects light saturated photosynthesis rate declines 27% in Douglas-fir and 30% in western hemlock from top to lower canopy. Such changes are consistent with the expectation that the potential daily carbon uptake should be higher for needles in the upper canopy relative to needles in the lower canopy.



At the WRCCRF data are being collected on the affect of hydraulic redistribution (HR) on whole-plant water use. The predicted decline in soil water potential in the absence of HR is substantially more rapid than the observed decline with HR at potentials less than -0.2 (Meinzer et al. 2004). This suggests that HR may delay the onset of summer drought. Although change in soil water volume is quantitatively small (mean 0.15 mm day^{-1}) it may be sufficient to prevent damage to root function (e.g., cavitations) (Warren *unpublished data*).

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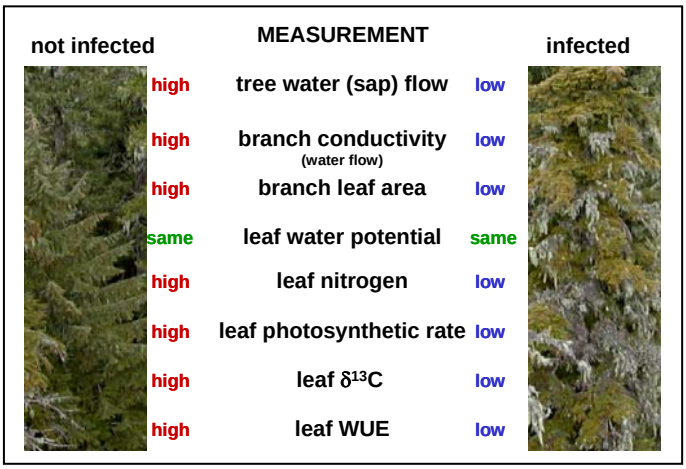
Winner, W. E., J. Berry, B. J. Bond, C. Cooper, T. Hinckley, J. Ehleringer, J. Fessenden, B. Lamb, S. McCarthy, N. McDowell, N. Phillips, S. C. Thomas, and M. Williams. *Accepted*. Canopy carbon gain and water use: Analysis of old growth conifers in the Pacific Northwest. *Ecosystems*.

Canopy Crane: Hemlock Dwarf Mistletoe

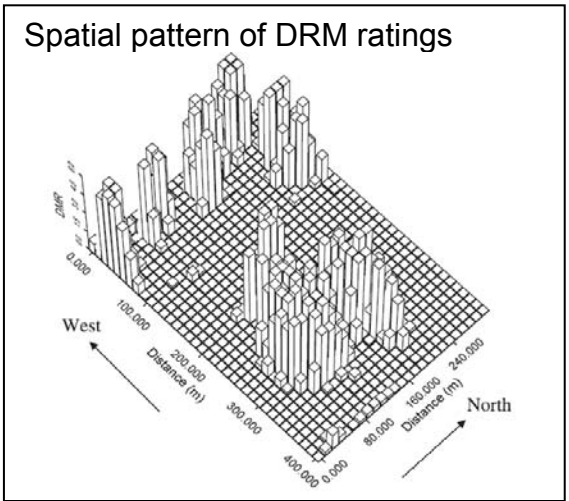
Western hemlock dwarf mistletoe (*Arceuthobium tsugense* spp*. tsugense,* Viscaceae) (ARTS) is a hemi-parasitic flowering plant that infects western hemlock trees, as well as Pacific silver fir, noble fir, and rarely grand fir. ARTS causes deformation and brooming of infected branches, which profoundly influences the structure of heavily infected trees. ARTS disperses by explosively discharged seeds, sending seed up to 15 m from the female plant. Forest composition and structure are controlling influences on the spread of ARTS. The sex ratio of this dioecious plant is 1:1 at Wind River (Mathiasen and Shaw 1998). 1,608 plants were sexed, with 805 males and 803 females. The aerial shoots of ARTS are small (4-12 cm) with reduced scale-like leaves, and do not appear to be important in carbohydrate production, the plants gets most carbohydrates, water and mineral nutrition from the host. Numerous small flowers (2-4 mm) are produced on aerial shoots.

Shaw and Weiss (2000) used hemispherical photography to estimate the light environments of living infections of ARTS in crowns of western hemlock trees. Photos were taken at 89 infections from 18 m to 60 m. 48 had aerial shoots while 41 had none. All infections above 50 m had aerial shoots while all infections (except one) below 30 m did not. Alternatively all infections with yearly estimated insolation less than 1,000 MJ m-2 yr-1 did not have aerial shoots while all infections above 3,200 MJ m-2 yr-1 did. Height and light are highly correlated in this closed canopy stand. The figure above, left indicates the mean height and annual insolation for no shoot vs. shoots. Plants higher in the canopy can be expected to produce more seed.

Meinzer et al. (2004) investigated the responses of hydraulic architecture, water and carbon relations of western hemlock to ARTS infection. Specific hydraulic conductivity (*k*s) of infected branches was approximately half that of uninfected branches, yet leaf-specific conductivity (*k*L) was similar because leaf area:sapwood area ratios (*A*L:*A*S) of infected branches were lower. Predawn and minimum leaf water potential and stomatal conductance (*g*s) were similar among infected and uninfected trees because adjustments in hydraulic architecture of infected trees maintained *k*L despite reduced *k*s. Maximum whole-tree water use was substantially lower in infected trees (~55 kg/day) than in uninfected trees (~90 kg/day) because reduced numbers of live branches in infected trees reduced whole-tree *AL*:*AS* in a manner consistent with that observed in infected branches. Maximum photosynthetic rates of heavily infected trees were approximately half those of uninfected trees. Correspondingly, leaf nitrogen content was 35% lower in infected trees. Foliar δ13C values were 2.8‰ more negative (i.e. A/E lower) in infected than in uninfected individuals, consistent with the absence of stomatal adjustment to diminished photosynthetic capacity (with lower rates of photosynthesis, discrimination against 13C was greater). Adjustments in hydraulic architecture of infected trees thus contributed to homeostasis of water transport efficiency and transpiration on a leaf area basis, whereas both carbon accumulation and photosynthetic water-use efficiency were sharply reduced at both the leaf and whole-tree scale.

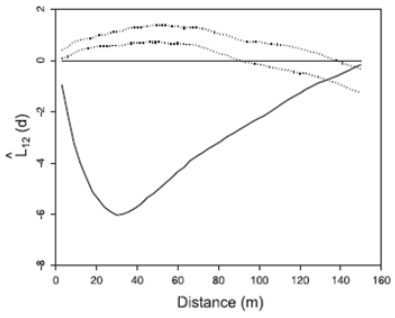


All western hemlock and true fir trees in the T.T. Munger RNA were investigated for ARTS infection using the 6-class dwarf mistletoe rating system (DMR). In this system, a tree crown is divided into thirds and each third is assigned a number. 0 if there are



no infections, 1 if < half the branches are infected, and 2 if > half the branches are infected. All thirds are summed for a total infection rating where DMR 0 is an un-infected tree and DMR 6 is a heavily infected tree. Along the series of 9 mortality strips, which include 103, one acre plots (figure at left, each rectangle = 1 acre). The average DMR for all trees within each acre plot was determined and shown in the figure. Spatial analysis indicates a patchy distribution.

Within the 12 ha canopy crane plot, 33 % of the area had some level of infection and 25% (719)of the western hemlocks, 2.2% (12) of the Pacific silver fir, and 29% (2) of the noble fir trees were infected. Infected trees are larger than uninfected trees, on average, and within the infected tree population, the severely infected trees averaged larger than lightly infected trees. This skewed distribution of larger trees positions the dwarf mistletoe population for future spread because large trees are better dispersers of seed, and hemlock is increasing in abundance. The infected trees form distinct mistletoe infection centers, with high (5,6) DMR's in the center and low DMR's in the margins. Bivariate Ripley's K analysis indicates a negative association between infected and uninfected hemlock trees, while nearest neighbor analysis indicated a distinct positive association between DMR 1 and uninfected trees, and a negative association between DMR 6 and uninfected trees. Infection centers appear to be actively spreading.



Bivariate Ripley's K analysis

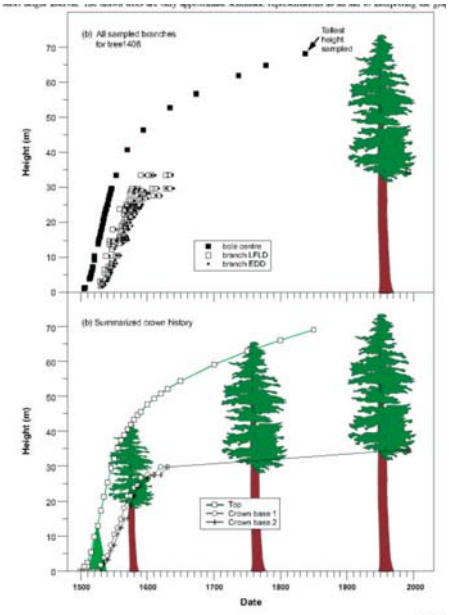
References:
Mathiasen, R. L., and D. C. Shaw. 1998. Adult sex ratio of western hemlock dwarf mistletoe in six heavily infected western hemlock. *Madrono* 45: 210-214.
Meinzer, F.C., D.R. Woodruff, and D.C. Shaw. 2004. Integrated responses of hydraulic architecture, water and carbon relations of western hemlock to dwarf mistletoe infection. Plant, Cell and Environment 27: 937-946.
Shaw, D. C., and S. B. Weiss. 2000. Canopy light and the distribution of hemlock dwarf mistletoe (*Arceuthobium tsugense* (Rosendahl) G.N. Jones ssp. tsugense) aerial shoots in an old-growth Douglas-fir/western hemlock forest. *Northwest Science* 74: 306-315.
Shaw D. C., Chen J., Freeman E. A., and Braun D. M. 2005 Spatial and population characteristics of dwarf mistletoe infected trees in an old-growth Douglas-fir – western hemlock forest. Can. J. For. Res. **35**: 990–1001

FIVE CENTRUIES OF STRUCTURAL DEVELOPMENT IN AN OLD-GROWTH DOUGLAS-FIR STAND IN THE PACIFIC NORTHWEST: A RECONSTRUCTION FROM TREE-RING RECORDS

Linda E. Winter

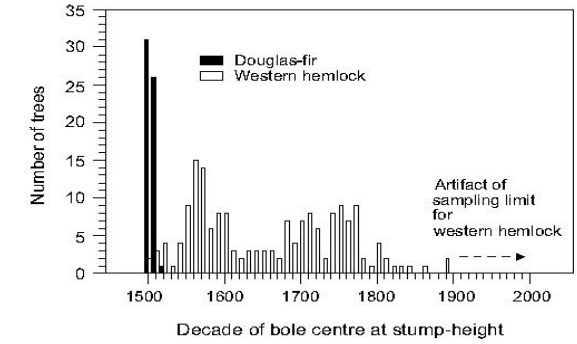
Tree-ring records were used to reconstruct the history of an old-growth Douglas-fir stand in the western Cascade Range of southern Washington. Prior to harvest, a 3.3 ha plot was inventoried and mapped. After felling, samples were collected from stumps of all mapped trees, and from multiple heights of a subset of these trees. One tree was intensively dissected to locate and extract embedded branches. Data taken from crossdated samples were used to reconstruct a history that focused on stand initiation and canopy disturbances, but also included diameter, height and crown development.

embedded branches



Height vs Date relationships for living and dead branches and tree top

All Douglas-fir were initial colonizers, establishing 1500-1521 under open conditions following a stand-replacing fire. A minor component of western hemlock were also initial colonizers. Growing space filled as tree crowns widened, and by 1540 closed canopy conditions had developed. At this time, Douglas-fir were spaced about 3.5 m from equivalent competitors. In the following centuries, considerable thinning of the initial colonizers occurred. Although the canopy never opened enough to allow further Douglas-fir establishment, at least three disturbances thinned the canopy, affecting areas of 0.2 to 0.8 ha. Surviving Douglas-fir increased in stature and developed long crowns despite the narrow initial spacing, and without epicormic branching.



age structure

Effects of Gap Size, Within-Gap Position, and Substrate

A. Gray, R. Van Pelt, T. Spies, J. Franklin

Gap size and position

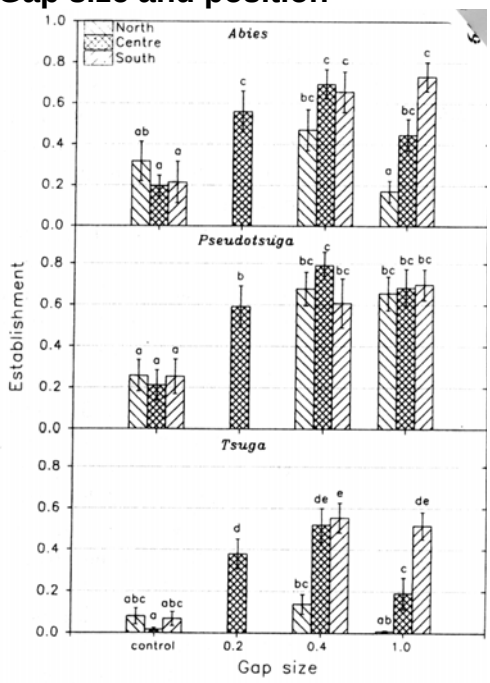
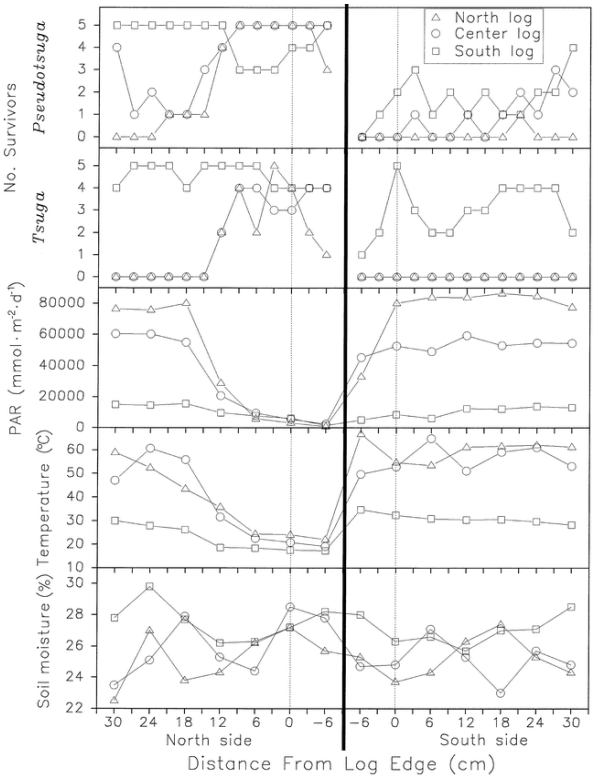


Fig. 1 Seedling establishment (fraction of maximum emerged) by gap size, within-gap position and species after two growing seasons in the seed-sowing experiment, showing means and standard errors ($n = 8$). Different letters indicate significantly different within-species means ($P < 0.05$).

Microclimate near logs



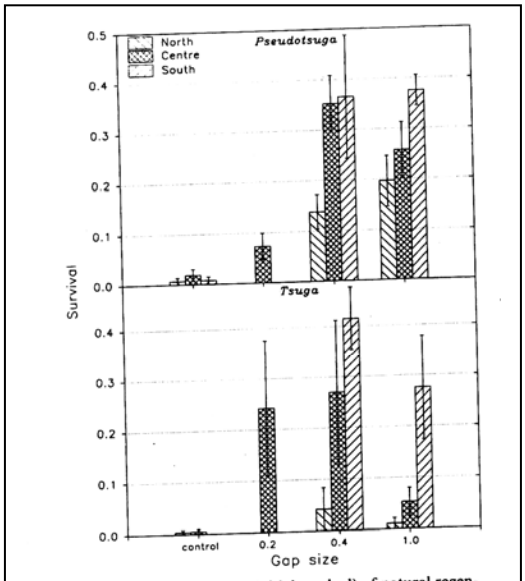


Fig. 3 Survival (fraction of initial marked) of natural regeneration after two growing seasons by gap size and within-gap position, showing means and standard errors ($n = 4$ for *Pseudotsuga*, $n = 2$ for *Tsuga*).

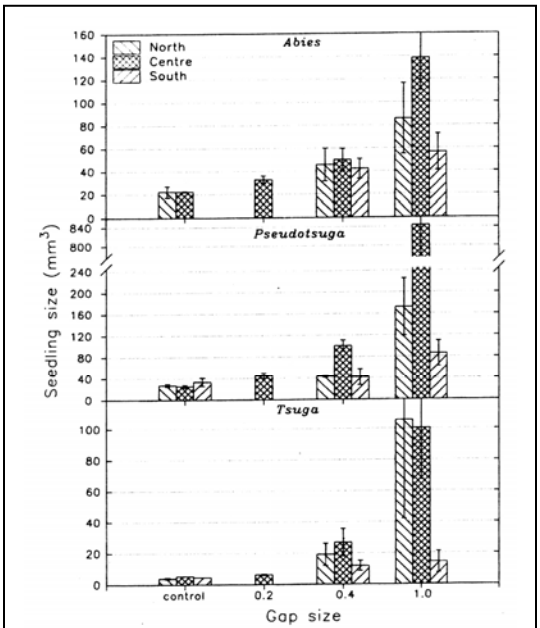


Fig. 2 Seedling size (basal area × height) after two growing seasons in seed-sowing experiment by gap size, within-gap position and species, showing means and standard errors ($n \leq 4$).

Response of Pacific silver fir (advanced regeneration) to gap formation

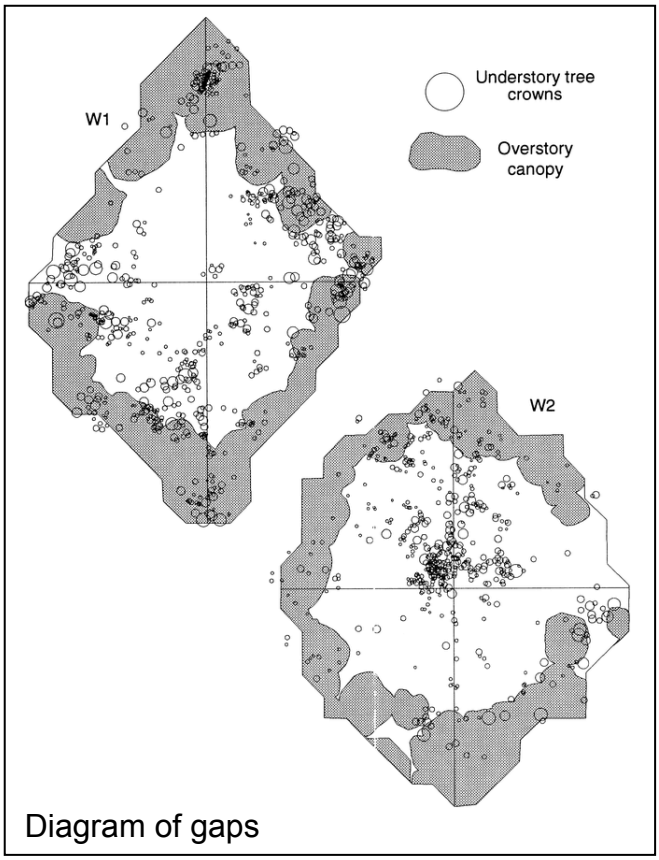
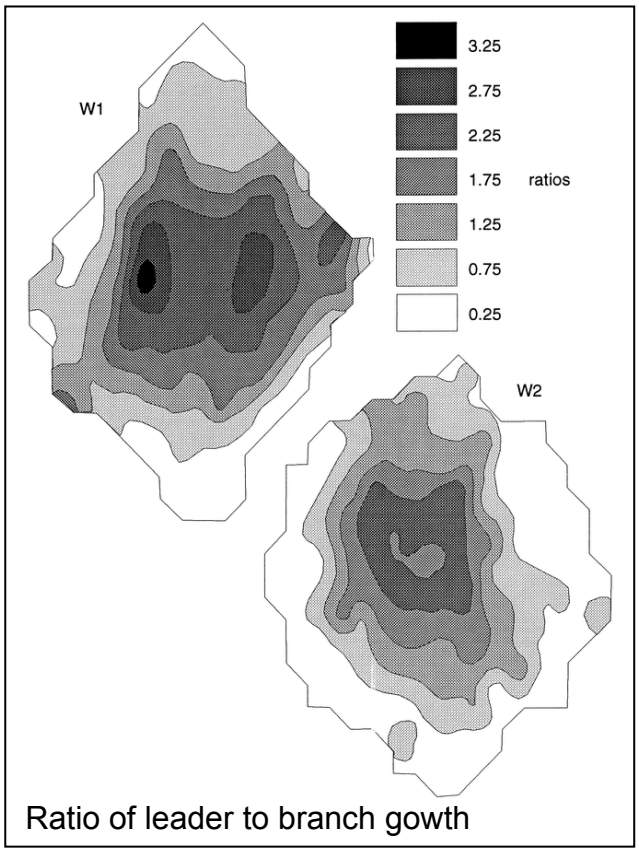


Diagram of gaps

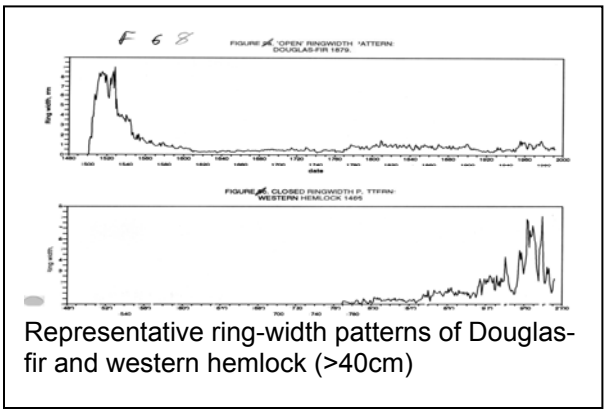


Ratio of leader to branch gowth

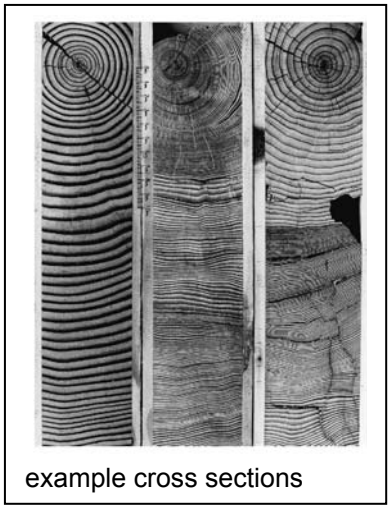
Canopy disturbances over the five-century lifetime of an old-growth Douglas-fir stand in the Pacific Northwest

Linda E. Winter, L. B. Brubaker, J. F. Franklin, E. A. Miller, and D. Q. DeWitt

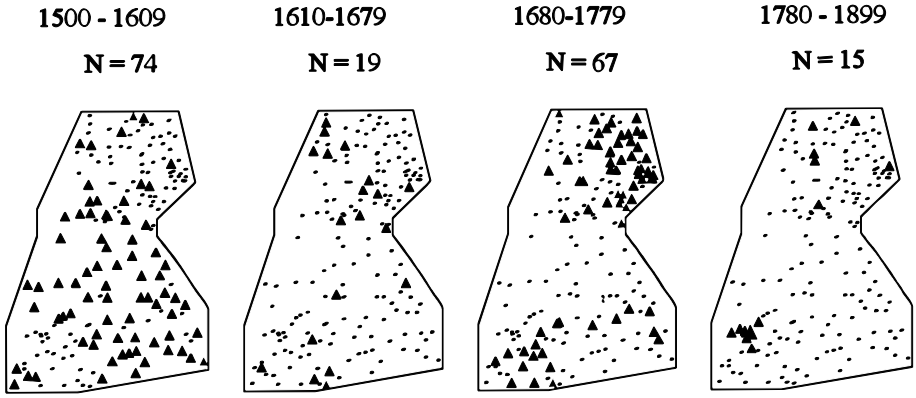
The history of canopy disturbances over the lifetime of an old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stand in the western Cascade Range of southern Washington was reconstructed using tree-ring records of cross-dated samples from a 3.3-ha mapped plot. The reconstruction detected pulses in which many western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) synchronously experienced abrupt and sustained increases in ringwidth, i.e., "growthincreases", and focused on medium-sized or larger (≥0.8 ha) events. The results show that the stand experienced at least three canopy disturbances that each thinned, but did not clear, the canopy over areas ≥0.8 ha, occurring approximately in the late 1500s, the 1760s, and the 1930s. None of these promoted regeneration of the shade-intolerant Douglas-fir, all of which established 1500–1521. The disturbances may have promoted regeneration of western hemlock, but their strongest effect on tree dynamics was to elicit western hemlock growth-increases. Canopy disturbances are known to create patchiness, or horizontal heterogeneity, an important characteristic of old-growth forests. This reconstructed history provides one model for restoration strategies to create horizontal heterogeneity



Representative ring-width patterns of Douglas-fir and western hemlock (>40cm)



example cross sections



Establishment of western hemlock

Robert Van Pelt and Nalini M. Nadkarni *2004* Development of Canopy Structure in *Pseudotsuga menziesii* Forests in the Southern Washington Cascades *Forest Science 50(3):324-341.*

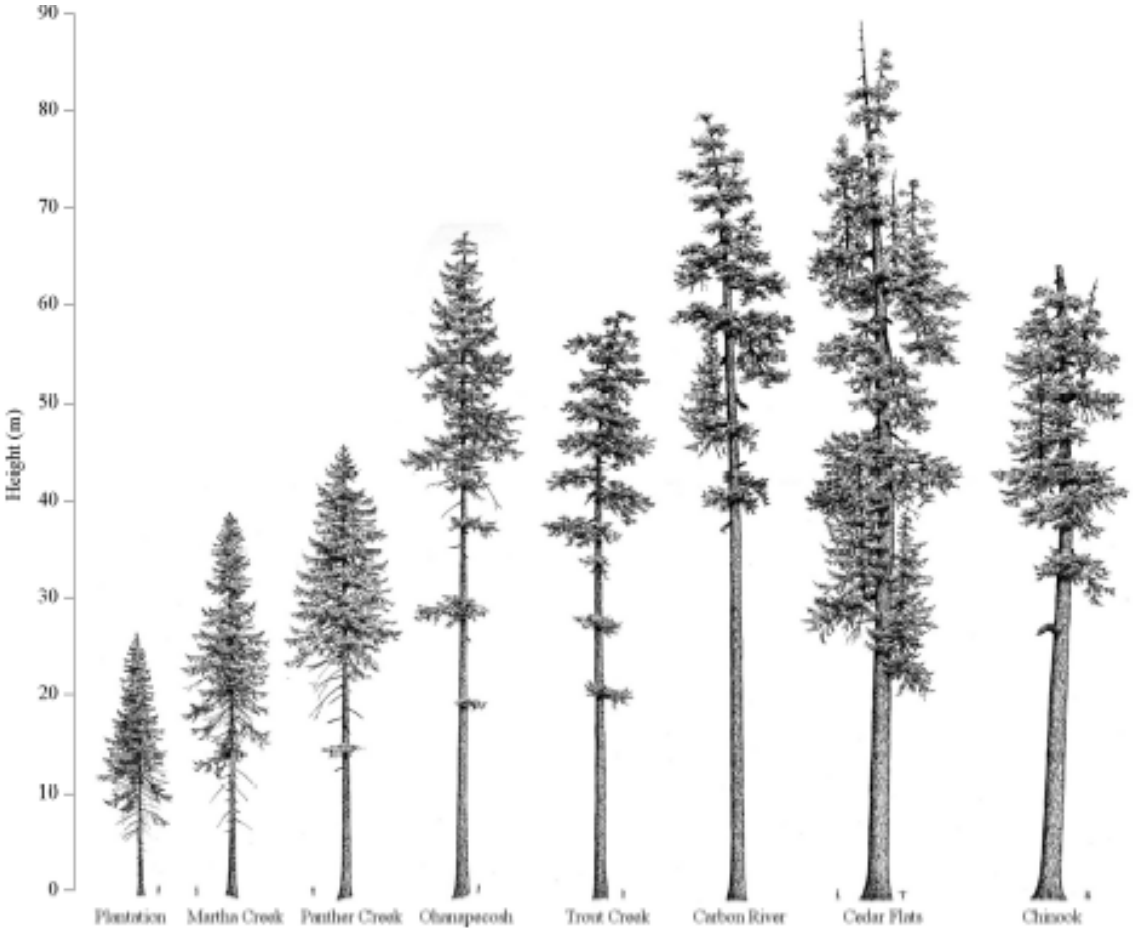


Figure 2. Detailed drawings to scale of a dominant tree from each of the eight sites. This will at least give a visual comparison of the size and structural changes discussed in the text.

Table 1. Summary of site characteristics. The Carbon River stand is on an alluvial flat, and the Cedar Flats stand is on swampy ground, thus reducing a need for summer precipitation at both sites. Precipitation data does not include condensation from fog, which can add 10–20% to all of these sites.

Site	Elevation (m)	Age	Slope (% aspect)	Plant association*	Precipitation (cm) Ann.	July–Sep.	Snowfall	Temp (°C) (annual Ave.)
PL Plantation	624	50	0–15% SE	*TSHE/RHNE*	253	12	233	0–17.5 (8.0)
MC Martha Creek	582	100	5–30% S	*TSHE/RHNE/GASH*	253	12	233	0.6–17.8 (8.5)
PC Panther Creek	732	157	0–15% W	*TSHE/RHNE/GASH*	264	13	254	0–17.5 (7.8)
OH Ohanapecosh	622	~280	0–10% SW	*TSHE/ACTR*	197	14	385	2.2–14.2 (7.9)
TC Trout Creek	613	~500	0–10% S	*TSHE/VAAL/CASH*	253	12	233	0–17.5 (8.0)
CR Carbon River	607	~500	0%	*TSHE/POMU/OXOR*	346	18	137	3.1–11.8 (7.5)
CF Cedar Flats	411	~650	0%	*TSHE/TITR*	317	20	77	5.0–14.4 (9.7)
CH Chinook	841	~950	0%	*ABAM/VAAL*	210	17	462	–0.6 –13.8 (6.6)

* Based on Topik et al. 1986 and Franklin et al. 1988. *TSHE*, *Tsuga heterophylla*; *RHNE*, Barbaris nervosa; *GASH*, Gaultheria shallon; *ACTR*, *Actlys triphylla*; *VAAL*, Vaccinium alaskaense; *POMU*, Polystichum munitum; *OXOR*, *Oxalis oregana*; *TITR*, Tiarella trifoliata.

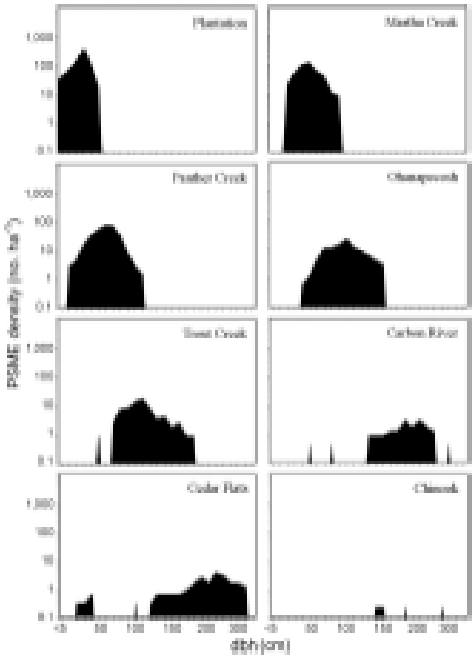


Figure 4. Diameter distribution for *PSME* among the eight sites. Note the vertical scale is logarithmic and the horizontal scale is not linear.

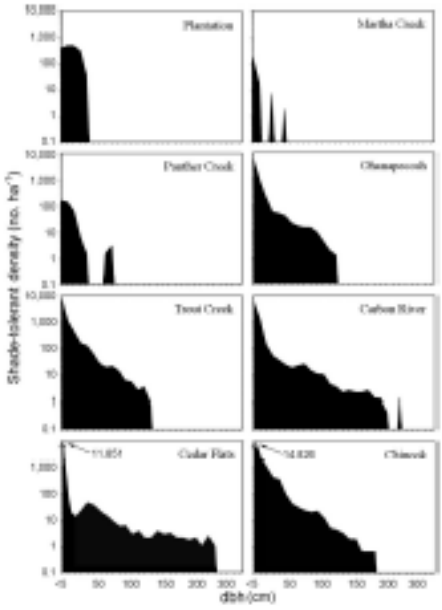


Figure 5. Diameter distribution for the shade-tolerant trees among the eight sites. The plantation has an unusually high number of shade-tolerant trees due to its proximity to an old-growth forest and thus an abundant seed source.

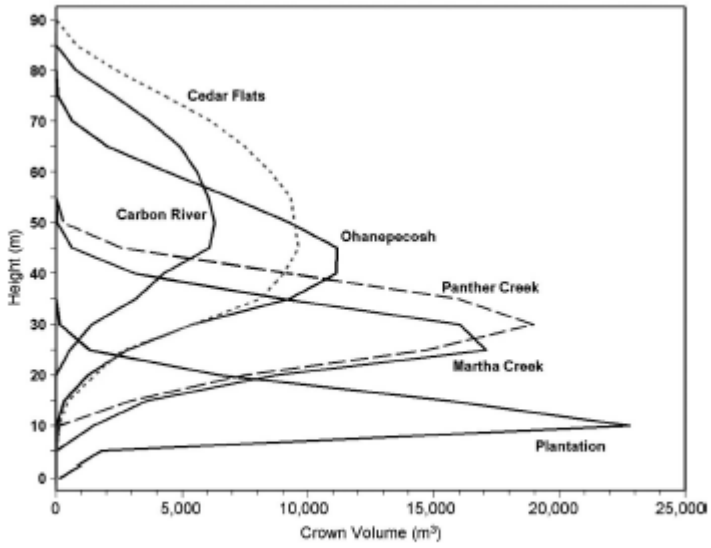


Figure 7. Canopy volume for *PSME* alone, extracted from Figure 6 for six of the sites. Note

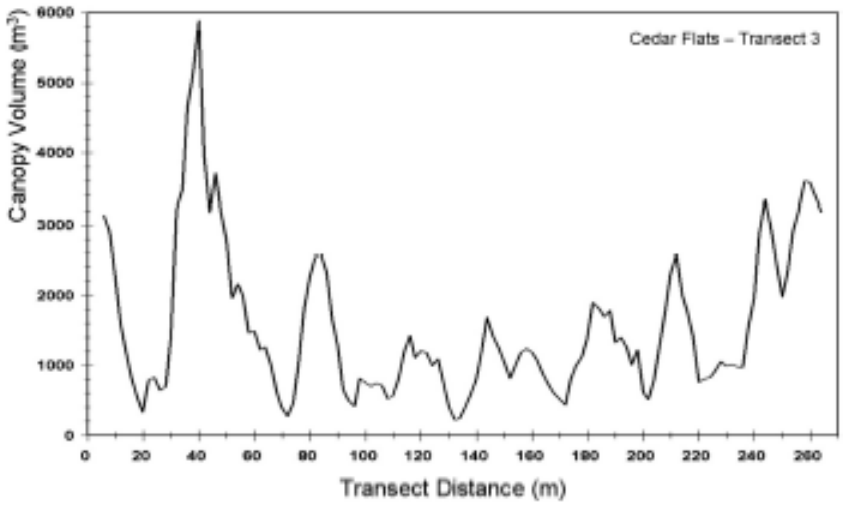


Figure 8. An example of the canopy density series curves used in the semivariance analysis. Only two of the transect curves are shown.