Proceedings from the Wood Compatibility Initiative Workshop, number 17.

FACTORS INFLUENCING GROWTH AND FLOWERING OF UNDERSTORY PLANTS IN CONIFER STANDS IN WESTERN WASHINGTON

Constance A. Harrington[1], Karl R. Buermeyer[2], Leslie Chandler Brodie[3], and Bryan W. Wender[4]

ABSTRACT

Managing forest stands to produce wood while also producing other values, such as wildlife habitat, recreation, or special forest products, requires information on forest components not always measured in traditional silviculture studies. For example, some managers may want to predict potential growth rates of herbs, shrubs, and trees in the understory—as these components will determine future forest composition and structure—or may be interested in flowering of plants in forest understories, since berry and seed production are important factors in determining species habitat suitability. We conducted several studies in conifer stands in western Washington to determine the effects of stand and site conditions on (1) response of understory vegetation to changes in overstory density, (2) flowering of selected shrub species, and (3) tree growth in forest understories. Responses of most factors were quite variable and indicate that managers may have to accept a lower level of certainty or invest more in research and monitoring when managing for components of forest stands other than overstory trees. The general results and management implications from the three studies are discussed and a reading list presented.

KEY WORDS: Plant ecology, silviculture, flowering, shrubs, understory, tree growth.

INTRODUCTION

For many forest lands in the Pacific Northwest, fiber production was the dominant objective for much of the 20th century. During the past 50 years, many stands were clearcut, planted with Douglas-fir, and managed as single-species, even-aged stands; research information produced during that time was geared to provide information pertinent to that type of management. In the late 1980's, however, management objectives for some lands broadened or changed to (1) produce or protect habitat for wildlife species with declining populations, (2) accelerate development of stand structures and plant and animal communities associated with late-successional forests, (3) produce special forest products, (4) meet aesthetic concerns, or (5) produce wood in ways compatible with achieving several other management objectives. The changes in management emphasis meant that more information was needed on stand components other than overstory trees. This report summarizes study results regarding three components relevant to the new information needs: development of understory vegetation after thinning, flowering of shrubs in forest understories, and height growth of understory trees.

DEVELOPMENT OF UNDERSTORY VEGETATION AFTER THINNING

The amount and type of plants found in forest understories will vary with plant association, site conditions, current overstory conditions, and past history of stand (e.g., burning, thinning, ground disturbance). Thinning, whether uniformly applied or with a variable density prescription, alters overstory density and light quality (if species composition was changed as a result of the thinning) and disturbs the soil and existing plant cover (creating a good seedbed for some species but damaging some existing plants). Because past management has focused primarily on tree growth in the main canopy, we do not have much information on understory response. Some researchers evaluated the effects of thinning on regeneration or understory vegetation but only limited information is available and the results

[1] Research Forester, [2,3,4] Foresters, Forestry Sciences Laboratory, 3625 93rd Avenue SW, Olympia, WA 98512-9193. Contact C. Harrington at charrington @fs.fed.us for more information on the projects described in this paper.

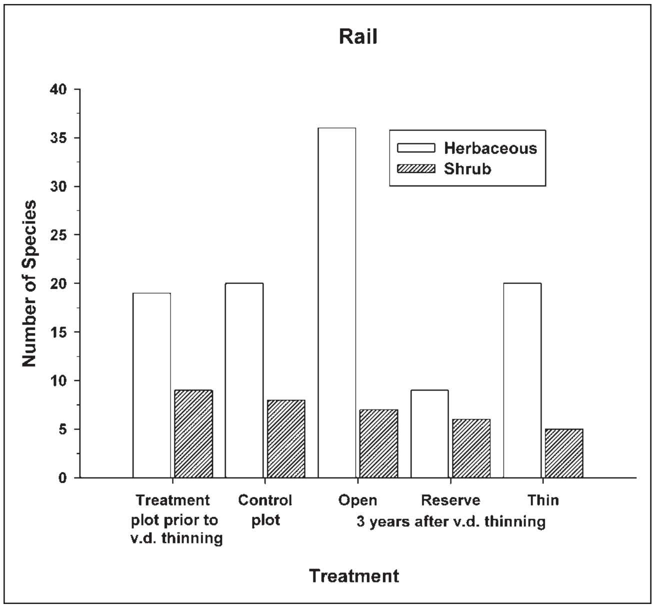

Figure 1—Number of herbaceous and shrub species at the Rail study area of the Olympic Habitat Development Study in an untreated control plot and in a thinned plot, before and 3 years after, implementation of a variable-density thinning. The "open," "reserve," and "thin" designations represent the three components of the variable-density thinning treatment.

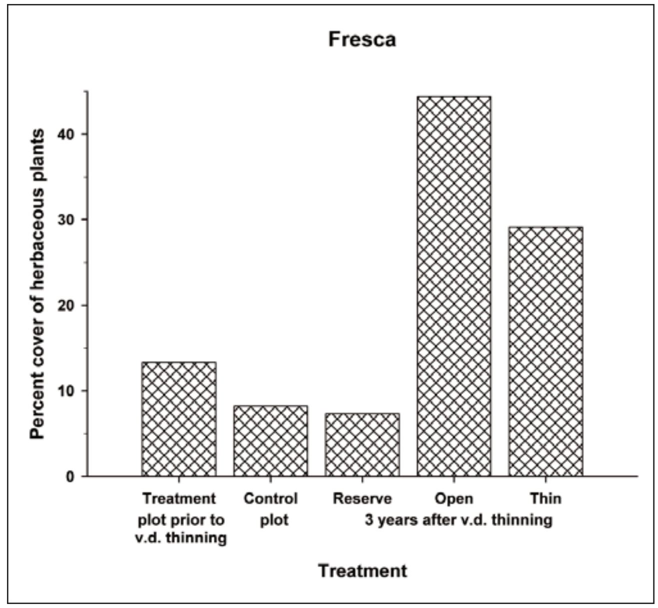

Figure 2—Percent cover of herbaceous plants at the Fresca study area of the Olympic Habitat Development Study in an untreated control plot and in a thinned plot, before and 3 years after, implementation of a variable-density thinning. The "open," "reserve," and "thin" designations represent the components of the variable-density thinning treatment.

were mixed (Kruger 1960; Worthington and Heebner 1964). Information available on understory response to thinning will greatly increase in the near future, however, since many recent Northwest studies have included an understory component in their measurements (c.f., Halpern et. al 1999; Halpern and Spies 1995; Thysell and Carey 2000).

We collected information on understory vegetation prior to and 3 years following implementation of a variable density thinning at two blocks in the Olympic Habitat Development Study. Both blocks were near Forks, WA (Clallam County). The variable density prescription included retaining uncut patches and creating gaps or openings as well as thinning within the general stand matrix. The uncut patches were also "no-entry" zones for equipment. One block, Fresca, had a dense stand of western hemlock and Sitka spruce, had not been thinned prior to implementation of variable density thinning, and had very low cover of understory species. The second block, Rail, primarily had Douglas-fir in the overstory; in some portions of the stand there were substantial numbers of understory western hemlock. The Rail stand had been thinned in the early 1980s. Prior to the implementation of the variable density thinning in 1997 at Rail, there was a fair amount of understory cover that was dominated by salal.

Three years following variable density thinning, the results from these two blocks were:

1. Number of herbaceous species was least in the unthinned areas (control plots and uncut or reserve portions of thinned plots), greatest in the openings or gaps, and intermediate in the thinned areas (Figure 1).

2. Number of shrub species did not differ among the unthinned areas, the gaps, or the thinned matrix (Figure 1).

3. The greatest numbers of tree seedlings in both blocks were western hemlock. Bigleaf maple seedlings were only found in open areas.

4. Percent cover of herbaceous plants was greatest in the openings (Figure 2).

5. Percent cover of shrubs at the Fresca block prior to variable density thinning was low (< 2%); shrub cover post-thinning remained low but exhibited the expected pattern of % cover in the open > % cover in the thinned areas > % cover in the uncut areas.

6. Percent cover of shrubs at the Rail block prior to treatment was patchy but overall was much higher than at the Fresca block; shrub cover 3 years after treatment at Rail

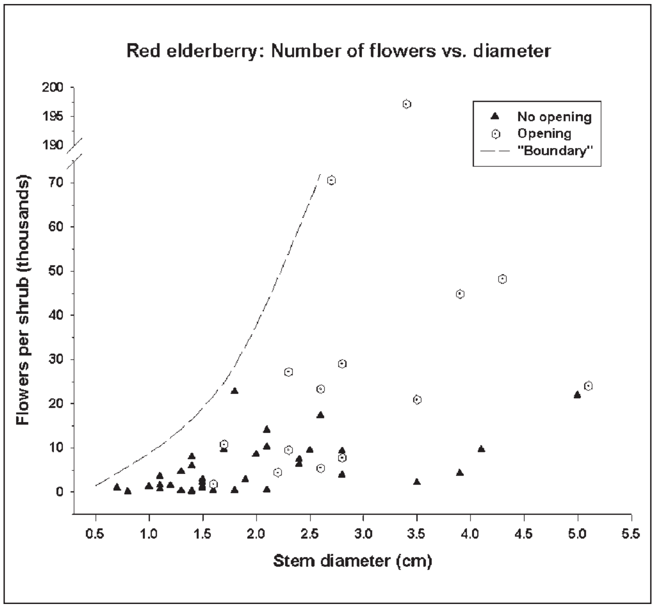

Figure 3—Relationship between number of red elderberry flowers per plant and stem diameter. The dashed line represents the upper boundary of the data. Note the tendency for plants in canopy openings to be larger in diameter than those not in openings and, for the same stem diameter, for plants in openings to have more flowers than those under intact forest canopies.

was more related to pretreatment conditions than to whether it was in an open, thined, or uncut area.

7. The presence of salal at Rail prior to treatment may have reduced the opportunity for germination and development of other species.

FLOWERING OF SHRUBS IN FOREST UNDERSTORIES

Some resource managers are interested in increasing flowering and fruit production of some understory shrub species to produce fleshy berries as food for wildlife species or for human consumption. Most managers are more interested in fruit production than flowering; however, flowering is a prerequisite to fruiting. In addition, fruit production is influenced by many factors not under management control such as spring frosts or summer drought. Thus, if we want to understand the importance of stand and site conditions on fruiting, we are most likely to be successful if we study flowering first.

Most species vary from year to year in flower production, so it would take several years of observation to accurately estimate or predict mean flowering per plant. The information in this report is preliminary as it is based on only one year.

We studied the relationships between flowering and attributes of plant size, age, overstory characteristics, light, and site conditions in eight shrubs common in understories of conifer stands in western Washington (Clallam, Grays Harbor, Mason, Pierce, and Thurston Counties). At least 50 observations were made for each species. The shrubs were salal, Oregon grape, vine maple, hazelnut, evergreen huckleberry, red elderberry, red huckleberry, and Indian plum. A sampling frame was used to select salal and Oregon grape "plants" because these species have rhizomes (underground stems) and it is difficult to determine individual plants.

Results from the flowering study indicated:

1. These species are adapted to growing in forest understories and the majority of plants flowered regardless of the light conditions.

   a. About 65% of plants flowered for Oregon grape, vine maple, and evergreen huckleberry,
   b. 85-90% of plants flowered for Indian plum and hazelnut, and
   c. 96-98% of plants flowered for salal, red huckleberry, and red elderberry.

2. Ages of sampled stems ranged from 1 to 64 years (not all plants were aged); four species had sampled stems > 20 years old (vine maple, hazelnut, evergreen huckleberry, and red huckleberry).

3. Species with the greatest maximum sizes had the greatest range in diameter or height.

4. The line that passes through the highest value of the dependent variable at each level of the independent variable defines the upper boundary of the points and may reveal the underlying relationship between the variables when other factors are not limiting. Boundary lines indicated possible relationships between number of flowers and some of the measured variables (Figure 3).

5. Predicting number of flowers from shrub size or age, overstory characteristics, light, and site variables was not very successful (R^2 values were never > 0.50 for models with one or two variables).

6. Characteristics of shrub size, especially stem diameter, were almost always the best predictors of number of flowers (Figure 3). Large shrubs were not only more likely to flower and produce seed, they also contribute to vertical structure in forest stands (Figure 4).

Figure 4—Large shrubs, such as the vine maple shown here, are important components in forest stands. They provide vertical structure as well as producing large numbers of flowers which will result in large amounts of seed.

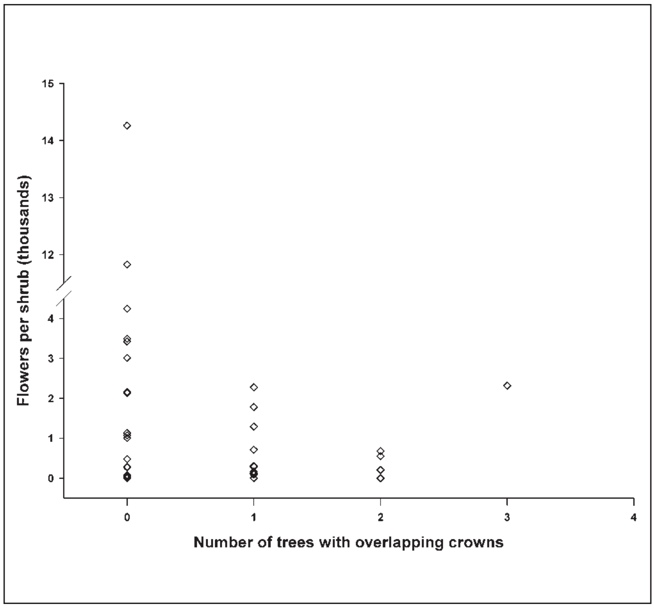

Figure 5—Relationship between number of evergreen huckleberry flowers per plant and number of trees whose canopies overlap the huckleberry plant canopy.

7. Three species—Indian plum, red huckleberry, and evergreen huckleberry— had improved prediction models for number of flowers if percent light, presence of a canopy gap or overstory characteristics were included; overall, these species also had the best fit models (Figure 5).

8. Salal, Oregon grape, and vine maple had the poorest fit prediction models for flowering. These clonal shrubs may share resources among above-ground stems, thus allowing stems in poorer environments to persist and flower. See Management Implications for more information on clonal shrubs.

9. Analyses that predicted which plants flowered did not select the same variables as the models predicting number of flowers (based on plants which *did* flower).

10. Direct measurement of light was only significant for Indian plum; thus, direct measurements (which require specialized equipment) may not be necessary to predict flowering.

HEIGHT GROWTH OF UNDERSTORY TREES

Most past management in Pacific Northwest forests focused on even-aged stands which had a single main canopy, had one or two main tree species, and were going to be regenerated by planting. Tree species in the understory or midstory were of little interest; advanced regeneration was often something to get rid of before planting, and midstory trees were usually too small to be of commercial value. In the late 1980's, interest in more complex forest structures began to increase because on some public lands it was deemed desirable to try to accelerate the development of stands with late-successional characteristics, such as multiple canopy layers, large diameter trees, several tree species, and presence of snags and down wood (See Franklin et al. 1986). In addition, some managers became interested in managing for natural regeneration. Thus, there is a need to understand more about trees in understory or midstory positions, especially their growth rates and ability to respond to release.

We sampled 75 forest stands in western Washington (Grays Harbor, Jefferson, King, Lewis, Mason, Pierce, Snohomish, and Thurston Counties) that had conifers present in understory or midstory positions. Understory trees (up to 8 m tall) of Douglas-fir, western hemlock, and western redcedar were measured for height, last 3-year height growth, crown length, and diameter. The overstory was characterized (height, distance to bottom of crown of dominant and codominant trees, length of crown for dominant and codominant trees, basal area), and the light environment and micro-site conditions were recorded. For each site, the plant association was determined and a soil moisture class assigned (dry, mesic, moist, or wet). The light environment was assessed in several ways: percent of full sunlight, analysis of digital photos of the sky with specialized software to determine percent of open sky, sunflecks, and other measures of light from the photographs, and a count of the number of open sky segments along the sun's path. The last variable, which we named "sunpath," was determined by drawing a line that represents the sun's mid-summer path, dividing the line into 20° segments, and then counting the number of segments that have 50% or more of the path without branches or stems blocking the sun.

Results were:

1. Trees in understory positions were found for all three species (Douglas-fir, western hemlock, and western redcedar) on several plant associations (except no Douglas-fir was present on the wettest plant associations).

2. For all three species, height growth was best on the "moist" sites.

3. For all three species, height growth prediction equations were better when done individually for the four moisture classes than when all moisture classes were combined.

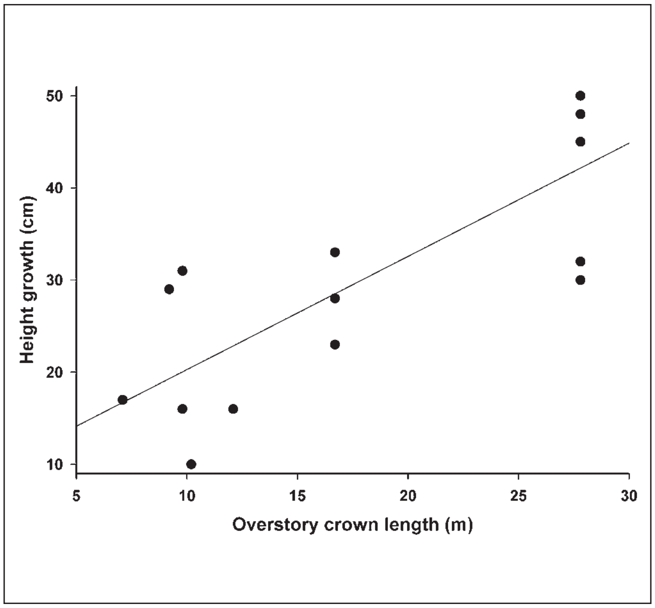

Figure 6—Relationship between 3-year height growth for Douglas-fir seedlings and saplings and mean of overstory trees crown length on plant associations classified as "dry" ($R^2 = 0.64$).

4. For 7 of the 11 species-moisture class combinations, a variable measuring tree size or size ratio was the first or only variable in the models predicting 3-yr height growth.

   a. Length of the live crown or live crown ratio was the best variable for predicting growth in several of the species-by-moisture-class models.
   b. Height/diameter ratio and stem volume were also selected but used in fewer models.

5. The model fit varied substantially among the species-moisture class combinations.

   a. Models were least successful for western hemlock (the best models had R^2 values of 0.35 and 0.37 for western hemlock on wet and mesic sites, respectively).
   b. Best-fit models were for Douglas-fir on dry sites ($R^2 = 0.71$) and western redcedar on moist sites ($R^2 = 0.83$). See Figure 6.

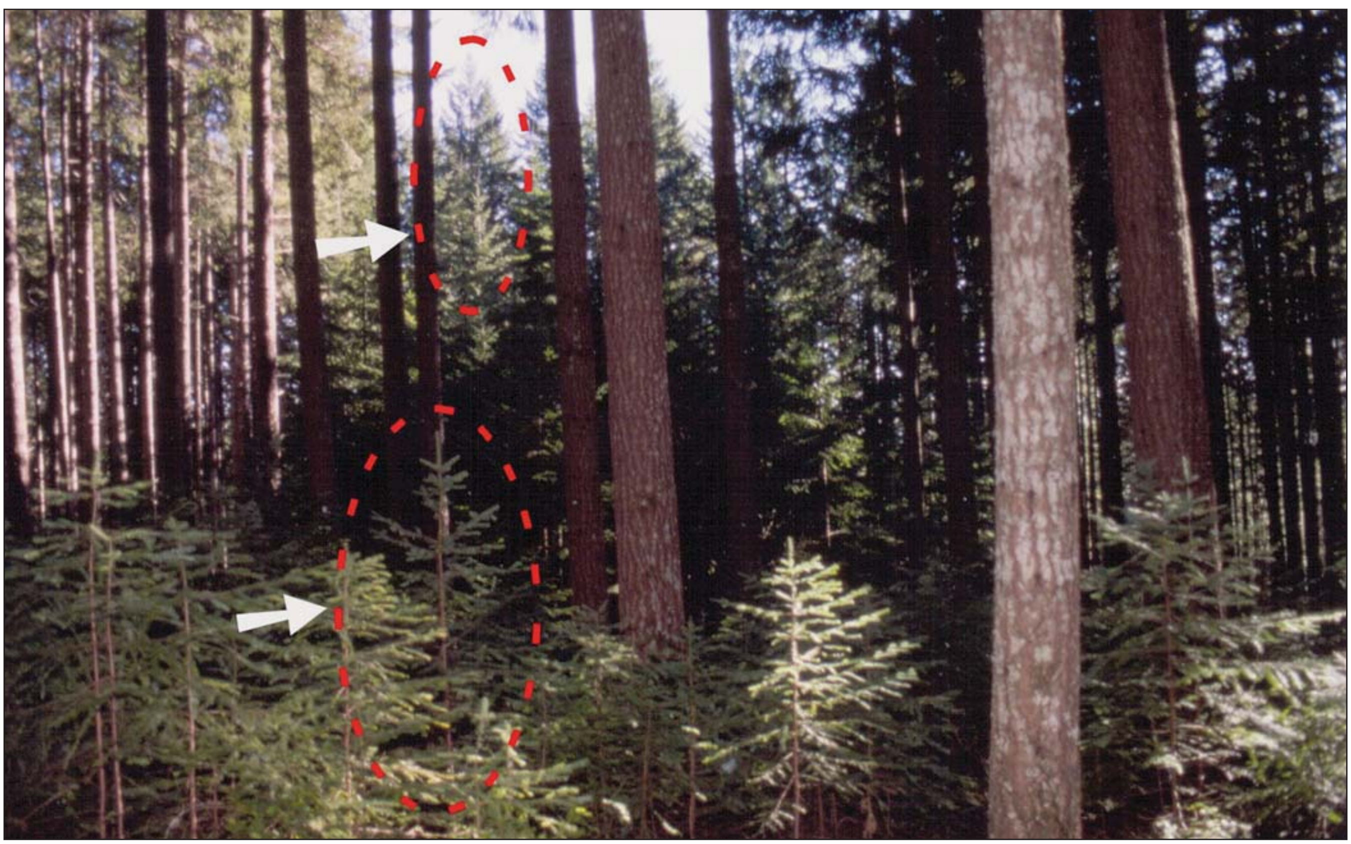

Figure 7—Many tree species will regenerate under a forest canopy but their future growth will depend on both overstory characteristics as well as site conditions. For example, the two groups of Douglas-fir saplings, indicated by the arrows above, are the same age but differ substantially in size.

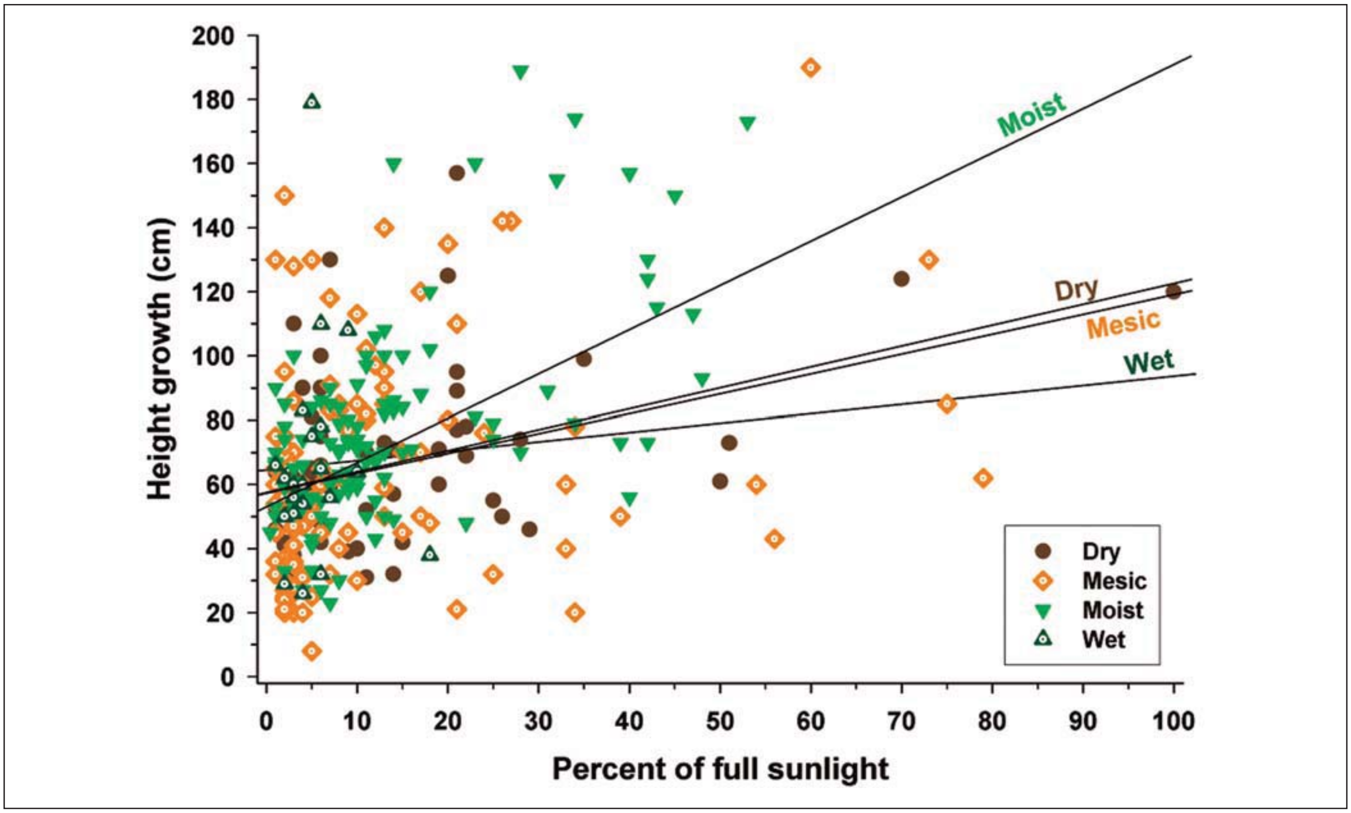

Figure 8—Relationship between 3-year height growth for western hemlock and percent of full sunlight by moisture class. Note that the regression line is steepest for the "moist" moisture class and the relationship is weak for the other three moisture classes.

6. Overstory characteristics were important variables in some height-growth prediction models, but the overstory characteristic selected varied among the species by moisture class combinations.

7. Growth rates of understory trees can differ substantially based on overstory conditions (Figure 7).

8. Overstory characteristics selected for models may provide clues to the factors limiting tree growth. For example, the fact that the best-fit model for western redcedar on dry sites includes basal area may indicate root competition is important as basal area is probably correlated with below-ground competition. On the other hand, selection of mean overstory crown length in the Douglas-fir model may indicate that light is more limiting growth than moisture on these sites; this would be consistent with the lower shade tolerance of Douglas-fir compared to western hemlock or western redcedar.

9. Five of the 11 models selected a light variable but the light variable selected the most, sunpath, was one that does not require specialized measurement equipment or software, or favorable weather and sun conditions.

10. Effects of light were most important on moist sites (Figure 8). This does not mean light was not a factor influencing growth on drier sites, merely that other variables were more strongly correlated with growth on the drier sites.

MANAGEMENT IMPLICATIONS

Our results are limited to a relatively small number of site and stand conditions, however, we can expand our scope of inference to some degree by looking at results from other researchers. The next section contains a list of suggested readings related to these topics. Based on our results, other field observations we have made, plus information in the literature from other studies, we have developed a list of management implications or ideas for managers to consider:

- Although measurable differences in vegetation composition and cover can occur fairly quickly after thinning, it will take many years to determine the overall response to treatment. Studies on new management techniques do not yet have long-term data so the results should be viewed with caution.

- Short-term understory response is strongly influenced by pre-treatment conditions (environmental conditions, presence of established plants, and seed sources) as well as type of treatment.

- Substantial spatial variation can exist in pretreatment cover and species composition; post-treatment response can be assessed more sensitively if pretreatment information is collected and used in the analysis.

- Salal, Oregon grape, vine maple, and salmonberry are examples of clonal shrubs. Although they reproduce by seed, they also reproduce vegetatively (via rhizomes, underground stems, or layering) to form large clonal colonies. Clonal shrubs (especially salal and salmonberry) can expand in cover very quickly when environmental conditions are favorable.

- Clonal shrubs may share resources so variations in growing conditions may be "averaged" within the clone.

- Thinning often favors expansion of clonal shrubs; thus, when they are present, different prescriptions may be necessary to achieve desired understory conditions.

- Large, older individuals of desired shrub species should be considered as legacies to be protected during thinning or other forest operations.

- Repeated thinning will accelerate the production of large diameter trees but may also introduce non-native species and promote development of dense understories. These conditions could delay or prevent the development of plant communities associated with late-successional stands. On the other hand, individual species characteristic of late-successional stands—such as western hemlock—will benefit from thinning. Managers need to determine which species, communities, or structures to target in prescriptions for individual stands.

- Variable density management, practiced on a stand basis (variation in density within a stand) or a landscape basis (varying density from stand to stand) has the potential to accelerate production of large diameter trees in some areas while maintaining optimal conditions for specific vegetation in other areas.

- Release of individual trees rather than a general thinning may prevent undesirable understory conditions from developing on some site types or plant associations.

- "No cut" patches within stands or uncut stands should also be "no entry" areas to prevent ground disturbance to reduce spread of exotic plants and expansion of less desired native species. No-cut patches may also be valuable to protect older shrubs.

- Adoption of one or a few "best guess" management prescriptions over a large portion of the managed forest landscape could result in producing many stands with undesirable vegetation characteristics. Responses to prescriptions should be monitored to verify that they are effectively meeting management objectives.

For those interested in predicting understory characteristics, we offer some additional observations:

- Models predicting growth or percent cover for plants in understory or midstory positions are often more complex and less accurate than models for overstory tree growth because plants below the main canopy are growing in a more complex competitive environment. Predicting functional attributes, such as flowering, is even more difficult.

- Models will vary by species and most will be improved by inclusion of variables that assess site conditions (such as moisture class) or variables that assess overstory competition. Variables selected in prediction models may provide clues to indicate which growth factors are limiting.

- A simple inexpensive technique of measuring light availability ("sunpath") gave superior results in models predicting height growth to techniques that require expensive specialized equipment and software.

SUGGESTIONS FOR FURTHER READING

New Management Ideas or Techniques
Carey et al. 1999
Curtis et al. 1998
DeBell and Curtis 1993
Franklin 1989

Understory Plant Communities
Halpern and Spies 1995
Halpern et al. 1999
North et al. 1996
Thysell and Carey 2000

Forest Shrubs and Flowering
Huffman and Tappeiner 1997
Huffman et al. 1994
O'Dea and Zasada 1995
Tappeiner et al. 1991

Understory Tree Growth
Brandeis, et al. 2001
Carter and Klinka 1992
Del Rio and Berg 1979
Wang, et al. 1994

Exotic Plant Species
Heckman 1999
Soule 1990
Duncan 2001

Other Topics
Franklin et al. 1986
Lieffers et al. 1999

ACKNOWLEDGEMENTS

We thank the following organizations for allowing access to their land: Olympic and Mt. Baker-Snoqualmie National Forests, Southwest Region Washington State Department of Natural Resources, Simpson Timber Company, Green Crow, Cowlitz Ridge Tree Farm, City of Hoquiam, Quinault Indian Nation.

LITERATURE CITED

Brandeis, T.J.; Newton, M.; Cole, E.C. 2001. Underplanted conifer seedling survival and growth in thinned Douglas-fir stands. Canadian Journal of Forest Research. 31: 302-312.

Carey, A.B.; Thysell, D.R.; Brodie, A.W. 1999. The Forest Ecosystem Study: background, rationale, implementation, baseline conditions, and silvicultural assessment. Gen. Tech. Rep. PNW-GTR-457. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 129 p.

Carter, R.E.; Klinka, K. 1992. Variation in shade tolerance of Douglas-fir, western hemlock, and western red cedar in coastal British Columbia. Forest Ecology and Management. 55: 87-105.

Curtis, R.O.; DeBell, D.S.; Harrington, C.A. [et al.]. 1998. Silviculture for multiple objectives in the Douglas-fir region. Gen. Tech Rep. PNW-GTR-435. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 123 p.

DeBell, D.S.; Curtis R.O. 1993. Silviculture and new forestry in the Pacific Northwest. Journal of Forestry. 73(special issue): 25-30.

Del Rio, E.; Berg, A.B. 1979. Growth of Douglas-fir reproduction in the shade of a managed forest. Research Paper 40. Corvallis, OR: Forest Research Laboratory, Oregon State University. 14 p.

Duncan, S. 2001. Invasion of the exotics: the siege of western Washington. Science Findings 38. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 6 p.

Franklin, J.F. 1989. Towards a new forestry. American Forestry. 73 (special issue): 37-44.

Franklin, J.F.; Hall, F.; Laudenslayer, W. [et al.]. 1986. Interim definitions for old-growth Douglas-fir and mixed-conifer forests in the Pacific Northwest and California. Research Note. PNW-RN-447. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 7 p.

Halpern, C.B.; Spies, T.A. 1995. Plant species diversity in natural and managed forests of the Pacific Northwest. Ecological Applications. 5: 14-934.

Halpern, C.B.; Evans, S.A.; Nelson, C.R. [et al.]. 1999. Response of forest vegetation to varying levels and patterns of green-tree retention: an overview of a long-term experiment. Northwest Science. 73 (special issue): 27-44.

Heckman, C.W. 1999. The encroachment of exotic herbaceous plants in the Olympic National Forest. Northwest Science. 73: 264-276.

Huffman, D.W.; Tappeiner, J.C., II. 1997. Clonal expansion and seedling recruitment of Oregon grape (*Berberis nervosa*) in Douglas-fir (*Pseudotsuga menziesii*) forests: comparisons with salal (*Gaultheria shallon*). Canadian Journal of Forest Research. 27: 1788-1793.

Huffman, D.W.; Tappeiner, J.C., II; Zasada, J.C. 1994. Regeneration of salal (*Gaultheria shallon*) in the central Coast Range forests of Oregon. Canadian Journal of Botany. 72: 39-51.

Kruger, K.W. 1960. Behavior of ground vegetation under a partially cut stand of Douglas-fir. Research Note 198. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 3 p.

Lieffers, V.J.; Messier, C.; Stadt, K.J. [et al.]. 1999. Predicting and managing light in the understory of boreal forests. Canadian Journal of Forest Research. 29: 796-811.

McComb, W.C.; Spies, T.A.; Emmingham, W.H. 1993. Douglas-fir forests: managing for timber and mature-forest habitat. Journal of Forestry. 91(12): 31-42.

North, M.; Chen, J.; Smith, G. [et al.]. 1996. Initial response of understory plant diversity and overstory diameter growth to a green tree retention harvest. Northwest Science. 70: 24-35.

O'Dea, M.; Zasada, J.C. 1995. Vine maple clonal development in coastal Douglas-fir forests. Ecological Applications. 5: 63-73.

Soule, M.E. 1990. The onslaught of alien species, and other challenges in the coming decades. Conservation Biology. 4: 233-239.

Tappeiner, J.C.; Zasada, J.C.; Ryan, P.; Newton, M. 1991. Salmonberry clonal and population structure: the basis for a persistent cover. Ecology. 72: 609-618.

Thysell, D.R.; Carey, A.B. 2000. Effects of forest management on understory and overstory vegetation: a retrospective study. Gen. Tech. Rep. PNW-GTR-488. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 41 p.

Thysell, D.R.; Carey, A.B. 2001. Manipulation of density of *Pseudotsuga menziesii* canopies: preliminary effects on understory vegetation. Canadian Journal of Forest Research. 31: 1513-1525.

Wang, G.G.; Qian, H.; Klinka, K. 1994. Growth of *Thuja plicata* seedlings along a light gradient. Canadian Journal of Botany. 72: 1749-1757.

Worthington, N.P.; Heebner, C.F. 1964. Light thinning of Douglas-fir does not stimulate regeneration. Research Note PNW-16. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 5 p.

Article taken from Johnson, Adelaide C.; Richard W. Haynes, Robert A. Monserud, eds. 2002. Proceedings from the Wood Compatibility Initiative Workshop. Gen. Tech. Rep. PNW-GTR-563. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Portland, OR: 159-168. Number 17.