
Development of Tree and Understory Vegetation in Young Douglas-Fir Plantations in Western Oregon

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ABSTRACT: *The prevalence of young even-aged Douglas-fir (*Pseudotsuga menziesii*) stands in Oregon and Washington has led to concerns about a landscape being dominated by stands in the stem exclusion phase. In this context, our study documented the development of two aspects important for the diversity of plant and wildlife habitat: tree characteristics and understory vegetation. Using a chronosequence approach, we measured conditions in 39 plantations ranging from 6 to 20 years. Results confirmed intuitive trends, but the quantification indicated that some of these trends develop earlier than commonly assumed. Tree growth in young stands was positively related to stand density, but this trend reversed fairly early. Crown characteristics were influenced very early by stand density, indicating that maintaining a long-lived crown in typical plantations can only be accomplished by lowering stand density through precommercial thinning. Understory herb cover was reduced throughout time, while shrub cover increased. Species compositions were quite complex, with an initial strong presence of invader species and later dominance of species usually associated with mature forests; however, there were many exceptions and early successional species were still present after 20 years. The study showed that this early stage is very complex, that the dynamics vary for different characteristics, and that a finer resolution of the stand initiation stage may be warranted for plantations. *West. J. Appl. For.* 21(2):94–101.*

Key Words: Density management, stand initiation phase, crown characteristics.

Forest managers are now challenged with creating a diversity of forest stand structures while also producing revenue, such as in the recent adoption of the Oregon Department of Forestry's Northwest Oregon State Forests Management Plan (Oregon Department of Forestry 2001). A diversity of stand structures is considered important to maintain the diversity of species and ecosystem functions (Spies et al. 1988, Oliver and Larson 1996). As a result of past harvesting practices in the Pacific Northwest, the reduced acreage in late-successional structures and the associated dominance of early successional stand structures (analogous to stem exclusion phase *sensu* Oliver and Larson 1996) have received recent attention (Kohm and Franklin

1997). This trend is of special concern because the stem exclusion phase is regarded as having less diversity in stand structures and habitats (Spies et al. 1988) than late successional stages.

Analysis of early growth rates of trees in old-growth stands in the Oregon Coast Range indicated that these stands may have initiated at lower densities than commonly found in current plantations and may have never gone through a classic stem exclusion phase (Poage and Tappeiner 2002, Tappeiner et al. 1997). These findings raised the question whether the current, dense plantations will develop efficiently into forests that provide late successional habitat. As a consequence, a number of studies have been initiated to investigate whether density reductions in dense plantations can accelerate the development of desirable stand characteristics, such as a diversity of understory vegetation or multiple crown layers. Most of these studies focused on the later stages of the stem exclusion stage, when trees are of sufficient size to make thinnings commercially attractive (for a listing of studies, see Monserud 2002). Little work however, has been done to investigate whether negative aspects of stem exclusion can be prevented or

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lessened through density management in the regeneration establishment phase.

The objective of this study was to characterize development of stand structure during the transition from the regeneration to the stem exclusion phase in young Douglas-fir plantations. Specifically, we wanted to quantify how development of tree and crown characteristics and understory vegetation was influenced by stand density during the transition. This information is crucial to evaluate whether preventing the loss of valuable structural components through early management is a viable option for forest managers. It may provide an alternative to currently common practices that focus on reintroducing these structural components through thinning after they had been lost during the stem exclusion phase.

Methods

Study Area

Study stands were located in three Oregon Department of Forestry districts (Astoria, Forest Grove, and Philomath) in the *Tsuga heterophylla* zone (Franklin and Dyness 1973) in the middle to northern part of the Oregon Coast Range. Dominant tree species in this zone include: Douglas-fir, western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*). The Coast Range has a maritime climate characterized by mild, wet winters and relatively dry summers. Mean temperatures range from 4° C in January to 16° C in July and annual precipitation, mostly occurring November through March, ranges between 115–255 cm. Soils differ between districts, but in general the soils in the Coast Range are derived from sandstones, siltstones, weathered basalts, and volcanic breccias and range from deep, rock-free materials to shallow, stony profiles (Oregon Department of Forestry 2001).

Study Layout

Using a chronosequence approach, Douglas-fir plantations from 6 to 20 years were selected from a list of candidate stands. Selection criteria included typical stand establishment procedures, average site quality, no major disease problems, and no release treatment in the previous 2 years. To ensure coverage of density gradients, we laid out three transects in each stand with each transect consisting of three areas ($n =$ nine plots per stand) in close vicinity, i.e., with similar slope and aspect, that differed in overstory densities. The three overstory densities on each transect included a low (open gap, typically one to three crop trees/plot), medium (transition or low density, typically

three to four crop trees/plot), and high (matrix or fully stocked, typically four to six crop trees/plot) density condition. Within this constraint, a 5-m radius plot was located randomly in each overstory density condition, resulting in a total of three plots per transect and nine plots in each stand. Crop trees included all planted trees that achieved locally dominant positions. To minimize the effect of other factors, areas were not selected if they were infected with rot pockets, part of an old skid trail or landing system, or had existing hardwoods that predated crop trees.

Tree and Crown Measurements

For all trees greater than 1.4 m in height and 2.5 cm in dbh we measured species, dbh, current total height in 2002, 2001 height, 2000 height, height to base of live crown, and crown radius. We also measured height, length, diameter, and angle of the lowest live branch for crop trees.

Understory Vegetation Measurements

Within each 5-m radius tree plot, four 1-m radius subplots were placed 2.5 m off tree plot center in the cardinal directions. In each subplot, percent cover was estimated to the closest 10% (also <1 and 1 to 5% noted) for all forbs, fern, grass, sedge, moss, lichen, shrub, and tree species. In addition, we estimated the cover of bare ground, rock, stumps, downed wood, and needles. All vegetation was identified to species except moss, lichen, grass, and sedges.

Data Analysis

An analysis of covariance test (data not shown) showed significant differences among districts. We considered these results an artifact of several factors, which cannot be separated (e.g., location, especially topography and history, and differences in recent silvicultural practices such as planting densities and site preparation treatments; see Table 1) and therefore analyzed the districts separately. The distinction of gaps, transitions, and matrices was used for the purpose of plot installation only. In the analysis, we used actual densities as independent variables. More specifically, we used total basal area, which accounts for numbers and sizes of all trees as a representation of stand density. Number of trees was not a proper reflection of the intensity of competition within a plot, because the number of trees in plots with only large crop trees does not have the same ecological influence in plots that contained small hardwoods (see Table 1).

To account for the potential correlation between plots on transects and within stands, we used a mixed model that included planted Douglas-fir basal area, site index (King

Table 1. Summary information for study sites. Plantation ages refer to years since planting and site index (SI) is measured in meters at 50 years (King 1966). Crop trees are limited to planted seedlings, while total density includes crop trees and conifer and hardwood natural regeneration.

District	Age (years)	SI (m)	Elevation (m)	Site prep	Crop tree density (tpha)			Total tree density (tpha)		
					Gap	Transition	Matrix	Gap	Transition	Matrix
Astoria	6–20	37–43	195–615	a, b, c, d*	127–637	127–892	127–1656	127–4076	127–3439	127–2166
Forest Grove	7–18	32–40	380–860	b	127–764	255–1019	382–1529	127–6497	255–2548	382–3185
Philomath	6–18	40–43	200–495	a, b, c, e	127–764	255–1019	637–1401	127–9809	637–7134	637–3822

*a = slash and burn, b = broadcast burn, c = chemical site preparation, d = forage seeding, e = trapping.

1966), and age as main effect terms (fixed factor), basal area \times age interaction, and stand identification (id), transect within stand id as random factors. Nonsignificant parameters were dropped and the final models only contained significant parameters. Means for tree and crown characteristics were computed and understory vegetation subplots averaged for each tree plot before analysis. Percent cumulative cover for forbs and shrubs was also calculated by adding up the percentage cover of individual species to account for multiple layers of species in a plot. Response variables were assessed for agreement with statistical assumptions (i.e., normality and homoscedasticity of residuals). All response variables were log transformed, except for forb and shrub cover in which a logit transformation was used (Sabin and Stafford 1990).

To analyze the understory vegetation (forbs and shrubs) further, nonmetric multidimensional scaling was used to ordinate plots and to assess overall gradients in vegetation community composition and their relationships with environmental variables. We ordinated vegetation community data from 140, 114, and 87 plots, in Astoria, Forest Grove, and Philomath, respectively. Species present in <5% of the plots were removed from the analysis. A multivariate outlier analysis was run for each district and analysis of all 140 plots in Astoria revealed one potential outlier with a SD three times greater than the 2.0 cutoff. Unlike other plots, this particular plot had zero forb species. After running the analysis with and without the outlier we concluded that the outlier was influential in the ordination and disrupted pat-

terns in the other points and was therefore excluded from further analyses (McCune and Grace 2002). Sørensen distance was used with the Slow and Thorough autopilot mode in PC-ORD 4.0 [40 runs of 400 iterations (Kruskal 1964, Mather 1976)]. The ordination was rotated to maximize the correlation of basal area in Philomath and Astoria and elevation in Forest Grove with one axis. We used coefficient of correlation to assess relationships with species abundance and environmental variables with the ordination axes and for presentation in the results chose a cutoff of $R^2 \geq 0.3$.

Results and Discussion

Tree and Crown Characteristics

The study was not designed to document average stand conditions, but to document conditions in areas with a range of stand densities. Thus, density and species composition of planted trees and natural regeneration as well as understory vegetation are not representative for plantations. Instead, they represent the specific spots selected for measurement. It is important to note that naturally regenerated conifers and hardwoods were concentrated in plots with low crop tree densities and not evenly distributed throughout the stand. Mean sizes of planted conifers and natural conifer regeneration and hardwoods were calculated for each plot and averaged by age in Table 2. The lack of significance of site index (Table 3) in all models is no indication that site quality did not affect tree and crown characteristics; instead, is an artifact of the selection criteria, which aimed for similar site conditions in all stands. Some coefficients such

Table 2. Mean dbh (cm) and height (m) of planted conifers and natural conifer and hardwood regeneration averaged across plots (SD in parentheses). $N = 9$, except for ages with multiple stands ($n = 18$).

	Age (years)	Planted conifer		Natural regenerated conifer		Natural regenerated hardwood	
		dbh	ht	dbh	ht	dbh	ht
Astoria	6	3.2 (0.78)	3.2 (0.38)			3.9 (0.85)	4.4 (0.75)
	7*	5.0 (1.40)	4.1 (0.78)			4.0 (1.00)	4.5 (0.64)
	8*	7.9 (2.39)	5.3 (1.06)	3.1 (0.64)	3.3 (0.59)	5.6 (1.16)	5.8 (2.69)
	9	9.0 (2.12)	6.2 (1.08)	3.1 (0.35)	4.2 (0.45)	4.8 (1.98)	5.9 (1.20)
	11*	11.6 (3.46)	8.7 (1.64)	5.0 (2.28)	5.4 (1.76)	6.1 (3.19)	7.4 (1.34)
	13*	14.8 (3.62)	10.4 (2.00)	4.2 (1.78)	5.2 (1.59)	3.9 (2.04)	6.4 (2.30)
	14*	15.4 (3.62)	10.8 (1.49)	3.8 (1.04)	4.7 (1.01)	4.7 (2.47)	7.1 (2.86)
	16	19.4 (4.37)	13.0 (2.01)			4.3 (3.54)	7.0 (2.45)
	17	21.0 (4.63)	13.6 (1.61)	7.5 (4.59)	8.2 (3.23)	3.5 (2.04)	6.7 (3.16)
	19	20.9 (5.07)	13.7 (1.63)	5.7 (2.41)	6.3 (2.01)	4.1 (2.65)	5.9 (1.09)
	20	20.8 (5.03)	14.5 (2.22)	7.1 (1.89)	7.1 (1.57)	7.5 (5.28)	9.0 (3.57)
Philomath	6	4.1 (1.19)	3.6 (0.82)			3.0 (0.44)	4.5 (0.59)
	8	7.4 (1.66)	5.8 (1.02)	3.0 (0.45)	3.4 (0.32)	3.5 (0.60)	4.1 (0.62)
	9*	10.4 (2.97)	7.3 (1.50)	3.7 (1.09)	4.1 (0.97)	3.2 (0.71)	4.9 (0.84)
	12*	14.0 (3.68)	9.7 (1.66)	3.6 (1.13)	4.7 (1.72)	4.5 (2.68)	6.3 (2.57)
	13	14.3 (4.54)	9.6 (2.06)	4.8 (-)	6.8 (-)	3.6 (1.30)	5.8 (1.45)
	14	15.3 (4.69)	10.3 (2.18)	5.6 (2.55)	6.9 (3.10)	5.7 (3.06)	7.4 (2.10)
	16	17.3 (5.27)	11.8 (2.35)	7.0 (5.10)	7.4 (1.93)	4.3 (1.93)	6.8 (1.44)
	18	20.4 (5.11)	12.7 (1.84)	5.5 (2.05)	6.8 (1.63)	3.0 (0.44)	5.0 (0.77)
Forest Grove	7*	4.6 (1.41)	3.8 (0.80)				
	9	6.9 (2.05)	5.2 (1.14)	3.5 (0.22)	3.5 (0.40)	2.7 (0.06)	3.3 (0.15)
	11	10.4 (2.32)	7.3 (1.21)	3.9 (1.25)	4.1 (0.91)	3.1 (0.33)	3.5 (0.57)
	12*	7.4 (2.52)	5.6 (1.48)	4.4 (1.83)	4.3 (1.23)		
	13*	8.4 (3.55)	6.3 (2.07)	6.3 (3.13)	5.1 (1.66)	2.7 (-)	4.9 (-)
	14	10.1 (3.23)	6.2 (1.78)	3.4 (0.89)	3.0 (0.32)	3.4 (0.78)	4.6 (-)
	15*	10.2 (3.19)	7.2 (1.88)	4.1 (1.70)	4.2 (1.01)	4.9 (2.46)	6.5 (1.83)
	16	12.5 (4.04)	8.6 (2.24)	4.8 (-)	5.4 (-)	3.8 (1.44)	6.4 (1.43)
	18	13.8 (5.78)	8.9 (2.94)	5.8 (2.29)	5.7 (1.48)		

* Multiple stands.

Table 3. Parameter estimates (SE in parentheses) for equations quantifying impacts of age and stand basal area on (transformed) tree and crown characteristics and understory vegetation.

	Intercept	Site index	Age (years)	Basal area (m ² /ha)	Age*Basal area
Philomath					
dbh (cm)	0.752 (0.16)		0.123 (0.01)	0.083 (0.01)	-0.005 (0.00)
2002 height growth (m)	-0.138 (0.10)			0.027 (0.01)	-0.001 (0.00)
Crown radius (cm)	4.237 (0.10)		0.079 (0.01)	0.054 (0.01)	-0.003 (0.00)
Height to base of crown (m)	-0.217 (0.17)		0.060 (0.01)	0.014 (0.00)	
Branch diameter (mm)	1.149 (0.16)		0.109 (0.01)	0.069 (0.02)	-0.004 (0.00)
Branch length (cm)	3.614 (0.15)		0.106 (0.01)	0.071 (0.01)	-0.004 (0.00)
Branch height (cm)	1.234 (0.56)		0.187 (0.05)	0.023 (0.01)	
Forb cover (%)	-0.683 (1.08)			-0.044 (0.01)	
Shrub cover (%)	-31.038 (11.30)	0.237 (0.08)		-0.514 (0.07)	0.026 (0.00)
Astoria					
dbh (cm)	0.720 (0.13)		0.126 (0.01)	0.060 (0.01)	-0.003 (0.00)
2002 height growth (m)	-0.360 (0.07)		0.031 (0.01)	0.038 (0.01)	-0.002 (0.00)
Crown radius (cm)	4.149 (0.09)		0.085 (0.01)	0.042 (0.01)	-0.002 (0.00)
Height to base of crown (m)	-0.100 (0.07)			-0.003 (0.01)	0.001 (0.00)
Branch diameter (mm)	1.201 (0.13)		0.095 (0.01)	0.046 (0.01)	-0.002 (0.00)
Branch length (cm)	3.625 (0.11)		0.093 (0.01)	0.043 (0.01)	-0.002 (0.00)
Branch height (cm)	1.635 (0.21)		0.135 (0.02)	0.030 (0.01)	
Forb cover (%)	-0.350 (0.90)			-0.113 (0.01)	
Shrub cover (%)	-16.540 (8.57)	0.152 (0.07)		-0.370 (0.05)	0.015 (0.00)
Forest Grove					
dbh (cm)	0.628 (0.19)		0.106 (0.02)	0.117 (0.03)	-0.006 (0.00)
2002 height growth (m)					
Crown radius (cm)	4.104 (0.08)		0.067 (0.01)	0.075 (0.02)	-0.004 (0.00)
Height to base of crown (m)	0.075 (0.06)		0.016 (0.01)	0.016 (0.00)	
Branch diameter (mm)	1.184 (0.15)		0.086 (0.01)	0.015 (0.01)	
Branch length (cm)	3.568 (0.13)		0.084 (0.01)	0.019 (0.01)	
Branch height (cm)	1.796 (0.38)		0.085 (0.03)		
Forb cover (%)					
Shrub cover (%)	-2.037 (1.39)			-0.077 (0.02)	

as height growth, diameter, and length of lowest live branch, shrub cover, and forb cover were inconsistent across districts (Table 3) and may be random effects or, if real, are possibly related to site conditions and specific area effects.

Our study design does not allow us to calculate the specific timing of the “crossover effect” (Scott et al. 1998, Turnblom and Pittman 2001) because of our choice of basal area. However, the results support the conclusion that the early positive effect of density on height growth, dbh, and crown radius (Figure 1) caused by dense planting is temporary and lost during the canopy closure stage (Scott et al. 1998). Future thinning studies will provide insight as to whether the initial growth benefits can be maintained throughout a rotation, but our data suggest that early density manipulations are necessary to capture the early growth advantage of dense plantations.

The effects of higher densities on crown recession (Figure 1) were already evident fairly early and diameter, length, and height of the lowest live branch were also strongly influenced by stand density throughout time (Note, a positive relationship between density and diameter and length of lowest live branch was found in Forest Grove) (Table 3). Thus, the relationships between crown structure and stand density, i.e., trees in denser stands have shorter crowns and smaller branch diameters (Maguire et al. 1999) is already evident in very young plantations, even though crown radius is not yet negatively influenced by stand density. We documented increased branch mortality that leads to crown recession and loss of the live crown (Maguire et al. 1991) at higher densities already in the youngest

plantations, indicating that on these sites the trends to lower live crown ratios and eventually narrow single-layered canopy structures (Marshall and Curtis 2002) were already established by age 5. Although at this early stage branch sizes are not large enough to affect wood quality, the loss of live crown is critical because it is not easily recovered. Any increase of live crown ratios after thinning is mainly caused by reduced or absent branch mortality in combination with height growth (which, in turn, is fairly insensitive to thinning) (Marshall and Curtis 2002). Although Douglas-fir is able to develop epicormic branches (Bryan and Lanner 1981), the initiation of epicormic branches has been associated with older crowns (Ishii and Ford 2001) or very open conditions around the stems, such as found after intensive pruning in low-density stands (Collier and Turnblom 2001). Consequently, under standard plantation management practices it is unlikely that epicormic branches replace dead branches in these stands as components of vigorous crowns.

Crown and branch size are important stand structural components because they are related to stand growth and vigor, thinning regime (Smith et al. 1997), wood quality (Barbour and Parry 2001), bole form and breakage resistance (Dunham and Cameron 2000, Mitchell 2000), and wildlife and epiphyte habitat (McCune et al. 2000). Although the structural components in the plantations in this study were not necessarily past any critical or threshold stage (Wilson and Oliver 2000), our analysis seems to indicate that crown development is very dynamic at early stages. Desired crown and canopy structure may be developed through early management practices, such as heavy

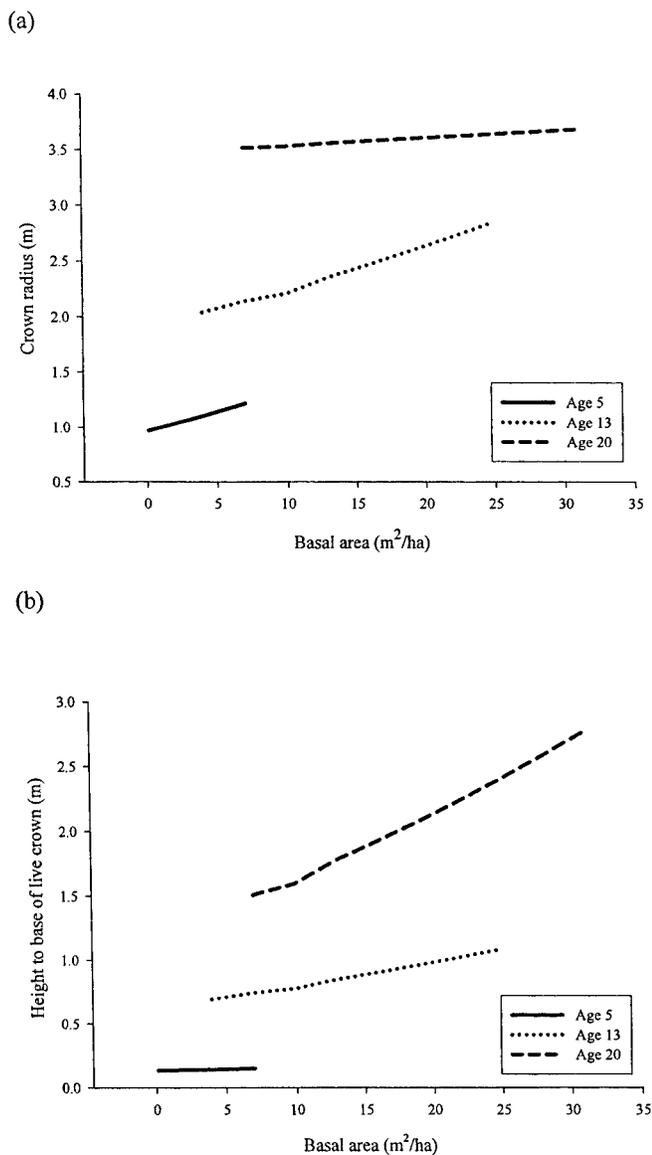


Figure 1. Fitted regression lines of crown radius (a) and height to base of live crown (b) for plantations in the Astoria district as a function of stand basal area. Lines represent different ages.

precommercial thinning or gap creation (Wilson and Oliver 2000).

Understory Vegetation

Understory vegetation data was recorded in June and July (2003) and quantified as a percent cumulative cover. Across all districts, percent cumulative shrub cover averaged 53% (ranged 0–143%) and forb cover averaged 20% (ranged 0.1–125%). Area of the plots occupied by bare ground, rocks, stumps, downed wood, or needles was also quantified. Percent bare ground varied greatly for each plot, averaging 2% (ranged 0–66%) cover. Studies investigating natural stands (e.g., Poage and Tappeiner 2002, Tappeiner et al. 1997, for further listings see Oliver and Larson 1996) showed long (>30 years) regeneration periods, indicating that quite likely the understory in these stands was quite a bit more open than in our study stands. This was expected,

as the management efforts (e.g., regular spacing, vigorous planting stock) were aimed at accelerating the development of tree cover.

A detailed analysis of the understory plant community indicated that the vegetation community composition in Philomath and Astoria were most strongly influenced by stand density (basal area) and age of all planted and natural regenerated tree species (Table 4). Additionally in Astoria, plant community composition was related to the presence of needle cover. However, needle cover was confounded by density, and other variables such as bare ground, rocks, or stumps, were not influential. Vegetation composition in Forest Grove was mainly influenced by elevation.

Shrubs

High overstory densities were indicative of lower shrub cover in Philomath and Astoria, but the influence of density on shrub cover decreased throughout time (Table 3). In both districts shrub cover was greater on higher quality sites and increased with age in Philomath. This increase is likely

Table 4. Coefficients of correlation (R^2) of environmental and species variables with NMS ordination axes. Coefficients were reported if R^2 was ≥ 0.3 . Bold numbers indicate an association with the axes. Vegetation community composition in Philomath was most strongly influenced by basal area (Axis 1, $R^2 = 0.44$) for example, and species such as *Pteridium aquilinum* had a negative association with Axis 1 therefore exhibiting greater abundance in low-density plots.

	Association with axis	Axis 1	Axis 2	Axis 3
Philomath				
Environment matrix				
Basal area	+	0.44	0.00	0.00
Age	+	0.34	0.12	0.05
Elevation	+	0.00	0.30	0.01
Site prep-slash and burn	+	0.10	0.41	0.01
Species matrix				
<i>Acer circinatum</i>	+	0.02	0.42	0.05
<i>Anaphalis margaritacea</i>	-	0.37	0.00	0.00
<i>Berberis nervosa</i>	+	0.10	0.52	0.02
<i>Dicentra formosa</i>	+	0.04	0.02	0.31
<i>Gaultheria shallon</i>	-	0.18	0.03	0.58
<i>Lotus crassifolius</i>	-	0.52	0.00	0.00
<i>Pteridium aquilinum</i>	-	0.46	0.02	0.23
<i>Rubus ursinus</i>	-	0.34	0.13	0.02
<i>Sambucus racemosa</i>	+	0.07	0.03	0.45
Astoria				
Environment matrix				
Basal area	+	0.70	0.00	0.00
Age	+	0.41	0.00	0.00
Needle litter	+	0.48	0.02	0.02
Species matrix				
<i>Anaphalis margaritacea</i>	-	0.30	0.02	0.03
<i>Berberis nervosa</i>	-	0.00	0.01	0.66
<i>Pteridium aquilinum</i>	-	0.33	0.06	0.18
<i>Rubus ursinus</i>	-	0.54	0.00	0.03
Forest Grove				
Environment matrix				
Elevation	+	0.54	0.00	0.00
Species matrix				
<i>Vaccinium parvifolium</i>	+	0.60	0.00	0.00
Grass spp.	+	0.22	0.34	0.01
<i>Lotus crassifolius</i>	+	0.00	0.42	0.16
<i>Pteridium aquilinum</i>	+	0.10	0.01	0.35
<i>Rubus ursinus</i>	-	0.02	0.01	0.30

caused by a combination of shrub recovery after damage from harvesting or early release operations and of a shift in species composition. High overstory density stands in Forest Grove were correlated with low shrub cover with no recovery throughout time. Apparently, in Forest Grove the influence of the large range in elevation overshadowed the impact of stand density and may be responsible for the inconsistencies between the results from Forest Grove and the other two districts.

Forbs

Forb cover was lower on high-density plots in Philomath and Astoria, but showed no relation to density in Forest Grove (Table 3). In all three districts, forb cover did not show any trends with age. The different responses of understory vegetation is probably caused by a combination of the amount and composition of vegetation in the earlier preharvest stands, weed control practices, invasion potential (e.g., seed sources), and environmental and resource conditions as modified by tree regeneration. In addition, different site preparation techniques were used in each district and although not strikingly evident in the community analysis (Table 4; i.e., Philomath, $R^2=0.10$), could perhaps be another explanation for the inconsistencies.

Overall, species responded individually and differed in their abundances and ability to survive in the understory throughout the chronosequence. Although our study did not cover the first 4 years after the harvesting disturbance (Schoonmaker and McKee 1988) and included fairly homogenous conditions in young stands, our sites seemed to exhibit a range of developmental patterns. Using the approach and species lists developed by Halpern (1989) species were grouped based on their seral origin and life history (Figures 2 and 3). Group A (labeled I3 in Halpern 1989) contained *Agoseris* spp. and *Cirsium* spp., and were characterized as invader species that exhibited slow rates of occupancy throughout the study period. Group B (labeled I6 in Halpern 1989) contained other invaders (*Rubus parviflorus* and *Pteridium aquilinum*) that experienced a shift from increasing to decreasing occupancy. As shown in the community analysis, *Pteridium aquilinum* was most abundant in low-density areas (Table 4) but remained persistent in our oldest stands (Figure 2) by taking advantage of the variation (i.e., gaps) within stand. Generally, these invaders decreased in abundance in older stands (Figure 2; Table 4), but were not eliminated in these stands and remained in stands as late as age 20, the maximum age of our study sites.

We expected residual species (as defined by Halpern 1989) to show substantial reductions after the previous harvest. However, *Acer circinatum*, *Berberis nervosa*, *Corylus cornuta*, *Polystichum munitum* (group C, labeled R3 in Halpern 1989) were present, showed continuous recovery on our study sites (Figure 3), and even became dominant features in fairly young stands (>12 years). *Rubus ursinus* (group D, labeled R1 in Halpern 1989) was persis-

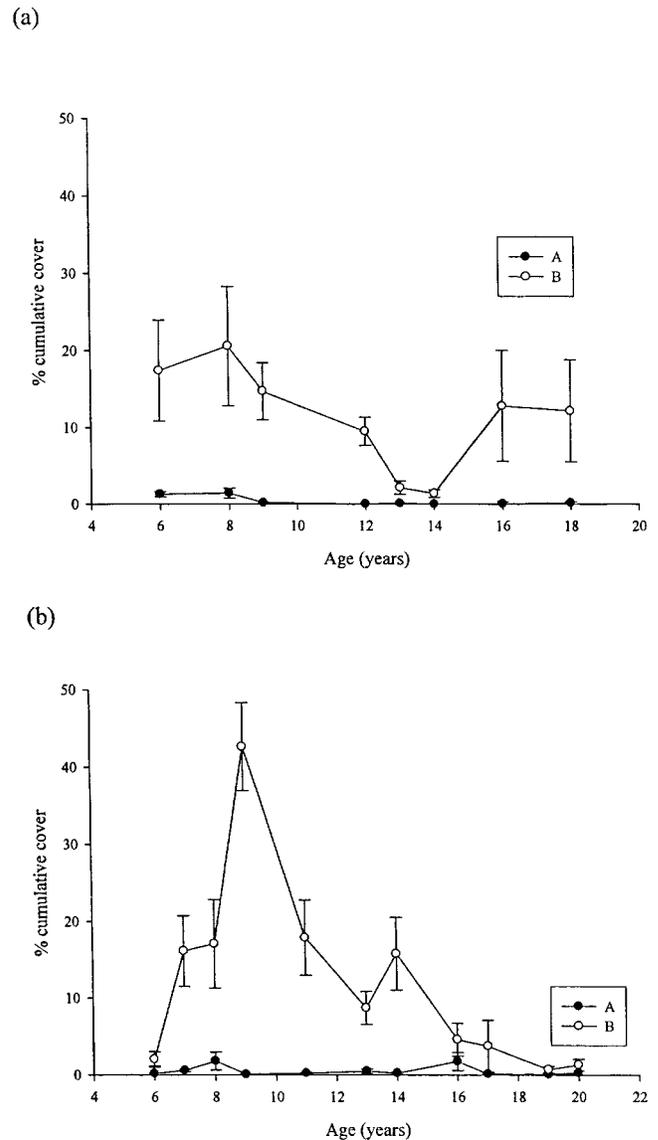
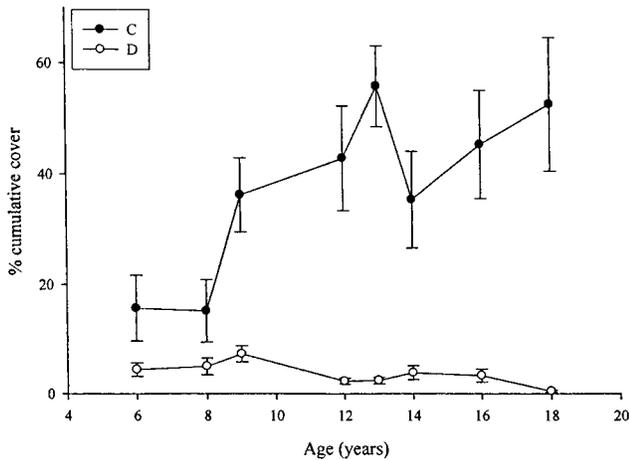


Figure 2. Cumulative percent cover (with SE bars) of group A (*Agoseris* spp., *Cirsium* spp.) and B (*Rubus parviflorus*, *Pteridium aquilinum*) invader species (as defined by Halpern 1989). Covers were summed for each plot and means calculated by age for Philomath (a) and Astoria (b).

tent in all cohorts but decreased in occupancy in the older stands.

Consequently, invader and residual species were all major contributors throughout the 20-year period. The dynamics of herbaceous and shrub layers were quite complex and in constant flux and general trends may not be associated with any successional stage (Halpern and Spies 1995) in these managed plantations. Instead, species vary in abundance and ability to survive throughout all stages depending on a combination of historical presence, disturbance timing and intensity, damage during harvesting and release operations, site preparation techniques, and resource availability (Schoonmaker and McKee 1988). Thus, the specific role of plantations in providing young successional habitat may have to be assessed on a case-by-case basis.

(a)



(b)

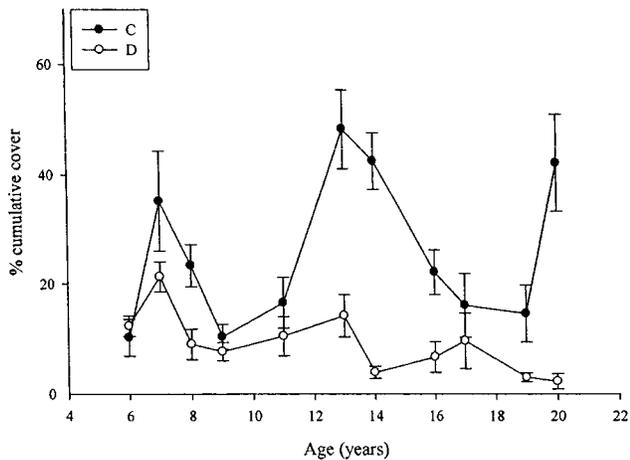


Figure 3. Cumulative percent cover (with SE bars) of group C (*Acer circinatum*, *Berberis nervosa*, *Corylus cornuta*, *Polystichum munitum*) and D (*Rubus ursinus*) residual species (as defined by Halpern 1989). Covers were summed for each plot and means calculated by age for Philomath (a) and Astoria (b).

Conclusion

The study showed that stand development, as characterized by tree characteristics and understory vegetation, is influenced by density fairly early and is very dynamic in young plantations. It highlights that development of some critical stand structural components in managed plantations may not be captured well in many stand development classification schemes developed for natural stands (e.g., Bormann and Likens 1979, Carey and Curtis 1996, Oliver and Larson 1996, Spies and Franklin 1996). Although we did not measure changes in microclimate, the early shift in crown conditions and vegetation composition suggests functional changes in forest ecosystems. Thus, any gaps or

openings in young plantations may provide opportunities for maintaining diversity of within stand conditions. In turn, this diversity may affect the role and impact of the stem exclusion phase. A study to investigate whether these openings can be maintained through management and used by wildlife species is currently underway.

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