Relationships between Overstory Structure and Understory Production in the Grand Fir /Myrtle Boxwood Habitat Type of Northcentral Idaho

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Abstract

Relationships between overstory structure and understory current year production on 20 undisturbed sites of the grand fir/myrtle boxwood habitat type were studied in the Clearwater Mountains of northcentral Idaho. Overstory characteristics measured were tree canopy coverage, sum of the tree diameters, basal area, stand height, and stem density. Understory production was divided into four vegetation classes: (1) shrubs, (2) forbs, (3) graminoid and (4) total production. Regression models predicting current year production of each understory vegetation class were developed using all possible combinations of overstory parameters as independent variables. Canopy coverage and sum of the tree diameters were found to be the best indices of understory production. Canopy coverage was most significantly correlated with total understory production and shrub production. Canopy coverage and sum of the tree diameters were the most significantly correlated overstory parameters with forb production. Graminoid production was not significantly correlated to any of the measured overstory parameters. Basal area, tree density, and stand height were not statistically related to the understory production. Further examination of the models is needed to validate these relationships over the range of the grand fir/myrtle boxwood habitat type. The models are not applicable to areas where recent disturbance such as logging, fire, or disease has affected overstory structure.

In forest stands, understory shrub and herb production available to herbivores is highly dependent on the structure of the tree overstory. Several studies have been conducted which relate understory production to overstory structure in forest stands and have proposed models to predict understory production based on tree stand characteristics such as basal area (Clary and Ffolliott 1966, Gaines et al. 1954, Halls and Shuster 1965, McConnell and Smith 1965) and canopy cover (Anderson et al. 1969; Cooper 1960; Ehrenreich and Crosby 1960; Halls and Shuster 1965; Jameson 1967; McConnell and Smith 1965, 1970; Young et al. 1967). The majority of the published accounts of overstory structure-understory production relationships are for forests in the south, southwest, or midwest United States. Little work has been done relating overstory structure to understory production in the Pacific Northwest.

The objective of this was to determine relationships between overstory structure and understory current year production on undisturbed sites of the grand fir/myrtle boxwood *(Abies grandis/ Pachistima myrsinites)* habitat type in the Clearwater Mountains of northcentral Idaho.

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Study Area and Methods

The study area was located in the Clearwater Ranger District, Nezperce National Forest, northcentral Idaho. Twenty study sites were selected to obtain a range overstory canopy coverage, basal area, stand height and stand density. All sites were of the grand fir/myrtle boxwood habitat type as described by Daubenmire and Daubenmire (1968). Overstories varied in maximum age breast height from 65 to 192 years. Site elevations range from 1120-1620 m with aspects representing all cardinal directions and slopes ranging from 0–54%.

Vegetation measurements were made within a 375-m^2 circular macroplot established on each site. Overstory canopy coverage was measured using a spherical densiometer leveled at 1 m above the ground at the center of the macroplots (Lemmon 1956). The densiometer employs a highly polished, convex, chrome mirror to reflect a large overhead area. Diameter at breast height was measured for all conifer trees over 1.4 m and used to calculate basal area in m^2/ha and sum of tree diameters in m/ha. Average height in meters of the combined dominant and codominant crown classes was determined with a clinometer. All trees greater than 1.4 m high were counted and stem density expressed as number of trees per hectare.

The understory vegetation was divided into four above-ground vegetation classes: (1) shrub, (2) forb, (3) graminoid, and (4) total production. Current year growth of these vegetation classes was sampled between August 9 and 17, 1976, the period of near maximum above-ground production for the year. The circular macroplot was bisected perpendicular to the contour of the slope and five, 0.45 m^2 production microplots were systematically located in each half. One microplot in each half of the macroplot was randomly selected for harvesting. The vegetation production of each class in the remaining 4 microplots was estimated as a percentage of the production of their counter-part class in the microplot to be harvested (Mueggler 1976). All herbaceous vegetation in the harvest microplot was then clipped to the upper surface of the litter layer and separated into their respective vegetation classes. Current year growth of shrubs in the harvest microplot was clipped at the previous spring's bud scar. No vegetation above 3 m from the ground was included in the sample. The clippings were air-dried for 3 days, oven-dried for 12 hours at 60° C, and weighed.

Estimation error was assessed by clipping all 10 microplots at 3 of the study sites after estimating production as described above. A regression equation relating estimates to actual production was derived to correct for estimation error prior to calculating the production for each macroplot.

Canopy coverage and rooted frequency data were collected on each site to characterize species composition of the understory. Forty 2 × 5 dm microplots were systematically placed along two 20 m transects passing through the center of the macroplot, one parallel and one perpendicular to the contour of the slope (Daubenmire 1959).

The production and overstory data were plotted and inspected to ascertain appropriate regression models. Relationships between overstory structure (independent variables), and understory production (dependent variables) were analyzed using the general linear model (GLM procedure), stepwise regression maximum R^2 improvement (STEPWISE procedure), and all possible regressions (RSQUARE procedure) of the Statistical Analysis System (SAS) (Helwig and Council 1979). Two general linear models were considered appropriate and tested for significance:

(1) $Y = a + bX$
(2) $Y = a + bX^{-1}$
where Y= understory production
X = overstory variables.

The best significant ($\alpha \leq .01$) single variable model for each dependent variable was selected.

Multiple independent variable models were also explored. The 3 multiple independent variable models tested were:

(3) $Y = a+b_1X_1 +b_2X_2...b_nX_n$
(4) $Y = a+b_1X_1^{-1}+b_2X_2^{-1}...b_nX_n^{-1}$
(5) all possible combinations of (3) and (4) where X_i could be used only once in the equation either as b_iX_i or $b_iX_i^{-1}$.

If the multiple independent variable model yielded a higher coefficient of determination (R^2), then an F-test was used to determine if the multiple variable model R^2 value was significantly ($\alpha \leq .05$) greater than the R^2 of the single variable model.

Results

The overstory on all study sites was dominated by grand fir. However 6 additional subordinate tree species were present in various proportions among the stands (Table 1). Fifteen of the 20 sites had overstory coverage greater than 75% (Table 2). Overstory coverages of less than 50% on undisturbed sites in the Clearwater Mountains were uncommon. Coverage of less than 50% was normally the result of recent disturbances such as logging, fire or disease. Disturbed areas were not sampled since the degree of disturbance can affect plant composition and production making comparisons difficult. A total of 136 vascular plant species were encountered among all 20 study sites. Constancy, canopy coverage, and rooted frequency for selected species sampled at the study sites are shown in Table 3.

Total Production

The relationship between overstory canopy coverage and total production was found to be highly significant ($R^2 = 0.76$) (Table 4, Fig. 1). In addition, sum of the tree diameters and basal area were also significantly related to total production as single variables with R^2 values of 0.54 and 0.37, respectively (Table 4).

None of the multiple independent variable models accounted for a significantly greater portion of the variability in total understory production than the single variable models.

Shrub Production

Three overstory characteristics were significant in predicting shrub production. Canopy coverage, as a single independent variable, had the highest correlation with shrub production (Table 4, Fig. 2).

Other overstory structures significantly correlated with shrub production were sum of the tree diameters and basal area with R^2 values of 0.67 and 0.34 respectively (Table 4).

None of the multiple variable models accounted for significantly greater portions of variability than the single variable model.

Table 2. Mean ($\bar{x}$), standard deviation (s) and range of the overstory and understory variables studied in the grand fir/myrtle boxwood habitat type in the Clearwater Mountains of Idaho.

Variable	$\bar{x}$	s	Range
Overstory			
Sum of the diameters (m/ha)	147.5	46.5	59–214
Canopy coverage (%)	82.4	14.5	50–96
Stand density (trees/ha)	1406.0	1377.6	320–3040
Basal area (m²/ha)	34.0	14.2	14–67
Stand height (m)	27.2	7.2	11–34
Understory			
Total production (kg/h)[1]	370.0	174.4	153–807
Shrub production (kg/h)[1]	128.3	140.5	3–511
Forb production (kg/h)[1]	195.7	57.5	118–292
Graminoid production (kg/h)[1]	46.0	49.4	0–164

[1]Dry weight.

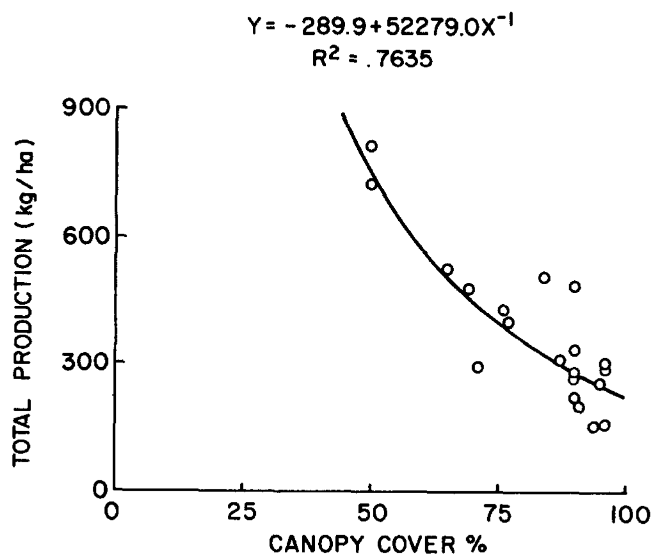

Fig. 1. *The relationship between total production (dry weight) and overstory canopy coverage in the grand fir/myrtle boxwood habitat type of the Clearwater Mountains of Idaho.*

Table 1. Mean ($\bar{x}$) and standard deviation (s) for three overstory structural features of tree species encountered in stands of grand fir/myrtle boxwood habitat type in the Clearwater Mountains of Idaho.

		Sum of the diameters (m/ha)		Basal area (m/ha)		Stand density (trees/ha)	
Species[1]	Common name	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Abies grandis	grand fir	112.2	53.7	24.8	18.6	849.4	685.6
Larix occidentalis	mountain larch	3.4	9.1	1.3	3.5	12.0	36.2
Picea engelmanii	engelmann spruce	10.0	23.7	3.2	8.7	37.8	76.1
Pinus contorta	lodgepole pine	.3	1.1	.1	.2	1.4	6.0
Pinus ponderosa	ponderosa pine	3.8	11.4	2.0	6.3	9.4	21.7
Pseudotsuga menziesii	Douglas fir	17.0	41.8	5.5	14.6	87.8	131.2
Taxis brevifolia	pacific yew	1.0	4.3	.7	2.9	8.0	35.8

[1]Nomenclature follows Hitchcock and Cronquist (1973).

Table 3. Constancy, canopy coverage, and rooted frequency for selected species encountered in stands of the grand fir/myrtle boxwood habitat type in the Clearwater Mountains of Idaho.

Species [1,2]	Common name	Constancy (%)	Canopy coverage[3] (%)	Rooted frquency[3] (%)
			$\bar{x} \pm s_{\bar{x}}$	
Understory trees				
Abies grandis	grand fir	85	9 ± 2	15 ± 3
Pseudotsuga menziesii	Douglas fir	50	2 ± 1	4 ± 1
Shrubs				
Acer glabrum	rocky mountain maple	70	7 ± 2	6 ± 1
Amelanchier alnifolia	western serviceberry	75	4 ± 1	5 ± 1
Chimaphila menziesii	little prince's pine	50	2 ± T[4]	6 ± 1
Chimaphila umbellata	prince's pine	60	2 ± T	16 ± 4
Linnaea borealis	twinflower	85	10 ± 2	50 ± 7
Lonicera ciliosa	trumpet honeysuckle	60	4 ± 1	12 ± 4
Lonicera utahensis	Utah honeysuckle	90	3 ± T	7 ± 1
Pyrola secunda	sidebells pyrola	85	1 ± T	8 ± 2
Ribes lacustre	prickly current	50	7 ± 5	9 ± 4
Ribes viscosissimum	sticky current	45	3 ± 2	6 ± 2
Rosa gymnocarpa	baldhip rose	100	6 ± 2	8 ± 2
Rubus parviflorus	thimbleberry	85	4 ± 2	6 ± 2
Symphoricarpos albus	common snowberry	85	15 ± 6	22 ± 8
Vaccinium membranaceum	big huckleberry	70	16 ± 6	23 ± 6
Xerophyllum tenax	beargrass	75	21 ± 5	18 ± 4
Perennial graminoids				
Bromus vulgaris	columbia brome	90	7 ± 1	25 ± 4
Carex rossii	ross sedge	85	6 ± 1	18 ± 4
Festuca occidentalis	western fescue	60	2 ± T	8 ± 2
Perennial forbs				
Adenocaulon bicolor	trail-plant	90	6 ± 2	25 ± 6
Anemone piperi	piper's anemone	95	4 ± 1	38 ± 4
Arenaria macrophylla	bigleaf sandwort	75	4 ± 1	23 ± 4
Clintonia uniflora	beadlily	100	5 ± 1	23 ± 4
Coptis occidentalis	Idaho goldthread	100	12 ± 2	60 ± 6
Fragaria vesca	woods strawberry	95	3 ± 1	22 ± 4
Galium triflorum	sweetscented bedstraw	85	3 ± 1	21 ± 4
Goodyera oblongifolia	western rattlesnake plantain	75	2 ± 1	10 ± 3
Hieracium albiflorum	white-flowered hawkweed	80	2 ± T	19 ± 3
Mitella stauropetala	side-flowered miterwort	80	2 ± T	15 ± 4
Osmorhiza chilensis	mountain sweetroot	90	2 ± T	14 ± 2
Pedicularis racemosa	leafy lousewort	75	2 ± 1	15 ± 3
Smilacina stellata	starry solomon-plume	95	4 ± 1	21 ± 3
Thalictrum occidentalis	western meadowrue	80	7 ± 1	20 ± 4
Tiarella trifoliata	foamflower	70	3 ± 1	16 ± 4
Trillium ovatum	western trillium	80	2 ± T	10 ± 2
Viola orbiculata	darkwoods violet	75	4 ± 1	42 ± 6

[1]Nomenclature follows Hitchcock and Cronquist (1973).
[2]Only those species which have constancies of 50% or greater are shown.
[3]Values represent averages based only on those macroplots in which the species was found.
[4]T = less than 0.5% coverage.

Forb Production

Overstory canopy coverage was the only significant, single variable related to forb production ($R^2 = 0.32$) (Table 4, Fig. 3). A multiple independent variable model combining overstory canopy coverage and sume of the tree diameters accounted for a significantly greater ($\alpha \leq 0.05$) variation than the single variable model alone ($R^2 = 0.47$) (Table 4).

Graminoid Production

The graminoid production was not significantly correlated with any of the measured overstory structures in both single and multiple independent variable models.

Discussion

Overstory canopy coverage, as measured with a spherical densiometer, was the best single independent variable for predicting the production of all understory vegetation classes except graminoids. Reifsnyder and Lull (1965) demonstrated a high correlation between overstory canopy coverage, as measured with a spherical densiometer, and light intensity and net radiation at the forest floor. Vezina and Pech (1964) and Reifsnyder and Lull (1965) have shown that measured light interception can be 60 to 100% in the range of canopy coverages examined in our study depending upon needle and branch density in the canopy of the stand.

The spherical densiometer integrates several structural features of the overstory into a single measurement of canopy coverage. Because of the convex curvature of the mirror, the view of the overstory canopy is like that of a wide angle lens with an infinite depth of field. At the center of the mirror, crown width is the predominant structural tree feature observed. Near the periphery of the mirror within the estimation grid, crown length, vertical bole area, and bole density become increasingly important structural features contributing to canopy coverage. The spherical densiometer accounts for a large portion of the total overstory which can inhibit light penetration to the understory, especially light penetrating the canopy from low angles.

Sum of tree diameters was found to be a good predictor of shrub

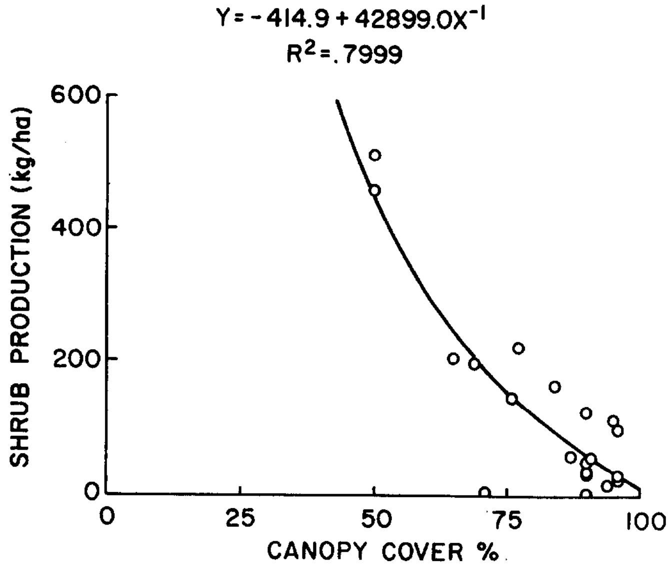

Fig. 2. *The relationship between shrub production (dry weight) and overstory canopy coverage in the grand fir/myrtle boxwood habitat type of the Clearwater Mountains of Idaho.*

Table 4. Coefficients of determination (R^2) and regression equations for estimating production (Y) in kg/ha of understory vegetation using sum of the diameters of tree (S) in m/ha, overstory tree canopy coverage (C) in % and basal area (B) in m^2/ha as independent variables for the grand fir/myrtle boxwood habitat type in the Clearwater Mountains of Idaho. All models are significant at $\alpha \leq 0.01$.

Vegetation class	Independent variables		Model	R^2
Total Production				
	C		$Y = -289.9 + 52279.0\ C^{-1}$	.7635
	S		$Y = 81.0 + 39048.7\ S^{-1}$	.5362
Shrubs				
	C		$Y = -414.9 + 42899.0\ C^{-1}$	.7999
	S		$Y = -131.6 = 34891.4\ S^{-1}$	.6661
	B		$Y = 65.3 + 5129.9\ B^{-1}$	.3385
Forbs				
	C	S	$Y = 388.5 - 3.6\ C + 0.7\ S$	.4738
	C		$Y = 380.0 - 2.2\ C$	.3216

and total understory production. This variable is easily measured and calculated and is readily available from timber survey data. This parameter has been shown to be closely related to the length and basal width of live tree crown (Arnold 1948), and also a good index of the transmission of solar radiation (Miller 1959, Reifsnyder and Lull 1965, Wellner 1948, Vezina and Pech 1964).

In contrast to sum of tree diameters, basal area was a poor predictor of all understory production classes. Basal area gives little weight to small bole diameter trees which can provide a substantial amount of light intercepting crown (Miller 1959). Basal area will generally increase with stand age and will not consistently reflect changes in the canopy due to the establishment or death of small bole diameter trees.

It is important to realize that sum of tree diameters and basal area do not completely represent the mass and distribution of the canopy that intercepts light in a forest stand. Assmann (1970) concluded that stem diameter and area cannot be considered at all times as a close correlate to canopy structure. In a completely closed stand where lateral growth of the crown is limited, stem diameters will continue to increase. When such a stand is thinned to substantially reduce canopy coverage, crown size increases at a faster rate than the stem diameters. Bole measurements serve only as estimations of canopy structure which actually intercepts solar radiation, where spherical densiometer measurements will more accurately reveal changes in the canopy.

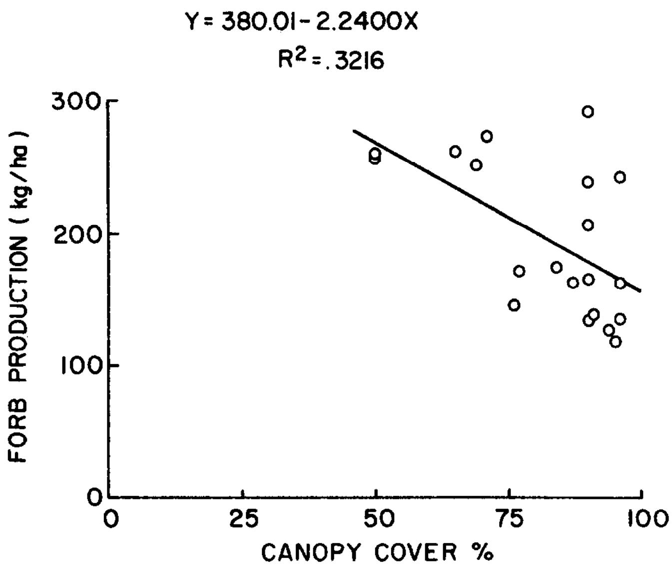

Fig. 3. *The relationship between forb production (dry weight) and overstory canopy coverage in the grand fir/myrtle boxwood habitat type of the Clearwater Mountains of Idaho.*

Stand height as a single independent variable was least correlated with production in all vegetation classes. When stand height was entered into a two variable model with canopy coverage or the inverse of canopy coverage, significantly correlated models were derived with coefficients of determination greater than models containing canopy coverage alone. Yet *F*-tests demonstrated that no significant additional variance was explained by the addition of stand height.

Stem density was not significantly correlated with any of the vegetation classes in single or multiple independent variable regression models. This could be attributed to the fact that as the canopy develops the stem density may remain constant and thus not reflect the decrease in light penetration to the understory.

Graminoid production was the only understory vegetation class not correlated with any of the measured overstory structural features. Thirteen species of graminoids were encountered among all the stands sampled; however, only 3 contributed significantly to understory production. These were, in decending order of abundance, columbia brome, ross sedge, and western fescue (Table 3). Graminoid production varied from 0–57 kg/ha under both high and low canopy coverage. Daubenmire and Daubenmire (1968) showed similar variation in graminoid abundance among climax stands of the grand fir/myrtle boxwood habitat type of northern Idaho and eastern Washington. The results of Daubenmire (1953) and Moir (1966) suggest that the soil nutrient status may be a major factor determining the growth response of graminoids under shaded conditions.

Conclusions

Our results indicate that understory production is closely correlated with overstory canopy coverage and sum of the tree diameters on undisturbed sites of the grand fir/myrtle boxwood habitat type. Since both overstory characteristics are good indices of solar radiation transmission through tree canopies to the understory, the data indicate that solar radiation is a major limiting factor of understory production in this study area. Both overstory characteristics are easily measured, and in the case of tree diameters, readily available from timber survey data. Use of such parameters would greatly facilitate estimation of understory production for range inventory purposes. Further examination of the models is needed to verify these relationships over the range of the grand fir/ myrtle boxweed habitat type.

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