Down woody material, litter, and duff characteristics in an old-growth Sierran mixed-conifer forest (Yosemite Forest Dynamics Plot): assessing correlation with overstory and topographic variables

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Background

•The Yosemite Forest Dynamics Plot (YFDP) is a 25.6 ha long-term ecological research plot consisting of 20m by 20m cells.
•All trees with a diameter at breast height greater than 1 cm have been measured, tagged, and mapped.
•Shrubs and downed woody debris (DWD) with a large end diameter greater than 50cm were measured and mapped.
•Fine and downed woody fuel data were measured in July, 2010.
•Field crews will return to the plot yearly to monitor changes in forest dynamics.
•Long-term goals of YFDP are to monitor change in forest structure and demographics, forecast change pertaining to global changes in climate, and provide spatially-explicit fire and fuels data for the Yosemite NP wildland fire use program.

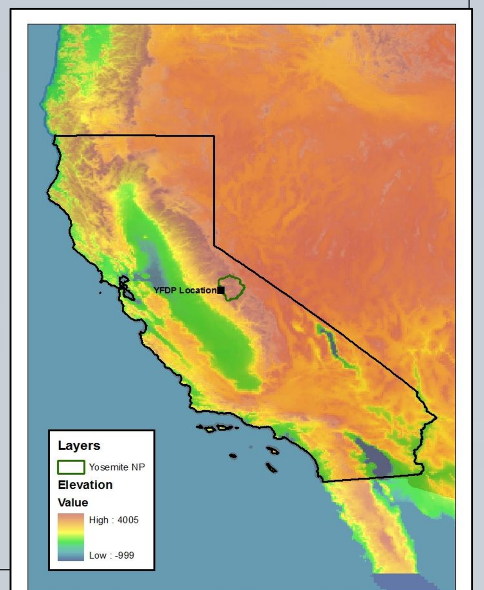

Figure 1. Location of the Yosemite Forest Dynamics Plot.

Introduction

• Old-growth mixed-conifer forests of the Sierra Nevada range represent some of the largest conifer forests in the world in terms of stature and biomass.
•In Yosemite NP, fire suppression has significantly altered the natural forest structure and fuel profiles.
•Down woody debris in large amounts can be negative as a factor in wildfire behavior, but some is necessary to provide habitat to both plant and animal species.
•Fine fuels (litter and duff) can be important nutrient sources and provide microhabitats for insects, fungi, and bacteria.
•Studies have shown that snag and DWD volumes vary topographically in tropical forests (Gale 2000).
•**It was our goal to assess correlations between fuel loads and predictors related to the forest overstory and topography, thus addressing the possibility for statistical models predicting fuel loads.**

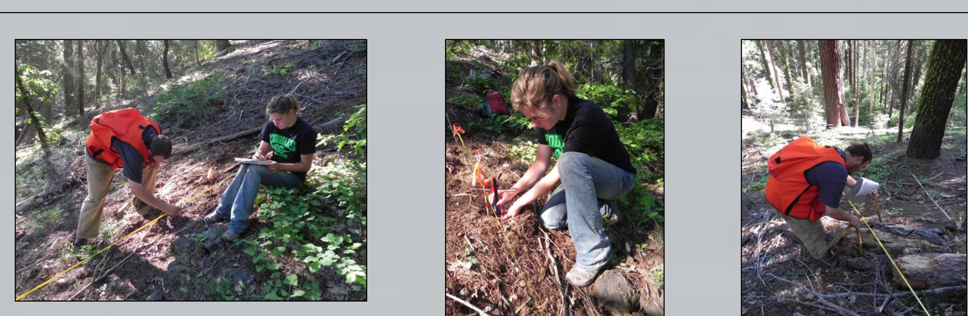

Figure 2. (*Left to right*) Tallying fine woody debris; Measuring depth of litter and duff; Sampling a piece of DWD along fuel transect.

Methods

Site location and description

The YFDP is located in an old-growth mixed-conifer stand in northwestern Yosemite National Park, near Crane Flat. Soils are palexeralfs on 15-45% slopes (USDA-NRCS 2007). Conifers dominate the overstory, with sugar pine (*Pinus lambertiana*), California white fir (*Abies concolor*), and incense cedar (*Calocedrus decurrens*) the most frequent. California black oak (*Quercus kelloggii*) is also present but in lesser amounts than the conifers. There is minimal anthropogenic disturbance via harvest, but historic forest structured has been altered significantly due to fire suppression.

Methods (cont.)

Forest floor depth

Forest floor characteristics (litter and duff) were sampled using line-intercept methods, using 20m transects. Depth measurements were taken at 1m, 5m, 10m, and 15m along the transect. Duff was considered to be the fibric layer consisting of decaying organic matter directly above mineral soil. The litter was the looser, undecomposed layer above the duff. A profile view of the layers was exposed and depths measured using electronic calipers.

Down woody debris sampling

DWD (≥3in.) was sampled continuously along the perimeter of the YFDP using the line-intercept method. Sampling protocol has been adopted from Van Wagner (1968) and Brown (1974). All DWD was tallied, measured, and assigned a decay class rating (1-5, with 1 being least decayed and 5 the most decayed).

Overstory variables

All trees with a DBH≥1cm were permanently marked with a steel tag during surveying of the YFDP. Species, DBH, status (live/dead), vigor class, and snag class were recorded for each tagged tree. Exact tree locations were determined using handheld laser rangefinders and compasses, based off the high-precision surveyed grid of 20m by 20m cells. DBH was used to calculate basal area (BA) for both live trees and dead snags.

Analysis

The R environment for statistical analysis was used for data exploration and analysis (http://www.r-project.org/).

Down Woody Debriss

Since down woody debris was estimated using the line-intercept method, the equation given by van Wagner (1968) and Harmon and Sexton (1996) was used to estimate volumes. Volumes were estimated by species, decay class, and 20-m transect segment. Volume estimates were then multiplied by species- and decay-class-specific tissue bulk densities (Harmon and Sexton 1996).

Duff/Litter

We used the non-linear regression equations from Stephens et al. (2005) to predict overall dry weight biomass in the combined duff and litter layers as a function of measured depth.

Statistical modelingg

Histograms show the distribution of woody debris diameters encountered along line-intercept transects. Linear regression models were used to relate forest floor and DWD variables to topographic and overstory predictors (phase-shift transformed aspect, slope, live overstory basal area, and snag basal area).

Results

Volume and Biomass

As shown in *Figure 3,* the majority of the fuel transects had less than 500 m^3 ha^{-1} and less than 150 Mg ha^{-1} DWD. Mean DWD volume was estimated at 240 m^3 ha^{-1} (SE=42.0). Total mean DWD mass was estimated at 53.1 Mg ha^{-1} (SE=9.7). *Table 1* and *Table 2* reveal that the overall volume and biomass are dominated by sugar pine and white fir, primarily in decay classes 3 and 4. Figure 4 can also help explain the dominance of sugar pine and white fir, illustrating that these two species account for a high proportion of pieces sampled across most diameter classes.

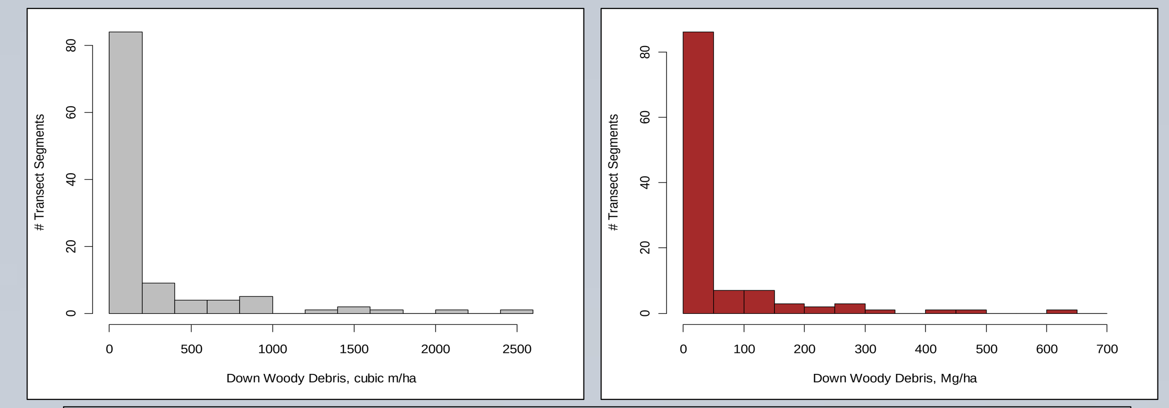

Figure 3. Frequency histograms illustrating the volume ha^{-1} and biomass ha^{-1} for the fuel transects.

Volume (m^3 ha^{-1})	Decay Class				
Species	*1*	*2*	*3*	*4*	*5*
Abies concolor	0.48	5.28	35.55	38.19	5.29
Calocedrus decurrens	-	0.2	11.29	-	-
Pinus lambertiana	0.53	5.24	106.73	21.68	-
Quercus kelloggii	-	-	2.66	-	-
Unknown	-	-	0.64	6.47	0.29

Table 1. Volume (m^3 ha^{-1}) separated by species and decay class.

Biomass (Mg ha^{-1})	Decay Class				
Species	*1*	*2*	*3*	*4*	*5*
Abies concolor	0.16	1.76	7.18	7.06	0.98
Calocedrus decurrens	-	0.07	3.7	-	-
Pinus lambertiana	0.19	1.85	24.55	3.75	-
Quercus kelloggii	-	-	0.74	-	-
Unknown	-	-	0.18	0.89	0.04

Table 2. Biomass in (Mg ha^{-1}) separated by species and decay class.

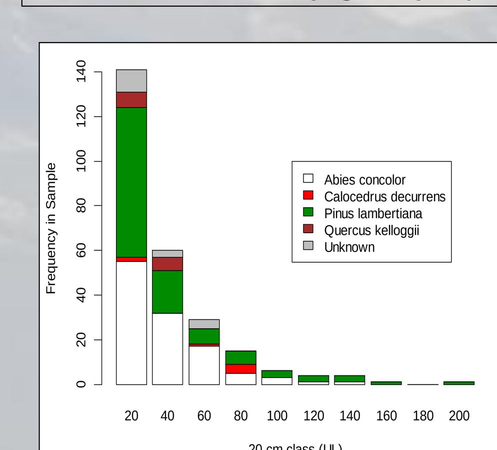

Figure 4. Diameter distribution of DWD by species based on 20cm diameter classes, inclusive of all decay classes.

Correlation to Slope and Aspect

When the DWD volume was plotted against the topographic variables slope and aspect, it appears that the highest volumes tended to occur on the lower to middle slopes and on northern aspects (see *Figure 5*). However, no statistically significant correlation was found for either variable (p_{slope}=0.22; p_{aspect}=0.13).

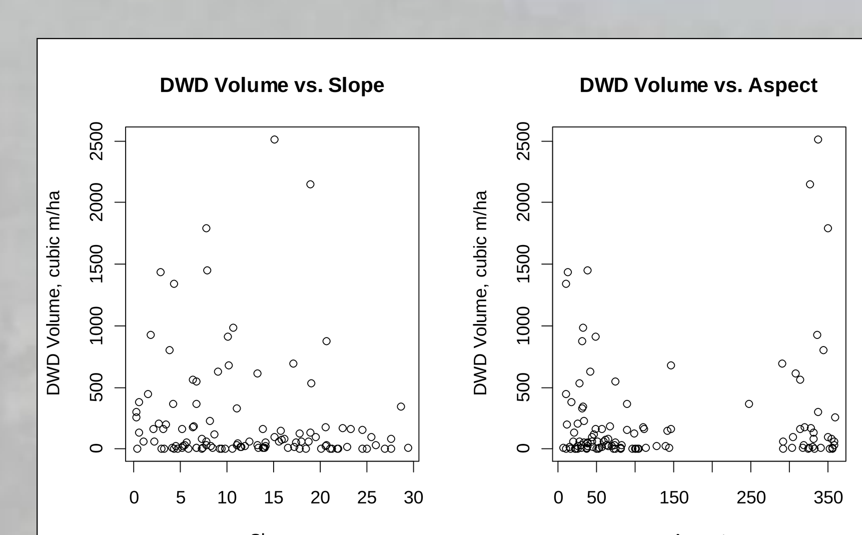

Figure 5. Scatter plots correlating DWD volume and topography. Regression ANOVA proved no significant correlation of DWD volume with either slope (p=0.22) or aspect (p=0.13).

Correlation to Overstory

Live overstory basal area was a weak predictor of DWD volume/mass, but had no relation to forest floor variables. Snag basal area had a weak predictive relationship with all four forest floor variables. Note the reciprocal relationship of the predictors to woody debris vs. litter/duff.

Predictor	Predicted	Equation	p-value	R^2
Live BA	DWD volume	467.58-85.71**LiveBA*	0.00466	0.06000
Live BA	DWD mass	104.5181-0.7760**LiveBA*	0.00570	0.05891
Live BA	Litter depth (cm)	-	0.41340	NS*
Live BA	Duff (cm)	-	0.89510	NS*
Live BA	Floor (cm)	-	0.65660	NS*
Live BA	Floor, Mg	-	0.77110	NS*
Snag BA	DWD volume	-	0.11400	NS*
Snag BA	DWD biomass	-	0.25780	NS*
Snag BA	Litter depth (cm)	2.1466+0.0191**SnagBA*	0.00562	0.05900
Snag BA	Duff (cm)	2.7781+0.02212 **SnagBA*	0.04096	0.02868
Snag BA	Floor (cm)	4.92475+0.04118**SnagBA*	0.00944	0.05113
Snag BA	Floor, Mg	117.1471+1.1598**SnagBA*	0.01415	0.04488

Table 3. Using regression ANOVA, predictor variables were compared with predicted variables to find significant correlations.
**NS – Not significant*

Spatial Analysis

Correlogram analysis showed that no significant spatial autocorrelation at >20m occurred in either DWD or forest floor mass. This suggests that sampling can occur at relatively fine spatial scales, and modeling need not include a spatial autocorrelation term.

Conclusions

Our results suggested no strong statistical correlation between fuel loads and topography/overstory, an unexpected outcome. An advantage of this is that sampling designs can be simplified when measuring DWD and forest floor depth. Sampling designs need not be stratified by slope and/or aspect. The nature of the woody debris data surveyed has implications with regards to fuel bed characteristics if fire suppression persists. Due to fire suppression, sugar pine has decreased in dominance due to competition with white fir. If fire suppression efforts continue, this will create a short-term influx of sugar pine debris. Long-term mortality of sugar pine due to increased competition with white fir will eventually shift the diameter distribution in Figure 4 to the left, resulting in a loss of large diameter sugar pine DWD, and an increase in smaller diameter white fir debris. If fire were reintroduced to resemble the historic fire regime, small-diameter white fir debris would be reduced and large-diameter sugar pine debris would become more abundant. This would shift the diameter distribution in Figure 4 from a negative exponential curve to a modal distribution (e.g., Weibull curve with s>2). A shift in mean DWD diameter has ecological implications as well, as smaller-diameter fuels will be consumed more readily in fire events. Post-fire DWD distribution may be reduced significantly, reducing fuel loads, but possibly resulting in a reduction of habitat for DWD-dependent organisms. Finally, DWD mass of YFDP is comparable to other international forest types under the current fire suppression regime (see *Figure 6)*, but may be reduced in the future.

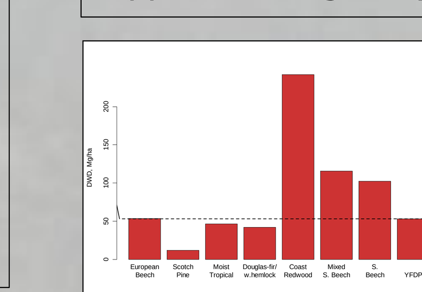

Figure 6. DWD mass of YFDP in relation to DWD mass of other forests, including on other continents.

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