Chapter 2: Pretreatment Variation in Overstory and Understory Vegetation

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Introduction

Changes in forest vegetation as a result of fire exclusion, sheep and cattle grazing, and large-tree logging have been well documented for western forests (Agee 1998; Arno et al. 1997; Covington and Moore 1994; Everett et al. 2000; Harrod et al. 1999; Hessburg and Agee 2003; Hessburg et al. 2000, 2005). These changes in forest structure and composition have increased the hazard of large, high-severity wildfires (Agee 1994, Peterson et al. 2005, Scott and Reinhardt 2001, Weatherspoon and Skinner 1996), which lead to degraded water quality and costly losses of wildlife habitat, wood products, and residential buildings (Armstrong and Cumming 2003). In addition, current forests have increased vulnerability to many insects and diseases (Hessburg et al. 2005); have altered understory diversity, composition, and abundance (Covington et al. 1997, Hall 1977, Smith and Arno 1999); and generally have an overall deterioration in forest ecosystem integrity (Everett et al. 1996). A reduction in the current risks of uncharacteristically severe wildfires and insect outbreaks is desirable for local communities and many land managers. Before restoration activities are planned, it is important to understand the current variability in vegetation so that treatment effects can be appropriately interpreted.

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Current dry forest landscapes have become homogeneous in their composition and structure (Hessburg et al. 2005), but variable vegetation patterns at small scales still exist. Restoration treatments are designed to incorporate natural or historical fire regimes, which promote heterogeneous landscapes, reduce stand density, raise height to live crown, and lead to tree clumping at fine scales (Agee 1993, Harrod et al. 1999). However, restoration treatments are often implemented with minimal information of how current, local vegetation patterns and composition will respond to treatment. Thus, better information is needed about the pretreatment structural and compositional elements of dry forests, so that treatment effects can better be distinguished from vegetation variability. The national Fire and Fire Surrogates (FFS) study was designed to be a long-term research project to evaluate treatment alternatives, but it also provides an opportunity to quantify pretreatment structure and composition of forest vegetation.

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In this paper, we describe the pretreatment overstory and understory vegetation at the Mission Creek site, with the specific purpose of determining potential differences in vegetation variables among units that are assigned to specific treatments. The specific objectives for the pretreatment overstory measurements were to:

1. Quantify the pretreatment forest structure within treatment groups and the variability among treatment units.
2. Determine how biophysical factors affected initial forest characteristics.
3. Determine potential effects of pretreatment structural variability on subsequent analyses.

The specific objectives for the pretreatment understory measurements were to:

1. Describe the understory plant community, including variability among and within units, and test for significant pretreatment differences among units assigned to specific treatments.
2. Identify environmental variables that are associated with the understory community.
3. Examine the relationship between overstory trees and understory vegetation.
4. Compare pretreatment species cover and richness between sampling years (2000 or 2001).

Sampling of overstory and understory vegetation was conducted on a series of fixed-area plots that were permanently established within each treatment unit.

Methods

Sampling Design

Sampling of overstory and understory vegetation was conducted on a series of fixed-area plots that were permanently established within each treatment unit. Based on a preliminary analysis of an adjacent site, it was determined that six, 20- by 50-m plots would adequately capture the within-unit variability and provide an accurate estimate of vegetation characteristics. In summer 2000, the sample plots were nonrandomly located in areas of continuous forest vegetation and were stratified to include the most dominant plant associations within each unit. Sampling of understory and overstory vegetation occurred in 2000 and 2001.

Overstory Sampling and Analysis

Within each sample plot, all live and standing dead trees >7.62 cm diameter at breast height (d.b.h.) were identified; permanently numbered; and measured for diameter, total height, height to crown base (height from tree base to the intersection of the lowest live limb at the tree bole), bole scarring, and crown condition (e.g. Hawksworth 1977, Keen 1943). Diameters were measured using a diameter tape, and heights were estimated using a clinometer. Saplings (height >1.37 m, diameter

<7.62 cm) were tallied by species at the plot level. Canopy closure was estimated at the four cardinal directions from the center of the plot using a Lemmon Spherical Densiometer, Model-A. Canopy cover was then calculated by averaging the four measurements, multiplying its inverse by 1.04 and subtracting it from 100 (Lemmon 1956). Slope was measured at each plot using a clinometer, and aspect was measured using a compass.

Data were averaged up from the plot level to the experimental-unit level for all analyses unless otherwise noted (Hurlbert 1984). Live trees, snags, and saplings were analyzed separately. Folded aspects were calculated for each following plot, where aspect values range from 0 (NE slopes) to π (SW slopes). Heat load index (HLI) was calculated for each plot using equation 3 of McCune and Keon (2002), where slope, aspect, and latitude are used to estimate incident radiation. Values for HLI range from 0 to 1 with 0 representing cool NE-facing, shallow slopes and larger numbers representing warmer, SW-facing steep slopes. Canopy bulk density, canopy base height, and canopy fuel loading were calculated using the Crown Mass model included in the Fire Management Analyst (FMA) software package. Data were entered into the program at the plot level for these analyses.

A two-factorial analysis of variance was used to identify initial differences in forest structural components among treatments prior to the experiment. Unlike the understory analysis (see below), the experimental design was a balanced completely randomized design. Factors were burn (two levels: burn or no burn) and thin (two levels: thin or no thin). Least square means were used to compare significance between treatments, and the experiment-wise error rate was controlled using the Tukey-Kramer adjustment for multiple comparisons. Two plots were removed from all overstory analyses because they were outside of the fire line and were mistreated during the prescribed burn in 2004. For purposes of future integration of these data with subsequent analyses, these two plots were removed from the current analyses. A significance level of $P < 0.10$ was set prior to analyses.

Correlation analysis was conducted to determine significant relationships between overstory structural characteristics and environmental factors. Data were averaged to the plot level ($n = 70$), and Pearson's correlation coefficients were computed for each combination of variables. Significant correlations were based on $P < 0.10$.

Understory Sampling and Analysis

The 72 permanent 20- by 50-m plots used to sample trees were also used for sampling understory vegetation. Ten nested 5- by 10-m subplots placed in a continuous 10- by 50-m strip in the center of each plot were used to collect shrub cover.

Cover was ocularly estimated to the nearest percentage point. Also, twenty 1- by 1-m quadrats were nested in each plot in a stratified random fashion for sampling herbaceous vegetation. In each quadrat, all herbaceous species were inventoried and their cover ocularly estimated to the nearest percentage point.

Cover for each shrub and herbaceous species (forbs and graminoids) were averaged to the plot level for each species (n = 72). Average cover and richness (number of species on each plot) were then calculated for each site. Species were grouped into shrubs, forbs, and graminoids (Collins et al. 2007, Metlen and Fielder 2006). Understory variability in cover and richness was partitioned into within- and among-site components using a Hierarchical Linear Model in the SAS (Littell et al. 1996) Proc Mixed procedure (Singer 1998). The simplest Unconditional Means Model was fit with the overall mean as the fixed effect and two variance components—one within units and one among units (Raudenbush and Bryk 2002, Singer 1998). Variability in understory plant cover and richness was partitioned into within- and among-site components for each life form (shrub, forb, and graminoid) as well as overall cover and richness.

Pretreatment differences in units assigned to treatments were evaluated using a general linear model in SPSS (2001). Prior to analysis, all data were averaged to the site level where the treatments were to be applied later (n = 12 units). Thinning (yes or no) and burning (yes or no) were treated as fixed factors in the model applied in factorial combination. As posttreatment understory data were collected in 2005 and two units were not burned until 2006, the analysis was unbalanced in regard to burning (eight units unburned, four units burned), but balanced in regard to thinning. Separate tests were performed for richness and cover of each life form and overall richness and cover of all understory species. Marginal means were used to estimate the mean value and standard error for each of the four treatments with each variable for interpretation of the statistical tests.

The influence of environmental variables on community composition was assessed using nonmetric multidimensional scaling (NMS) (McCune and Grace 2002). We used the slow and thorough autopilot mode in PC-ORD (McCune and Mefford 1999) with a stepdown from six dimensions, with a random starting configuration and Sorenson distance measure. A Monte Carlo test with 250 randomizations was performed to determine the likelihood of obtaining as good a solution by chance. All species (including those that were uncommon) were included in the analysis. The final NMS solution had three axes, and correlations with environmental variables were calculated for each axis. Those with an r^2 greater than 0.2 were plotted on the graphs with site scores.

Relationships between overstory and understory variables were assessed using Pearson correlations in SPSS (2001). All data were averaged to the plot level (n = 72) for these analyses. Four measures of overstory trees, basal area, trees per hectare, canopy cover, and percentage of trees per hectare that are ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) were correlated with understory richness and cover for each life form and overall.

Total understory cover and richness were averaged to the site level for each year of pretreatment sampling (2000 or 2001) to determine if obvious trends between years were evident. Means and standard errors for cover and richness were calculated for each site in each year to look for systematic year biases. One site (Sand 19) had three plots sampled in each year. Therefore, the three plots sampled in each year were considered separately.

Diameter distributions for each unit were generally bell-shaped indicating an even-sized structure.

Results and Discussion

Overstory Structure and Composition

Forest density and stocking were similar among the study units prior to the experiment (table 2-1). Live tree density averaged 589 (standard error [SE] = 52) trees/ha, and basal area averaged 33.2 (SE = 1.5) m^2/ha over all treatment units. Diameter distributions for each unit were generally bell-shaped indicating an even-sized structure; however, the distribution of tree diameters on higher elevations

Table 2-1—Pretreatment structural characteristics for each treatment combination at the Mission Creek study site

	Control		Burn		Thin		Thin-Burn	
Structural characteristic	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Live tree density (trees/ha)	593	104	478	79	627	125	659	135
Basal area (m^2/ha)	33.5	0.5	31.9	5.9	34.5	2.9	33.1	2.1
Stand density index	616	16	572	97	643	42	626	43
Quadratic mean diameter (cm)	28.8	1.5	29.9	0.1	27.7	2.5	26.2	1.7
Overstory ponderosa pine (% of trees)	22.2	15.2	56.5	20.0	43.8	26.4	40.7	28.2
Canopy cover (%)	87.6	1.8	79.1	4.4	82.4	7.9	87.7	6.3
Canopy height (m)	18.7	0.7	18.9	0.5	19.1	0.1	17.8	0.1
Canopy base height (m)	3.9	0.6	3.8	0.7	4.6	0.6	4.2	0.7
Canopy bulk density (kg/m^3)	0.077	0.002	0.067	0.008	0.080	0.007	0.078	0.006
Snag Density (snags/ha)	58.3	11.1	49.2	13.8	51.1	17.5	30.6	11.3
Snag basal area (m^2/ha)*	1.4ab	0.4	1.8ab	0.3	2.5b	0.3	0.8a	0.4

SE = standard error, n = 3.

* No significant differences were found between treatments for forest structural components, with the exception of snag basal area. For this variable, cells with different letters are significantly different ($p < 0.1$), with analyses based on post hoc pairwise comparisons.

units tended to be slightly irregular (i.e., Ruby and Camas). Units dominated by Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) had higher densities of understory or subcanopy trees, particularly in the 10- to 20-cm d.b.h. class (fig. 2-1). Density, basal area, and stand density index (SDI) were somewhat lower on burn-only units as compared to the other treatments, but the differences were not significant. Tree density was higher on cooler, NE-facing units and on steeper slopes (tables 2-2 and 2-3). These sites are generally less water-limited, and dense understory tree layers often form under these conditions. Basal area was not correlated with either aspect or

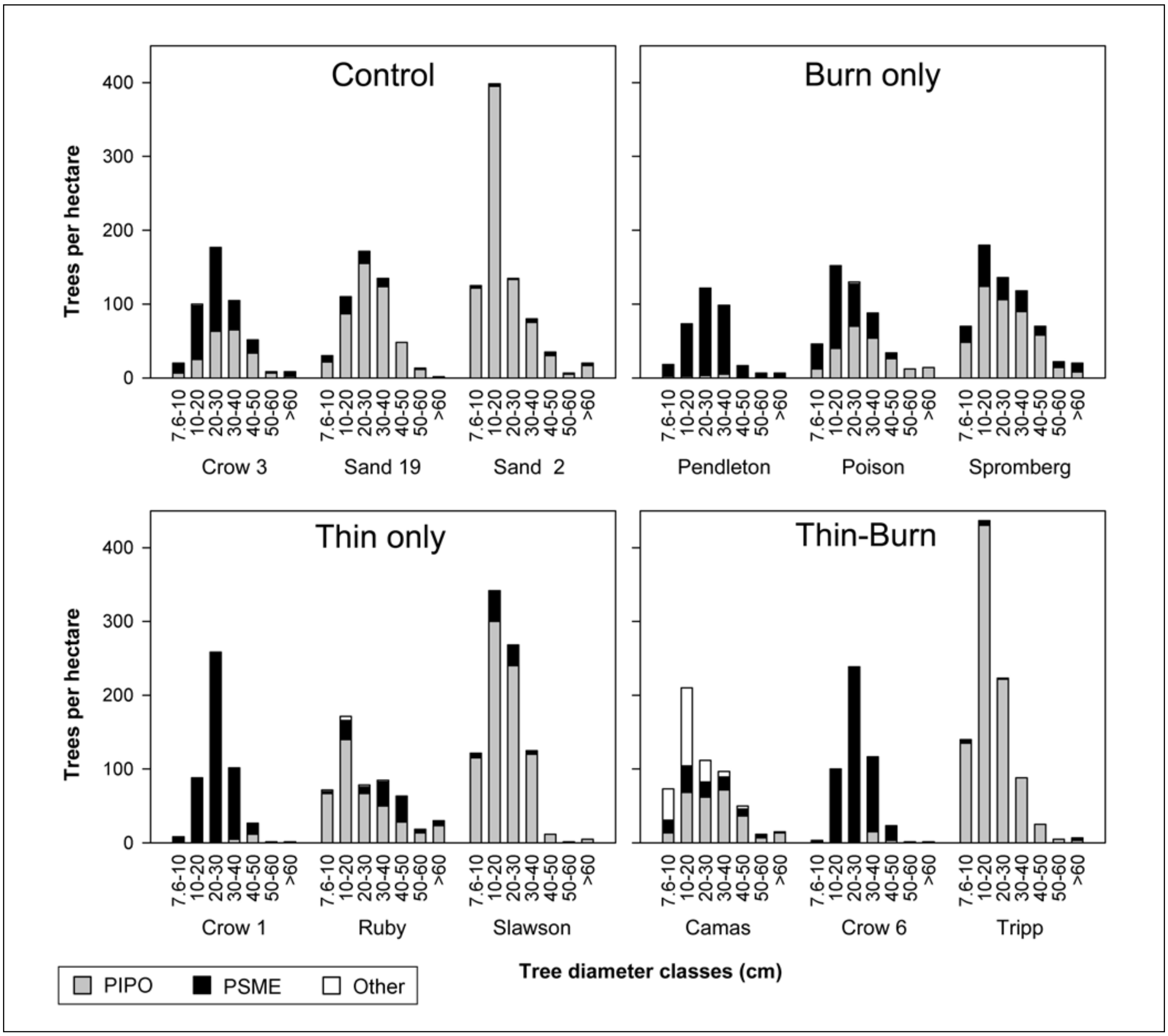

Figure 2-1—Diameter distributions for live trees located on treatment units within the Mission Creek study site. Units are arranged by treatment based on a balanced design with three replications per treatment combination. PIPO = *Pinus ponderosa*; PSME = *Pseudotsuga menziesii*.

HLI, most likely because the large number of small-diameter trees on the cooler sites does not contribute appreciably to basal area. Quadratic mean diameter was similar among treatments and averaged 28.1 (SE = 0.8) cm. Average diameters were larger on drier units where densities of small understory trees were lower.

Douglas-fir represented over half of the trees on experimental units and ponderosa pine made up >40 percent.

Douglas-fir represented over half of the trees on experimental units and ponderosa pine made up >40 percent (fig. 2-1). Ponderosa pine dominance was somewhat lower on control units and higher on thin-only units, but there were no significant differences between treatments. Although there was much variability in species

Table 2-2—Treatment unit descriptions, including treatment applied (planned treatment in parentheses), topographic attributes, and forest structural characteristics for the Mission Creek study sites

Treatment unit	Treatment description	Mean elevation	Mean slope	Folded aspect	Heat load index	Tree density	Tree basal area
		Meters	*Percent*			*Trees/ha*	*(m^2/ha)*
Crow 3	Control	747	38	2.17	0.87	470 (48)	32.5 (1.9)
Sand 19	Control	780	43	2.46	0.93	510 (93)	34.0 (3.1)
Sand 2	Control	683	58	1.40	0.70	800 (129)	34.1 (1.6)
Pendleton	Control (burn only)	841	16	2.59	0.91	342 (70)	22.7 (2.3)
Poison	Burn only	768	40	2.50	0.90	476 (77)	30.2 (2.8)
Spromberg	Burn only	848	57	2.36	0.90	616 (48)	42.7 (3.5)
Crow 1	Thin	738	21	2.18	0.90	487 (54)	29.0 (2.3)
Ruby	Thin	975	43	2.60	0.94	518 (104)	38.7 (4.9)
Slawson	Thin	838	35	1.39	0.81	875 (132)	44.6 (3.4)
Crow 6	Thin (thin-burn)	718	26	2.04	0.84	568 (98)	34.1 (4.9)
Camas	Thin-burn	1097	43	1.30	0.73	485 (38)	29.0 (2.4)
Tripp	Thin-burn	765	67	0.79	0.57	925 (116)	36.1 (2.6)

Note: Numbers in parentheses for tree density and basal area are standard errors.

Table 2-3—Pearson's correlation coefficients (r) for basic overstory structural and compositional components and biophysical environment

Variable	Slope (percent)	Folded aspect	Heat load index	Tree density (trees/ha)	Pine percentage of trees	Basal area (m^2/ha)	Mean diameter (cm)	Canopy cover (percent)	Sapling density (trees/ha)	Snag density (snags/ha)
Slope (percent)	1.00	**-0.31**	**-0.46**	**0.28**	**-0.64**	0.21	-0.15	**0.26**	-0.14	0.08
Folded aspect	**-0.31**	1.00	**0.92**	**-0.47**	**0.37**	0.00	**0.55**	**-0.33**	**-0.32**	-0.19
Heat load index	**-0.46**	**0.92**	1.00	**-0.39**	**0.38**	0.07	**0.50**	**-0.29**	-0.23	-0.11
Tree density (trees/ha)	**0.28**	**-0.47**	**-0.39**	1.00	**-0.44**	**0.50**	**-0.76**	**0.39**	**0.46**	**0.44**
Overstory ponderosa pine (percentage of trees)	**-0.64**	**0.37**	**0.38**	**-0.44**	1.00	**-0.44**	0.10	**-0.59**	-0.18	-0.18
Basal area (m^2/ha)	0.21	0.00	0.07	**0.50**	**-0.44**	1.00	0.09	**0.44**	0.07	**0.36**
Mean diameter (cm)	-0.15	**0.55**	**0.50**	**-0.76**	0.10	0.09	1.00	-0.10	**-0.39**	**-0.29**
Canopy cover (percent)	**0.26**	**-0.33**	**-0.29**	**0.39**	**-0.59**	**0.44**	-0.10	1.00	0.09	0.24
Sapling density (trees/ha)	-0.14	**-0.32**	-0.23	**0.46**	-0.18	0.07	**-0.39**	0.09	1.00	0.05
Snag density (snags/ha)	0.08	-0.19	-0.11	**0.44**	-0.18	**0.36**	**-0.29**	0.24	0.05	1.00

Note: Correlation analyses were conducted at the plot level. Bold-faced type indicates statistically significant correlations ($p < 0.05$).

composition, there were no significant differences between treatment combinations (table 2-1). The lack of significance is most likely due to the large standard errors associated with ponderosa pine dominance, which represents high within-treatment variability (table 2-1). In general, each treatment combination included one unit dominated by ponderosa pine, one by Douglas-fir, and one by mixed conifers (fig. 2-1). Douglas-fir dominance was higher on cooler, NE-facing units and on steeper slopes, and ponderosa pine dominance increased on warmer, SW-facing slopes. Other species observed in the experiment include grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.) and western larch (*Larix occidentalis* Nutt.), which generally occurred at higher elevations (>900 m).

The overstory composition at the Mission Creek site is somewhat different than other dry forest sites in the FFS network. The Southwest Plateau site in northern Arizona is more dominated by ponderosa pine than Mission Creek, largely owing to warmer and drier conditions (Fulé et al. 2001b). The Blodgett site in the southern Sierra Nevada is more overstory-species rich with higher tree densities than Mission Creek (Stephens and Moghaddas 2005) and the Lubrecht site in western Montana has a lodgepole pine (*Pinus contorta* Dougl. ex Loud.) component (Metlen and Fiedler 2006), which is missing from Mission Creek. The overstory at our site is probably most similar to Hungry Bob in eastern Oregon, although our climate is slightly more maritime as opposed to continental conditions in eastern Oregon (Youngblood et al. 2006). These differences in overstory structure make the Mission Creek site important to the overall understanding of treatment responses in a range of dry forest types.

Canopy cover averaged >80 percent across all treatment units.

Canopy cover averaged >80 percent across all treatment units, and there were no significant differences between treatments. Canopy cover was higher on Douglas-fir-dominated units and increased with higher tree densities. Canopy bulk density (CBD) averaged 0.071 (0.005) kg/m^3 and was statistically similar among treatments. Canopy base height (CBH), a measure of the vertical distance from the forest floor to the lowest point in the canopy where CBD is equal to 0.011 kg/m^3 (Reinhardt and Crookston 2003), averaged ~4 m on all treatment units and was not significantly different among treatments. These values are comparable to those reported by Stephens and Moghaddas (2005) for mixed-conifer forests of the Sierra Nevada, which were found to be highly susceptible to crown fires modeled under 90th- and 97th-percentile weather conditions. Similar results were found in ponderosa pine forests of northern Arizona prior to restoration treatments (Fulé et al. 2001a). Further, recent large-scale high-severity fires have burned in the forests surrounding Mission Creek, which suggests that our study area is susceptible to such a disturbance.

Sapling densities were also similar across all treatments prior to the experiment and averaged 235 per ha (range 32 to 405 per ha). There were no significant differences in sapling densities between treatments; however, sapling densities were highly variable within treatment with densities increasing on cooler, moister units. On average, about two-thirds of the saplings were Douglas-fir (range 9 to 97 percent). Grand fir saplings were present on higher elevation units, particularly at the highest elevation site where more than 300 grand fir saplings were tallied per hectare. The sapling layer at Mission Creek was most likely not present historically as it was suppressed by frequent, low-intensity surface fires (Harrod et al. 1999). This layer adds structural complexity to the forest by increasing canopy layering and lowering CBH; both of which increase crown fire susceptibility (Peterson et al. 2005).

Snag density (snags per hectare), but not snag basal area, was statistically similar across units prior to treatments.

Snag density (snags per hectare), but not snag basal area, was statistically similar across units prior to treatments (table 2-1, fig. 2-2). Snag density was higher in denser stands, and most snags were <20 cm d.b.h. The majority of snags were ponderosa pine on most units, with the exception of the higher elevation units and units heavily dominated by Douglas-fir (fig. 2-2). Snag basal area was significantly higher on thin-only units compared to thin-burn units, which had one-third the snag basal area of thin-only units.

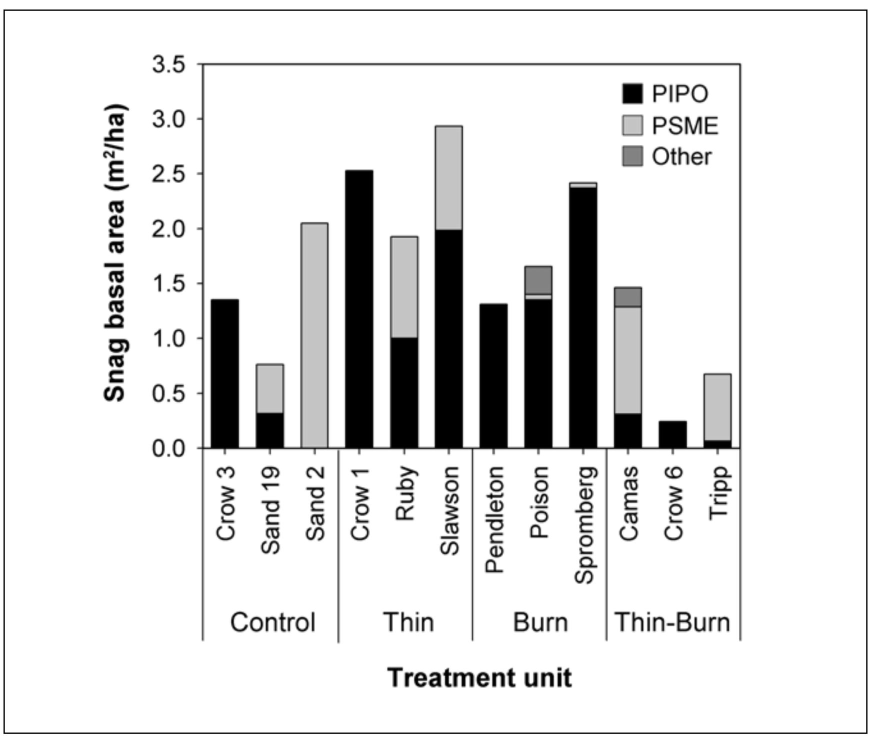

Figure 2-2—Basal area of snags on treatment units within the Mission Creek study site. PIPO = *Pinus ponderosa*; PSME = *Pseudotsuga menziesii*.

Understory Structure and Composition

A total of 124 species were identified at our 12 units, but the majority of these species were not abundant.

The majority of species found at our study site had low cover and frequency prior to any treatment application, which is similar to other forest ecosystems (Dodson et al. 2007, Peterson and Reich 2008, Stohlgren et al. 2005). A total of 124 species were identified at our 12 units, but the majority of these species were not abundant. The five most frequent species were all graminoids and shrubs; *Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roem., *Carex geyeri* Boott, *Calamagrostis rubescens* Buckley, *Rosa* spp., and *Symphoricarpos albus* (L.) S.F. Blake. The most frequent forb was *Osmorhiza berteroi* DC., which was the sixth most frequent species overall, and the forb with the highest cover was *Arnica cordifolia* Hook., which had the ninth highest cover among all species. Only 10 species had more than 1 percent cover each and made up over 78 percent of total understory cover. Eighty-three species had less than 0.1 percent cover each, making up just over 3 percent total understory cover. A similar pattern was also apparent with frequency. There were only 15 species that occurred on more than half the plots, and 67 species occurred on less than one-tenth of the 72 plots.

Shrubs and graminoids made up the majority of understory cover across all units, whereas forbs made up the majority of understory richness (fig. 2-3). There was considerable variability among units in total cover and cover for each life form (fig. 2-3a). Average vascular plant cover for the 12 units ranged from 23.7 to 78.7

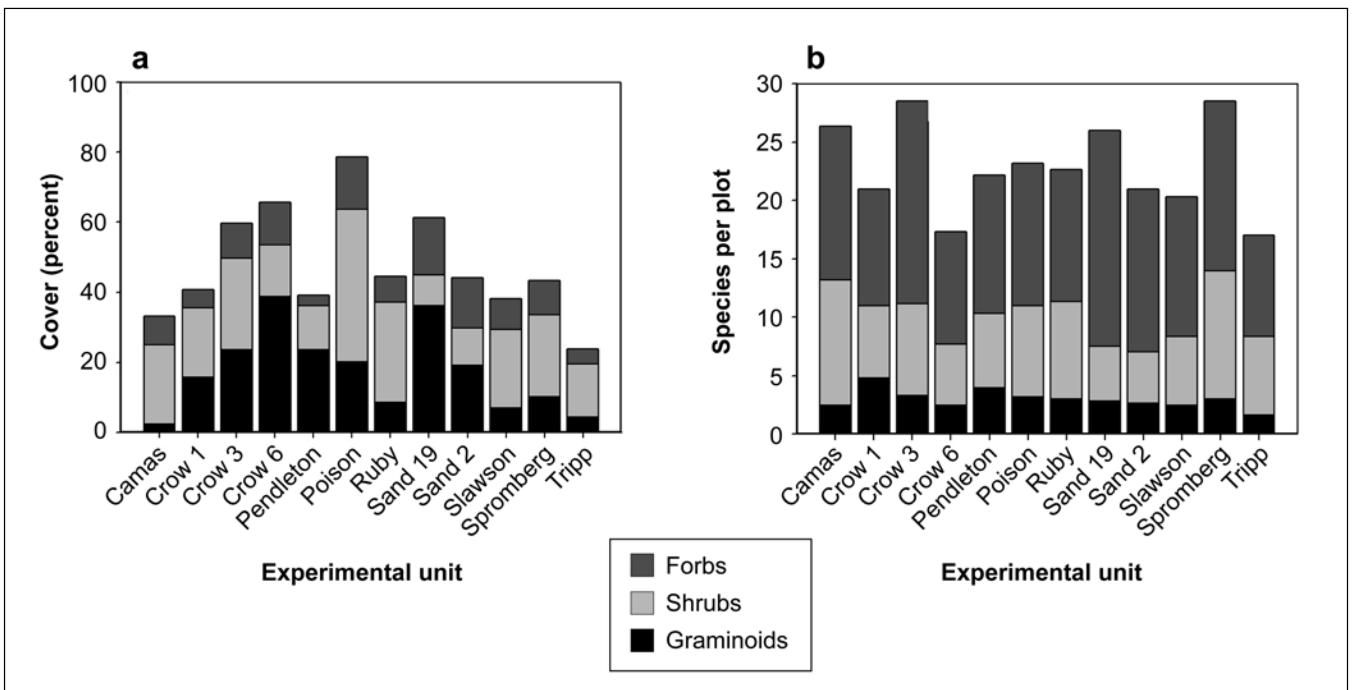

Figure 2-3—Mean cover (a) and richness (b) for each life form on the 12 Mission Creek treatment units.

percent. Each life form also differed among units, ranging from 2.4 to 38.7 percent cover for graminoids, from 3 to 16.3 percent cover for forbs, and from 8.8 to 43.5 percent shrub cover. Richness also showed considerable variability among units, although the variability was considerably less than for cover (fig. 2-3b). Among the 12 units, total richness per plot ranged from 17.3 to 29.8, graminoid richness from 1.7 to 4.8, forb richness from 8.6 to 18.5, and shrub richness from 4.3 to 11.

Despite the considerable variability among units in cover and richness for each life form, much of the variability was still within units. Partitioning the variance in cover into within- and among-site components revealed that most of the variability in cover for shrubs and forbs was within units (fig. 2-4). Only graminoid cover varied more among units than within units. Richness was about roughly equally divided into within and among unit components for each of the three life forms (fig. 2-4).

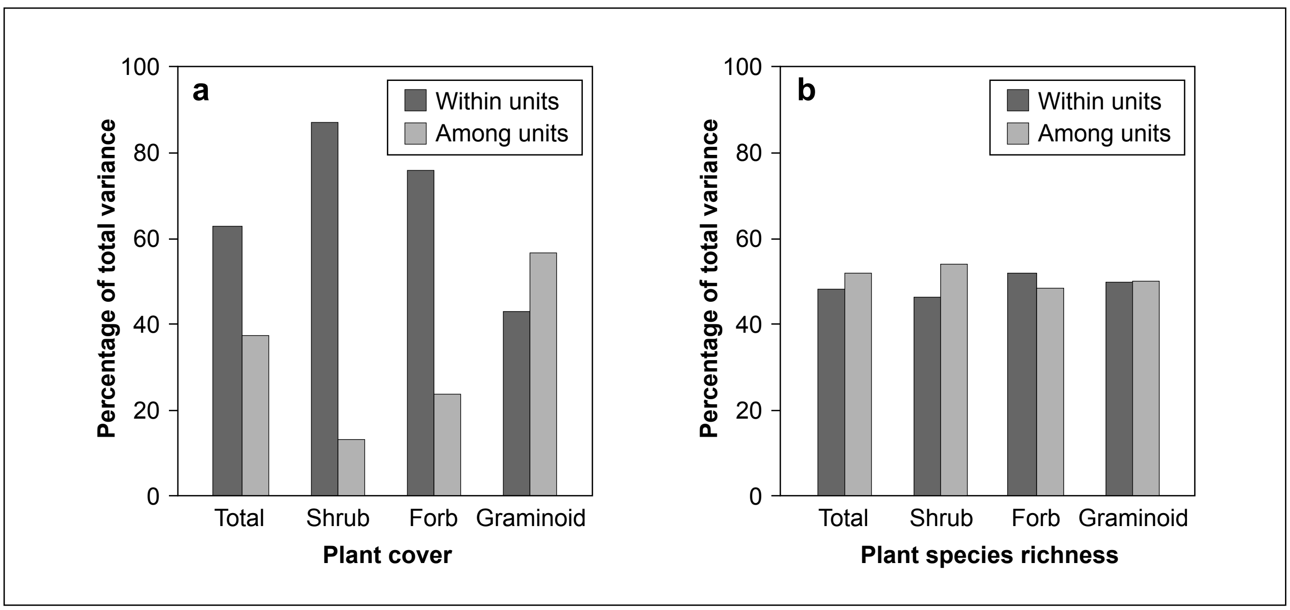

Figure 2-4—Diversity partitioning into within- and among-unit components for (a) cover and (b) richness of the Mission Creek site.

The understory vegetation at the Mission Creek units has notable similarities with and differences from the understory in other dry forests of the Western United States. Understory cover at our study site was dominated by shrubs and graminoids, whereas forbs and shrubs made up the majority of cover in a dry Montana mixed-conifer forest (Metlen and Fiedler 2006). Graminoids and forbs are more dominant in ponderosa pine forests in the Blue Mountains of eastern Oregon (Metlen et al. 2004, Youngblood et al. 2006) and in northern Arizona (Bailey and Covington

There were numerous significant pretreatment differences in understory vegetation among treatment units.

2002). As on our site, high forb richness is a common pattern throughout dry forests of the Western United States (Metlen and Fiedler 2006, Wayman and North 2007).

Comparisons among assigned treatments—
There were numerous significant pretreatment differences in understory vegetation among treatment units (table 2-4). Total understory cover averaged 56.5 percent in the unthinned units (burn-only and control) and was significantly greater than the 38.0 percent total cover in the thinned units (thin-burn and thin-only) (P = 0.0562). There was also a significant difference in species richness between the thinned and unthinned units (P = 0.0879), with the unthinned units averaging almost five more species per plot than thinned units (table 2-4).

Table 2-4—Means (and standard errors) of understory vegetation conditions within and among treatment groups prior to treatment

	Mean treatment value				Pretreatment effect significance		
Variable	Control	Burn-only	Thin-only	Thin-burn	Thin	Burn	Thin × Burn
Total understory cover (%)	51.44 (5.52)	61.62 (17.09)	47.38 (6.23)	28.69 (5.00)	0.056	NS	NS
Total understory richness	25.37 (1.78)	27.00 (2.83)	21.13 (1.15)	22.17 (4.83)	0.088	NS	NS
Shrub cover (%)	14.50 (3.93)	33.34 (10.13)	21.32 (2.9)	18.88 (3.68)	NS	NS	0.063
Shrub richness	5.79 (0.81)	9.42 (1.58)	6.38 (0.69)	8.67 (2.00)	NS	0.029	NS
Forb cover (%)	10.89 (2.93)	12.39 (2.61)	8.41 (1.44)	6.14 (2.09)	NS	NS	NS
Forb richness	15.42 (1.53)	13.33 (1.17)	10.75 (0.55)	10.92 (2.25)	0.040	NS	NS
Graminoid cover (%)	25.59 (3.66)	15.18 (4.94)	17.5 (7.33)	3.42 (1.00)	NS	0.089	NS
Graminoid richness	3.21 (0.30)	3.08 (0.08)	3.21 (0.55)	2.08 (0.42)	NS	NS	NS

Pretreatment conditions analysis of variance (using unbalanced design produced by actual, not planned, treatments).
Note: NS = No statistically significant differences among treatment groups (P > 0.1)

There were also pretreatment differences among assigned treatment units for each life form (table 2-4). The interaction of thinning and burning treatment assignments was significant for shrub cover (P = 0.0630), suggesting that units assigned to each treatment had different values for shrub cover (table 2-4). Shrub richness was significantly higher at the units that were slated to receive burn treatments than the units not designated for a burning treatment (P = 0.0291). Forb cover did not differ significantly among units assigned to treatments, but forb richness was significantly lower on thinned units than on unthinned units (P = 0.040). Similarly, graminoid cover was significantly lower in the burned units than in the unburned units (P = 0.089; table 2-4) reflecting especially high graminoid cover in control units and low graminoid cover in thin-burn units.

High variability among sites has also been observed in southwestern dry conifer forests (Abella and Covington 2006, Fulé et al. 2005, Gildar et al. 2004). The ubiquity of pretreatment differences in understory vegetation suggests that site characteristics, including the biophysical environment and the disturbance history of the site, may significantly influence vegetation composition. This highlights the need for pretreatment data to draw reasonable conclusions in these highly variable forests. Partitioning the variance into within- and among-unit components also revealed that much of the variability in these forests occurs at smaller spatial scales (i.e., much of the variabilities in cover and richness were within the 10-ha units). This high pretreatment variability among and within units contributes to the biodiversity of the Mission Creek dry forest ecosystem.

Site characteristics, including the biophysical environment and the disturbance history of the site, may significantly influence vegetation composition.

Environmental influences on understory—

Units differed considerably prior to treatment application in their understory communities as evidenced by the separation in ordination space (fig. 2-5). The nonmetric multidimensional scaling (NMS) ordination resulted in three axes that explained 83 percent of the variation in the original data set. The final solution with three dimensions was much better than expected by chance (P = 0.004). The third axis explained by far the most variation in the understory community (52 percent), and was positively correlated with trees per hectare and elevation while negatively correlated with the percentage of trees that were ponderosa pine and graminoid cover. The first axis explained 16 percent of the variation in the original data set, and was positively correlated with shrub cover (fig. 2-5a). The second axis explained 15 percent of the variation and was not significantly correlated with any measured environmental variables. Pretreatment canopy cover and basal area were not strongly correlated ($r^2 < 0.2$) with any of the axes in this study.

Understory vegetation showed significant correlations with overstory variables (table 2-5). In general, trees per hectare, basal area, and/or canopy cover were negatively correlated with understory cover and richness. However, tree density had a much stronger negative effect on understory vegetation than basal area or canopy cover (table 2-5). Graminoids had more significant correlation with overstory structure variables than forbs and shrubs. Despite being negatively correlated with tree density, basal area, and canopy cover, graminoid cover and richness were positively correlated with a ponderosa pine overstory. Shrubs were not significantly correlated with a ponderosa pine overstory, but forb richness was reduced with an increased presence of ponderosa pine in the overstory (table 2-5).

The understory vegetation in this study was influenced by environmental conditions and overstory trees. Elevation played an important role in dictating understory

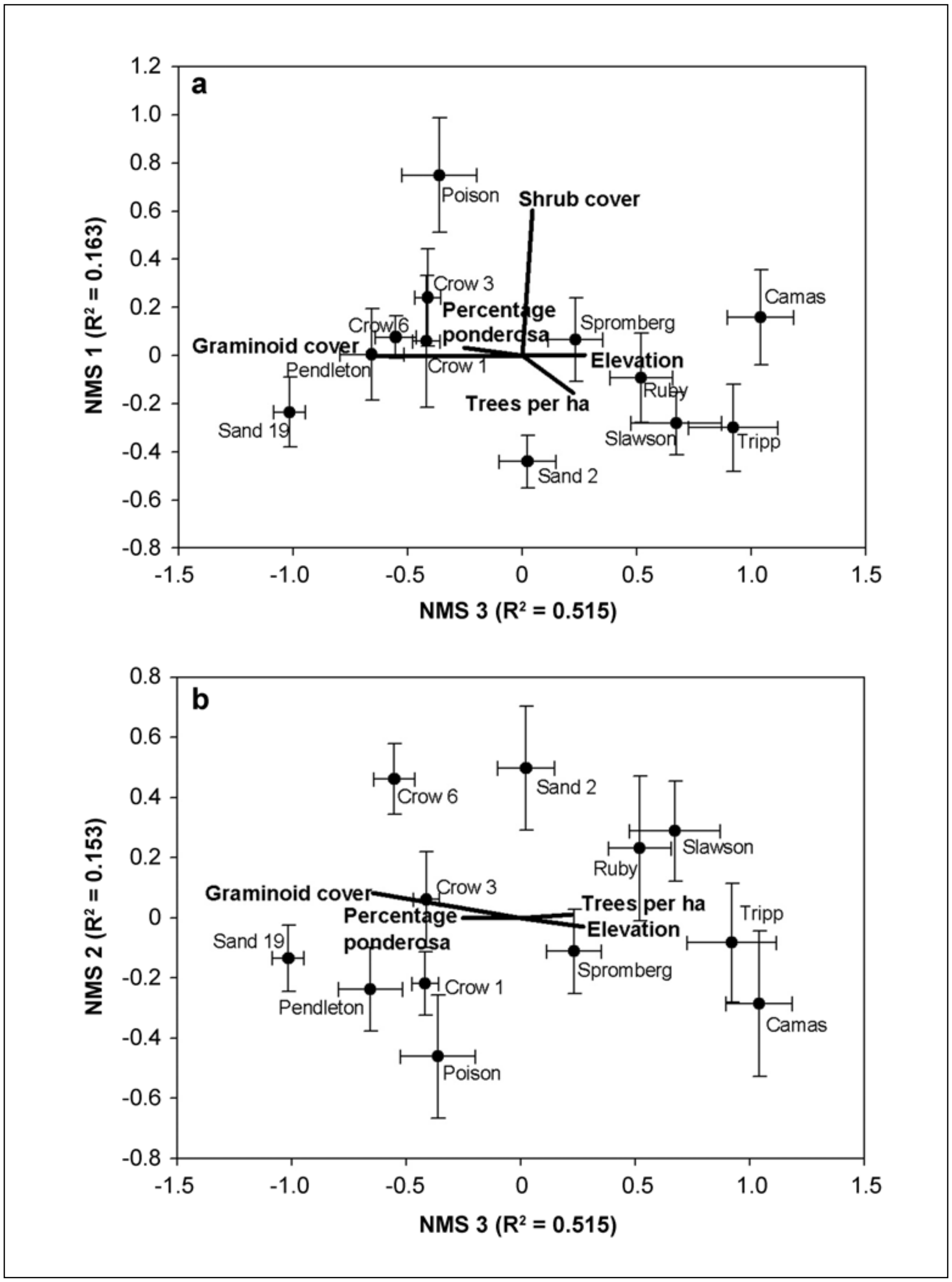

Figure 2-5—Nonmetric multidimensional scaling (NMS) ordination of Mission Creek understory species data prior to treatment with environmental variables with >0.2 correlation with axes 1 and 3 (a) and 2 and 3 (b).

Table 2-5—Relationships between overstory stand structure and understory vegetation characteristics prior to treatment, as indicated by Pearson correlation coefficients (r) and associated significance levels (P) in parentheses

	Tree basal area (m^2/ha)		Tree density (trees/ha)		Tree canopy cover (percent)		Ponderosa pine (percent)	
Understory vegetation characteristic	r	(P)	r	(P)	r	(P)	r	(P)
Understory cover (percent)	**-0.24**	**(0.04)**	**-0.45**	**(< 0.001)**	-0.10	(0.44)	**0.20**	**(0.09)**
Understory richness	-0.09	(0.46)	**-0.38**	**(0.001)**	**-0.22**	**(0.09)**	-0.13	(0.26)
Shrub cover (percent)	-0.02	(0.86)	**-0.24**	**(0.04)**	-0.02	(0.89)	-0.05	(0.66)
Shrub richness	**0.20**	**(0.09)**	-0.14	(0.24)	-0.08	(0.54)	-0.13	(0.29)
Forb cover (percent)	-0.15	(0.22)	-0.17	(0.16)	0.01	(0.97)	-0.07	(0.56)
Forb richness	-0.14	(0.23)	**-0.26**	**(0.03)**	-0.06	(0.63)	**-0.26**	**(0.03)**
Graminoid cover (percent)	**-0.27**	**(0.02)**	**-0.30**	**(0.01)**	-0.13	(0.31)	**0.41**	**(< 0.001)**
Graminoid richness	**-0.32**	**(0.01)**	**-0.37**	**(0.002)**	**-0.50**	**(< 0.001)**	**0.52**	**(< 0.001)**

Note: Ponderosa pine (percent) is the percentage of overstory trees that are ponderosa pine (tree density basis). Bold-faced type indicates statistically significant correlations ($P < 0.10$).

composition (fig. 2-5), which has also been documented in dry coniferous forests of the Southwestern United States (Fischer and Fulé 2004). In general, overstory trees had negative effects on understory species (table 2-5), a pattern that has been well documented for dry coniferous forests (Riegel et al. 1992, 1995). Interestingly, graminoid cover and richness were positively associated with stands that had higher proportions of ponderosa pine. Tree density had much stronger negative effects on the understory community than basal area or canopy cover. In dry forests, trees may reduce understory growth more by competing for belowground nutrients than by shading (Riegel et al. 1992). Units with higher tree densities were the result of many trees in smaller size classes (fig. 2-1), which may have a larger effect on understory species than basal area or canopy cover. This suggests that treatments should focus more on reducing stand density (trees per hectare) than on basal area to benefit understory species.

Treatments should focus more on reducing stand density than on basal area to benefit understory species.

Effects of sample year—

There was a large amount of unit-to-unit variability in understory cover within both pretreatment sample years. On average, units sampled in 2000 had 9.1 percent more cover than units sampled in 2001 (fig. 2-6). Much of the difference between years may be due to one unit with very high cover sampled in 2000 (Poison). The understory cover in Poison was more than 13 percent higher than the second highest unit in either pretreatment sampling year. Also, Sand 2, which had plots sampled in both years, actually had higher average cover on the plots that were sampled in 2001, contradicting the overall trend. Overall, there appears to be no obvious trend between the 2 years of pretreatment sampling for understory cover.

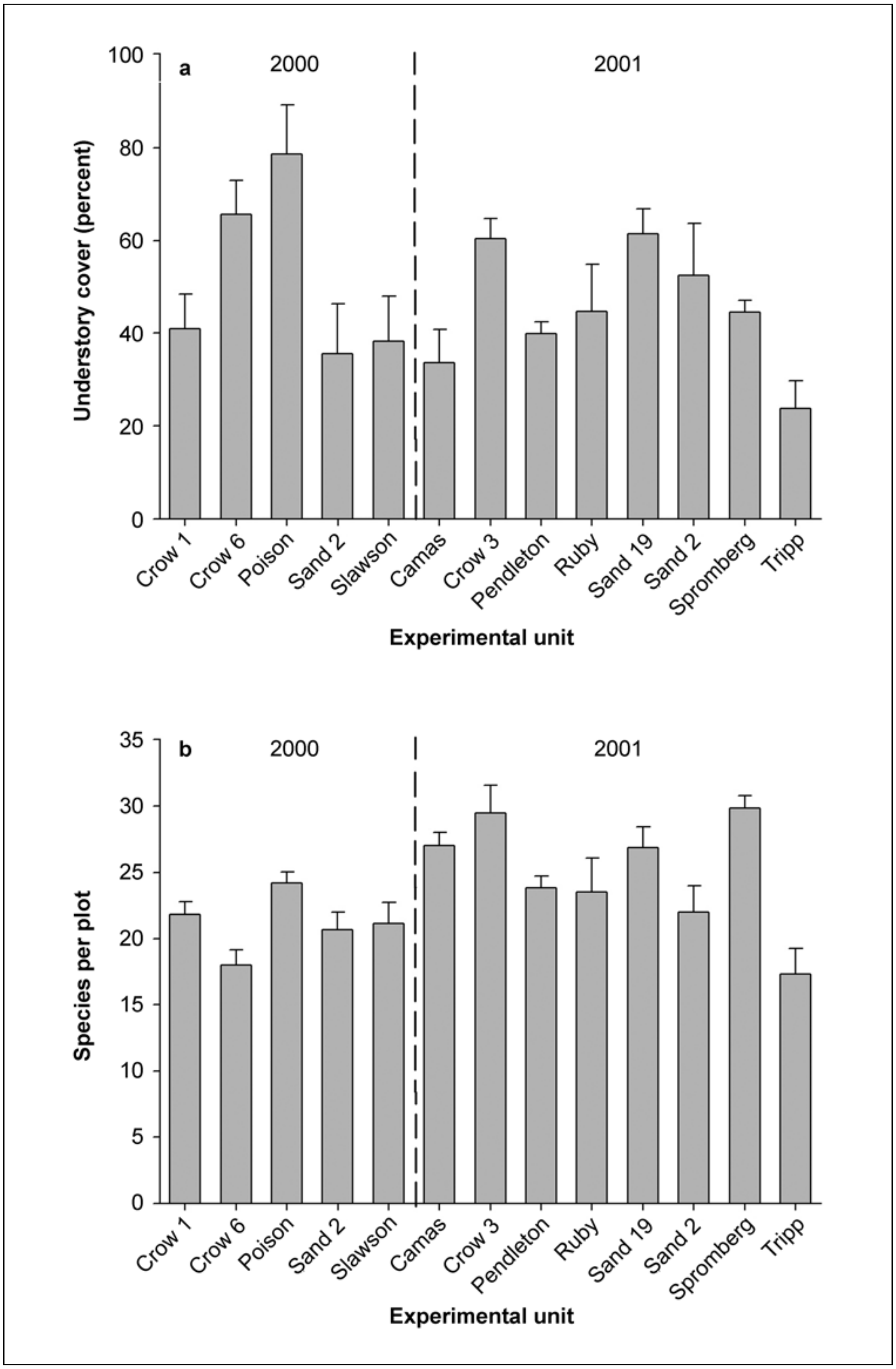

Figure 2-6—Site means for (a) cover and (b) richness (+ standard error) for the two pretreatment sample years at the Mission Creek site.

There was high variability among units, even within a given year, for understory richness. Richness was higher in 2001 than in 2000 by an average of about four species per plot, which was opposite the pattern for cover (fig. 2-6). Sand 2 had very little difference in species richness between plots sampled in 2000 and those sampled in 2001. Overall, there was little evidence of a strong year effect that may bias later results.

Conclusions

Overstory vegetation at the Mission Creek site was generally similar across all pretreatment units, but understory vegetation was highly variable. Tree density, snag density, live tree basal area, stand density index, sapling density, species composition, canopy cover, canopy bulk density, and canopy base height were statistically similar among the four assigned treatments. Only snag basal area was significantly higher on thin-only units compared to thin-burn units. Overstory vegetation at Mission Creek is relatively unique compared to most other sites in the FFS network.

Understory vegetation was variable among treatment units, but much more variable within units. The Mission Creek site is fairly species rich with 124 species, mostly dominated by graminoids and shrubs, but most species had low cover and frequency prior to treatment application. Species richness and cover was significantly different among assigned treatments, highlighting the importance of pretreatment measurements rather than the use of just control units. Understory community structure also differed among treatment units, and understory vegetation was correlated with physical and biological elements, such as elevation and overstory tree density. These correlations suggest that restoration treatments may be targeted to have positive effects on understory vegetation. Finally, there was a large amount of unit-to-unit variability in understory cover and richness between sample years, but there was little evidence of a strong year effect that may bias later results.

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