



Integrated Upland Vegetation and Soils Monitoring for Grand Canyon National Park

2007 and 2008 Summary Report, revised January 2011

Natural Resource Data Series NPS/SCPN/NRDS—2011/159



ON THE COVER

Integrated Upland Crew sampling vegetation in the mixed-conifer forest at Grand Canyon National Park
Photograph by: Jim DeCoster

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The corresponding author and project manager for this project is Jim DeCoster (jim_decoster@nps.gov). Megan Swan is the botanist and crew leader for the project. Other contributions were made by the SCPN staff. The 2008 field crew consisted of Jessica Erickson, Anna Lowell, and Eric Vasquez.

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Introduction and Background

The National Park Service Inventory and Monitoring (I&M) Program was designed to determine the current status and monitor long-term trends in the condition of park natural resources, providing park managers with a strong scientific foundation for making decisions and working with other agencies and the public for the protection of park ecosystems. The Southern Colorado Plateau Network (SCPN) is monitoring vegetation and soils as overall indicators of upland ecosystem integrity (Thomas et al. 2006).

SCPN and park staff selected the mixed-conifer forest to monitor for vegetation and soils at Grand Canyon National Park (GRCA). The mixed-conifer forest is a unique ecosystem. There are few extensive areas of this system on the Colorado Plateau, and climate change and altered fire regimes threaten its integrity.

In 2007, the Integrated Upland Monitoring program of SCPN began monitoring the mixed-conifer forest at GRCA with the installation of 16 plots. We plan to sample the quadrats annually for 3-5 years to determine the range of temporal variability for key metrics. Power analysis will then be used to determine the total number of plots necessary to detect change in the key metrics. In 2008, the Upland Crew revisited the 16 plots to reread the quadrats. In this report, we document monitoring activities in the 2007 and 2008 field seasons and summarize the data that were collected.

Methods

Sampling frame

The sampling frame is the area from which we randomly select our sites, and hence the area to which statistical inferences can be made. We derived the sampling frame from the maps of two ecological sites developed by the US Natural Resources Conservation Service (NRCS): Loamy Hills Cold and Loamy Hills ecological sites (See Appendix A of DeCoster et al., in review). Ecological sites are landscape divisions with characteristic soils, hydrology, plant communities, and disturbance regimes and responses and are based on soil survey data (Butler et al. 2003). The Loamy Hills Cold and Loamy Hills ecological sites are high elevation areas with mixed-conifer forests and spruce-fir forests.

The two ecological sites were merged into one, henceforth referred to as the Mixed-Conifer ecological site. To complete the sampling frame, we modified the map of the ecological site with Geographical Information System (GIS) technology. These modifications were necessary to avoid

- areas that were not within the target ecological site (roads, buildings, and infrastructure, and elevations below 2500 m),
- areas that were expected to differ substantially from the norm, such as burned areas of moderate to high burn severity and mechanically treated areas, because these areas would have increased ecological variation, making it more difficult to detect trends,
- areas with slopes $\geq 30\%$ to prevent erosion from occurring (fig. 1).

We generated a set of spatially distributed sampling points using the Generalized Random-Tessellation Stratified (GRTS) design (Stevens and Olsen 2004). Park staff reviewed the sampling points, and an archaeologist visited the sites to ensure that there were no archaeological sites in the immediate vicinity. Before establishing a plot, the Integrated Upland Crew conducted an ecological site assess-

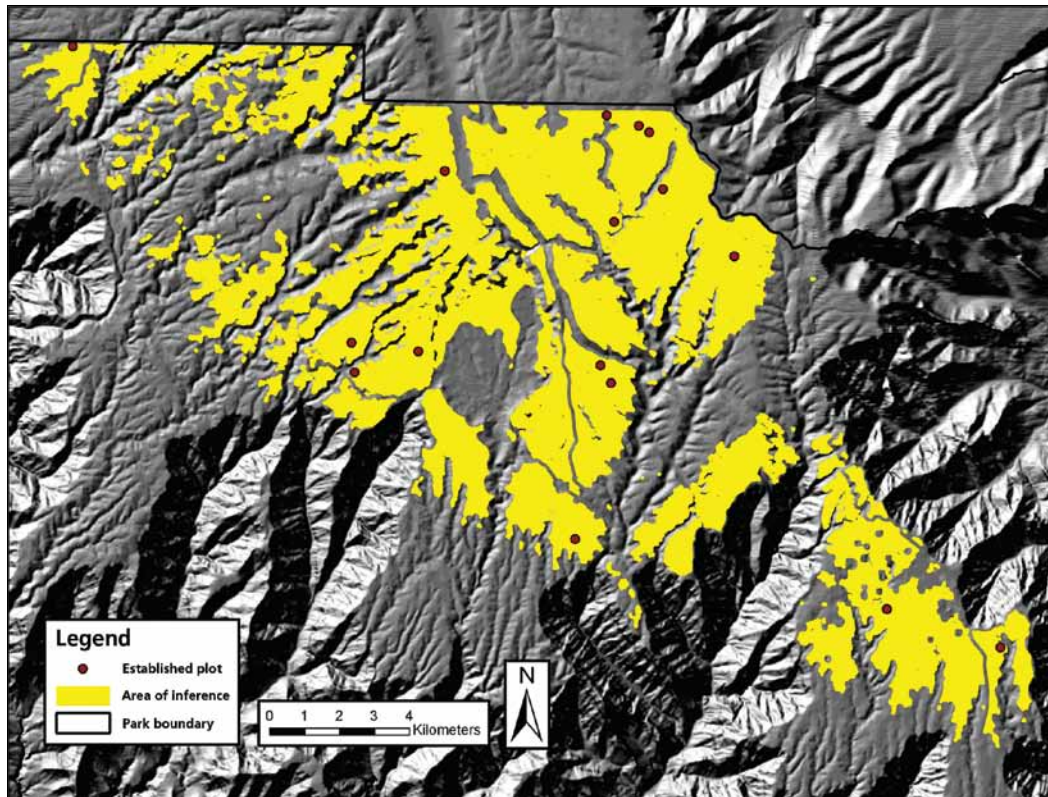


Figure 1. Sampling frame for Mixed-Conifer ecological site on the North Rim at Grand Canyon National Park, with the 16 plots established in 2007.

ment, and they rejected the site if it did not fall within the ecological site, had a slope greater than 30%, or contained a major disturbance. They rejected five points: four points occurred on slopes greater than 30%, and one point occurred in a ponderosa pine forest.

Field methods

The SCPN Upland Monitoring crew began monitoring at GRCA in 2007 with the establishment of 16 plots. Plots are 0.50 ha in size, measuring 71 m x 71 m. All plots were installed and sampled in July. Herbaceous and shrub data were collected on three 50 m transects, spaced 25 meters apart, within each plot. Overstory tree and sapling data were collected in subplots located between two of the transects. In 2008, shrub and herbaceous data was collected again and canopy closure was measured in late June through early July. Field methodology is provided in detail in the SCPN Integrated Upland Protocol (DeCoster et al., in review).

Shrub and herbaceous vegetation

The crew sampled shrub and herbaceous vegetation with five sets of nested quadrats at 10 m intervals along each transect. The largest quadrat size was 10 m² (2m x 5m) with three smaller quadrats nested inside (0.01 m², 0.1 m², and 1 m²). A fourth nested quadrat of 5 m² was added in 2008 to better capture diversity at multiple spatial scales. The presence of individual vascular species was recorded for each nested sub-quadrat. Percent cover of individual herbaceous and shrub species was then estimated in the 10 m² quadrat and placed in one of 12 cover classes, e.g. 2-5%, 5-10%, etc. Percent cover of each functional group (e.g. graminoids, forbs, shrubs) was also estimated in the largest quadrat and placed in one of 12 cover classes. (In 2007, tree foliage under 2 m in height was included

in the estimation of total live vegetation cover, but it was not included in 2008).

Overstory trees and saplings

In 2007, overstory trees and saplings were measured. Overstory trees, defined as having a diameter at breast height (dbh) greater than or equal to 15 cm, were measured within a 20 x 50 m (0.1 ha) subplot between two of the transects. For each individual tree, species, dbh and status (live, dead) was recorded. Density and basal area were also calculated for snags (standing dead overstory trees). Saplings (≥ 2.5 and < 15 cm dbh) were sampled in a 10 x 25 m subplot and were tallied by species and size class. Tree seedlings were recorded in the 10 m² quadrats in conjunction with the shrub and herbaceous data and were tallied by species and size class. In 2008, canopy closure was measured with a hemispherical densitometer at five points along each transect.

Soil stability and hydrologic function

Because soil erosion is not considered a serious threat in these systems, we did not use the basal gap and soil aggregate stability procedures that had been developed for drier, lower-elevation ecosystems. However, we did measure the cover of ground surface features in the quadrats to obtain estimates of the relative amounts of different types of ground cover. Percent cover of surface features was estimated in the 1 m² quadrats in conjunction with shrub and herbaceous data and then placed in one of 12 cover classes.

Data summary

The sample unit for summary and analysis is the plot; hence, we summarized data at the level of the plot. In order to calculate summary statistics for the ecological site, we calculated means and standard deviations from plot means.

For herbaceous and shrub vegetation, cover and frequency were calculated for each species from the cover class midpoints, e.g. using 7.5% for cover class 5-10%. The mean cover was calculated for each plot, and the mean and standard deviation (SD) were calculated for the entire ecological site. Species frequency was calculated for quadrats (mean percentage of quadrats per plot where the species occurs) and for plots (percentage of plots where the species occurs). The mean cover and SD of functional groups and surface features were calculated in a similar fashion.

We calculated four diversity measures for herbaceous and shrub species (Magurran 1988)—first for all species and then for native species only.

(1) Species richness (S) is the number of species at a given spatial scale, and it was calculated at all spatial scales (i.e. for each nested quadrat size, for the plot, and for the ecological site).

(2) The Shannon Diversity Index (H') provides a measure of species diversity that takes into account the relative abundance of each species:

$$- \sum_{i=1}^n p_i \ln p_i$$

where p_i is the abundance of each species.

(3) Species evenness (J') is a measure of the degree to which all species are equal in abundance:

$$H' / \ln(S)$$

(4) Beta diversity (β_w) is a measure of within-ecological site heterogeneity:

$$S_e / (S_p - 1)$$

where S_e is the total number of species found in the ecological site, and S_p is the mean number of species found per plot.

Tree basal area (the total area of the tree cross-sections at breast height) was calculated for each overstory tree species in terms of m²/ha. Tree density was calculated for all species and all size classes for overstory, sapling and seedling layers in terms of stems/ha. Mean diameter of overstory trees was also calculated by species. Mean canopy closure was calculated for each plot and then the mean and SD were calculated for the ecological site.

Results

Shrub and herbaceous vegetation

The herbaceous/shrub cover was sparse, with perennial grass and graminoids, forbs, and shrubs codominating the cover (table 1 and fig. 2). The cover of each of these functional groups ranged between 1% and 3 %. There were no annual grasses or cacti/succulents in any plots. The large change seen between the total live vegetation cover of functional groups between 2007 and 2008 is due to slight changes in methods: in 2007, foliar cover of trees (< 2 m in height) was included in the estimation of total live vegetative cover, but trees were not included in 2008. Also, standing dead woody cover in 2007 included trees (< 2 m) and shrubs, while in 2008 it included only shrubs. Otherwise, changes in the cover of the functional groups between 2007 and 2008 were small. The greatest changes occurred in the cover of perennial grass and graminoids, which decreased from 2.24% to 1.61%.

Similar to the functional groups, the species composition of herbaceous and shrub vegetation showed a co-dominance of a number of species (table 2 and fig. 3). No species exceeded a mean

Table 1. Foliar cover of functional groups for 2007 and 2008.

Functional groups	Foliar cover (%)			
	2007		2008	
	Mean	(SD)	Mean	(SD)
Total foliar cover	14.44	(5.73)	5.17 ^a	(3.67)
Perennial grasses, graminoids	2.24	(1.70)	1.61	(1.74)
Annual grasses	0.00	(0.00)	0.00	(0.00)
Forbs	1.51	(1.55)	1.55	(1.53)
Shrubs	1.40	(1.72)	1.41	(1.45)
Cacti, succulents	0.00	(0.00)	0.00	(0.00)
Understory trees (< 2m height)	7.44	(5.30)	n/a ^a	n/a
Standing dead herbaceous	1.05	(0.83)	0.87	(1.14)
Standing dead woody	0.53	(0.30)	0.07 ^b	(0.09)

Note: Components of total live vegetation are not strictly additive due to the fact that calculations are made from cover class midpoints, the various components may overlap, and estimations were derived independently.

^a Foliar cover of understory trees was not estimated or included in the total foliar cover in 2008.

^b Standing dead woody cover did not include tree components in 2008.

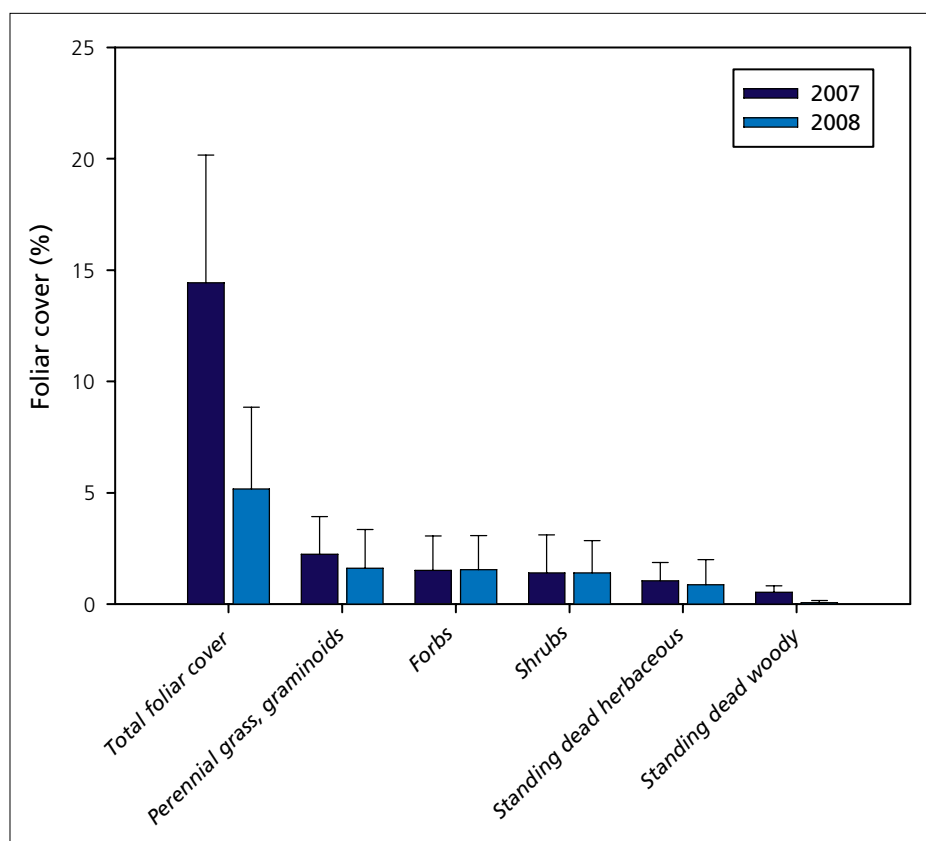


Figure 2. Mean cover of functional groups in 2007 and 2008. Note: means for total foliar cover and standing dead woody cover included tree components in 2007, but not in 2008. Error bars represent one standard deviation.

cover of 1%, which indicates a lack of dominance by any one species. The most abundant species were *Carex siccata* (dry-spike sedge), *Juniperus communis* (common juniper), and *Carex rossii* (Ross' sedge). Other species that occurred in a majority of plots included *Fragaria virginiana* (Virginia strawberry), *Poa fendleriana* (muttongrass), *Bromus ciliatus* (fringed brome), and *Pedicularis centranthera* (dwarf lousewort). Several species were less frequent, but locally abundant where they occurred. These included *Robinia neomexicana* (New Mexico locust), *Pteridium aquilinum* (western bracken fern), and *Chenopodium album* (fetid goosefoot). One nonnative species, *Taraxacum officinale* (common dandelion), was found in the plots, but it occurred in low abundance. High among-plot variability in species composition is indicated by standard deviations that exceed the mean cover values and the low quadrat frequencies.

Several species showed large decreases in cover between 2007 and 2008, in particular *Carex siccata*, *Carex rossii*, and *Pteridium aquilinum*. Quadrat and plot frequencies showed little change. Many species, on the other hand, showed little change in cover. Appendix A lists all the species and their abundances, along with common names, families, mean foliar cover, and plot frequencies.

We recorded 7 species in this ecological site in 2007 and 86 species in 2008 (table 3). Mean plot richness for 2007 was 22.9 species per plot, and it decreased slightly in 2008 to 22.6. The Shannon diversity was moderately low (1.828), and evenness (0.588) and beta diversity (3.977) indices were moderately high in 2007. Values for Shannon diversity generally fall between 1.5 and 3.5; values for evenness range from 0 to 1, where a value of 1 indicates that all species are of equal abundance

Table 2. Foliar cover and frequency of the fifteen most abundant vascular species and all nonnative species in 2007 compared to 2008.

Species	2007				2008			
	Mean cover (%)	SD	Quad Freq	Plot Freq	Mean cover (%)	SD	Quad Freq	Plot Freq
<i>Carex siccata</i>	0.966	0.942	42.08	87.50	0.519	0.785	42.50	81.25
<i>Juniperus communis</i>	0.836	1.240	20.42	68.75	0.939	1.159	17.92	62.50
<i>Carex rossii</i>	0.682	0.777	65.42	100.00	0.452	0.367	74.17	100.00
<i>Robinia neomexicana</i>	0.404	1.185	7.50	12.50	0.236	0.674	7.50	12.50
<i>Pteridium aquilinum</i>	0.254	0.532	9.17	37.50	0.062	0.111	7.50	31.25
<i>Fragaria virginiana</i>	0.242	0.703	23.33	100.00	0.315	0.747	23.33	100.00
<i>Poa fendleriana</i>	0.178	0.277	36.67	100.00	0.179	0.186	37.08	100.00
<i>Bromus ciliatus</i>	0.139	0.284	30.83	100.00	0.161	0.348	34.17	100.00
<i>Pedicularis centranthera</i>	0.114	0.112	38.75	87.50	0.15	0.125	37.92	87.50
<i>Geranium richardsonii</i>	0.081	0.187	10.00	25.00	0.145	0.438	12.08	25.00
<i>Mahonia repens</i>	0.069	0.082	17.50	68.75	0.099	0.121	17.08	68.75
<i>Ligusticum porteri</i>	0.064	0.147	9.58	43.75	0.045	0.100	10.00	43.75
<i>Chamerion angustifolium</i>	0.061	0.128	8.75	50.00	0.053	0.096	10.42	50.00
<i>Chenopodium album</i>	0.060	0.231	4.17	12.50	0.033	0.129	4.17	18.75
<i>Lotus utahensis</i>	0.042	0.065	12.08	50.00	0.032	0.044	12.50	56.25
<i>Taraxacum officinale</i> ^a	0.003	0.012	0.83	12.50	0.003	0.008	1.67	12.50

Note: Species are arranged in descending order by their 2007 cover.

^a Nonnative species.

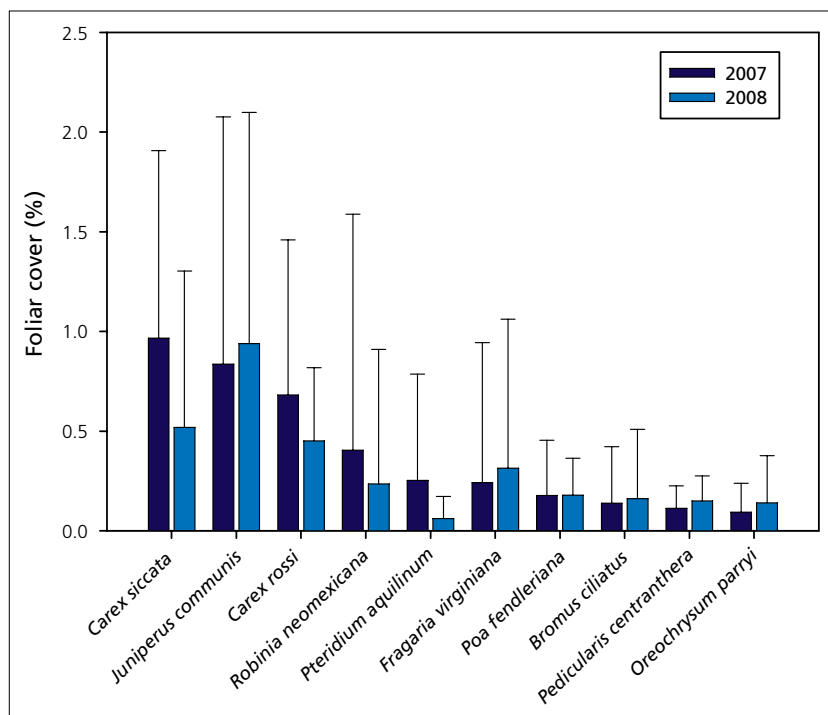


Figure 3. Mean foliar cover of the ten most abundant vascular species in 2007, as compared to 2008. Error bars represent one standard deviation.

Table 3. Species diversity metrics for all species and for native species only.

Metric	2007		2008	
	Mean	(SD)	Mean	(SD)
All species				
Plot				
Plot richness	22.9	(5.7)	22.6	(5.7)
Shannon diversity	1.828	(0.358)	1.987	(0.491)
Evenness	0.588	(0.097)	0.638	(0.134)
Ecological site				
Ecological site richness	87		86	
Beta diversity	3.977		3.988	
Native species				
Plot				
Plot richness	22.8	(5.7)	22.4	(5.5)
Shannon diversity	1.826	(0.358)	1.984	(0.488)
Evenness	0.588	(0.097)	0.638	(0.134)
Ecological site				
Ecological site richness	86		85	
Beta diversity	3.954		3.965	

(Margalef 1972). Values for beta diversity greater than 5 indicate large differences among plots; values less than 1 indicate similar composition among plots (McClune and Grace 2002). Shannon diversity, evenness, and beta diversity all increased between 2007 and 2008. When these indices were recalculated using only native species, they did not change substantially.

The species area curve (fig. 4) illustrates how the species richness accumulated with increased area. The concave shape of the curve indicates low species richness at finer spatial scales (1 m² and less) and high species richness at coarser spatial scales.

Trees

Trees were sampled in 2007, but not in 2008. Table 4 shows the relative abundance of trees, as expressed by density and basal area of trees by species and size class. *Abies concolor* (white fir) and *Pinus ponderosa* (Ponderosa pine) had the greatest basal area, followed by *Picea engelmannii* (Engelmann spruce) and *Populus tremuloides* (quaking aspen) (fig. 5). *Abies concolor*, *Picea engelmannii* and *Populus tremuloides* (quaking aspen) occurred in the highest densities. The large error bars in figure 5 indicate large variations in basal area among plots. Snags (standing dead stems) had both a fairly high density and basal area. *Abies concolor* had the greatest basal area of snags.

The size structure of trees varied among species (fig. 6). *Abies concolor*, *Pinus ponderosa*, *Picea pungens* (blue spruce), and *Pseudotsuga menziesii* were represented in most of the size classes. *Abies lasiocarpa* (subalpine fir) and *Populus tremuloides* only occurred in the smaller size classes.

Seedling and sapling densities provide insight into the structure, demographics, and dynamics of the forest. *Abies concolor* and *Picea engelmannii* had the highest sapling densities (table 4), particularly

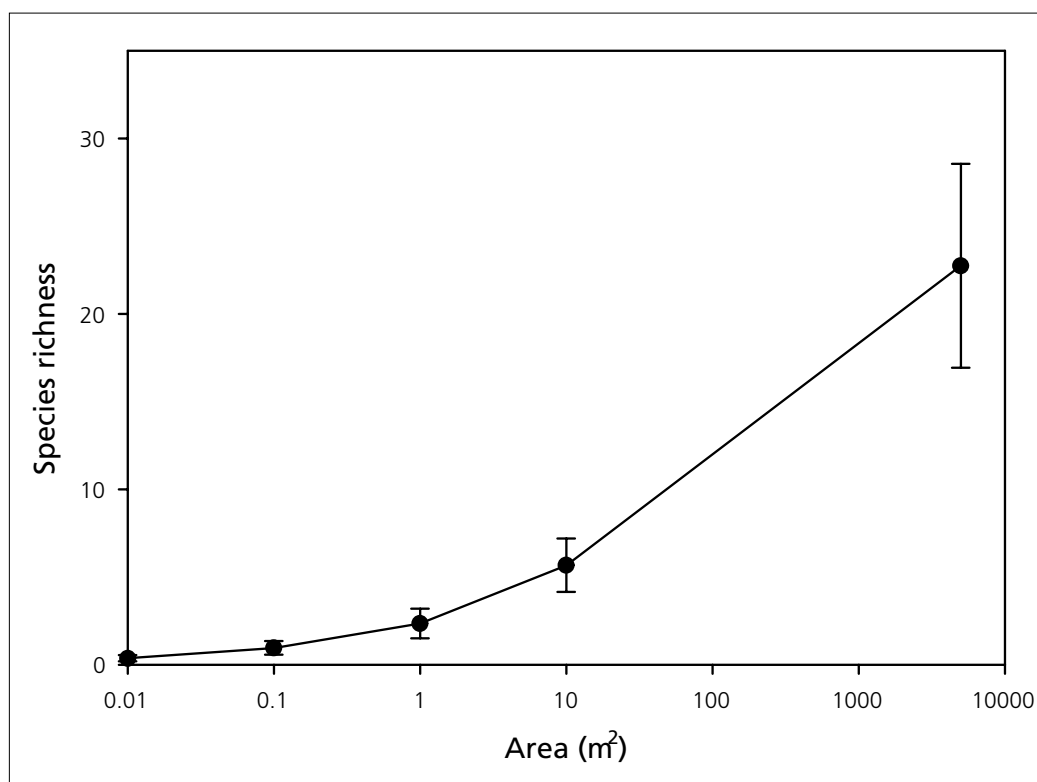


Figure 4. Species area curve for 2007, showing species richness at five spatial scales. Species richness is defined as the number of vascular species in a given area. Estimates are based on 16 plots with 15 quadrats each. The point at 5000 m² represents plot species richness. Error bars represent one standard deviation. Due to their similarities, the species area curve for 2008 is not presented.

Table 4. Density and basal area of trees by species and size class.

Species	Seedling density (stems/ha)	Sapling density (stems/ha)	Overstory density (stems/ha)	Snag density (stems/ha)	Overstory basal area (m ² /ha)	Snag basal area (m ² /ha)	Mean DBH (cm)
<i>Abies concolor</i>	2483.3	327.5	61.3	44.4	5.82	7.23	32.1
<i>Abies lasiocarpa</i>	1283.3	85.0	23.8	11.9	1.25	0.47	22.7
<i>Picea engelmannii</i>	445.8	232.5	38.1	8.1	3.38	0.99	32.1
<i>Picea pungens</i>	162.5	82.5	14.4	0.6	2.06	0.03	30.0
<i>Pinus ponderosa</i>	3612.5	7.5	43.1	10.6	9.44	2.33	51.8
<i>Populus tremuloides</i>	4695.8	167.5	47.5	30.6	3.41	1.92	29.4
<i>Pseudotsuga menziesii</i>	129.2	67.5	31.3	6.3	2.87	1.20	29.4
Total	12,812.5	970.0	259.4	112.5	28.24	14.17	33.7

Note: Seedlings have <2.5 cm diameter at breast height (dbh), saplings have 2.5-14.9 cm dbh, and overstory trees have ≥15 cm dbh.

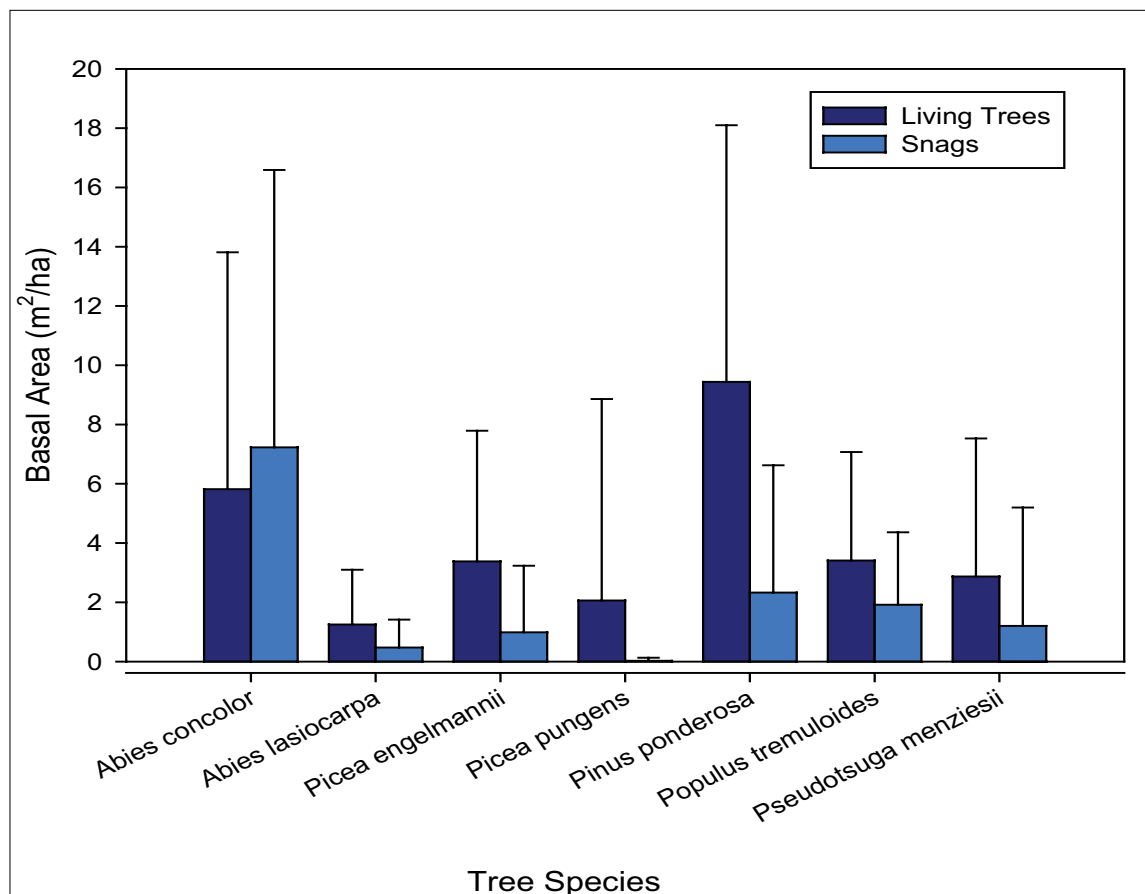


Figure 5. Mean basal area of living trees and snags by species. Error bars represent one standard deviation.

in the two smaller sapling classes (fig. 7). The largest sapling class is co-dominated by *Abies concolor*, *Abies lasiocarpa*, *Picea engelmannii*, and *Populus tremuloides*. High variability among plots is indicated by the large standard deviations. *Pinus ponderosa* and *Populus tremuloides* had the highest seedling densities (table 4). *Pinus ponderosa* had the highest density in the smallest seedling class (with very high variability), while *Populus tremuloides* and *Abies concolor* had the highest densities in the two larger seedling classes (fig. 8). The structure of both overstory and sapling layers (fig. 9), indicates a typical decline in density with increasing size.

Canopy closure was measured in 2008. Mean canopy closure was 71.3% with a standard deviation of 17.3.

Ground surface features

The cover of ground surface features (table 5 and fig. 10) showed that the majority of the ground surface was covered with duff and litter, between 79% and 81%. Woody debris was the second largest component, ranging from 6 to 10%. Live plant base and bare soil cover were less than 2%, and all other features were less than 1%. Standard deviations were moderately low, indicating low variability among plots. Differences in cover between 2007 and 2008 were not large. Woody debris showed a moderate increase, likely because a number of trees fell in the plots between 2007 and 2008.

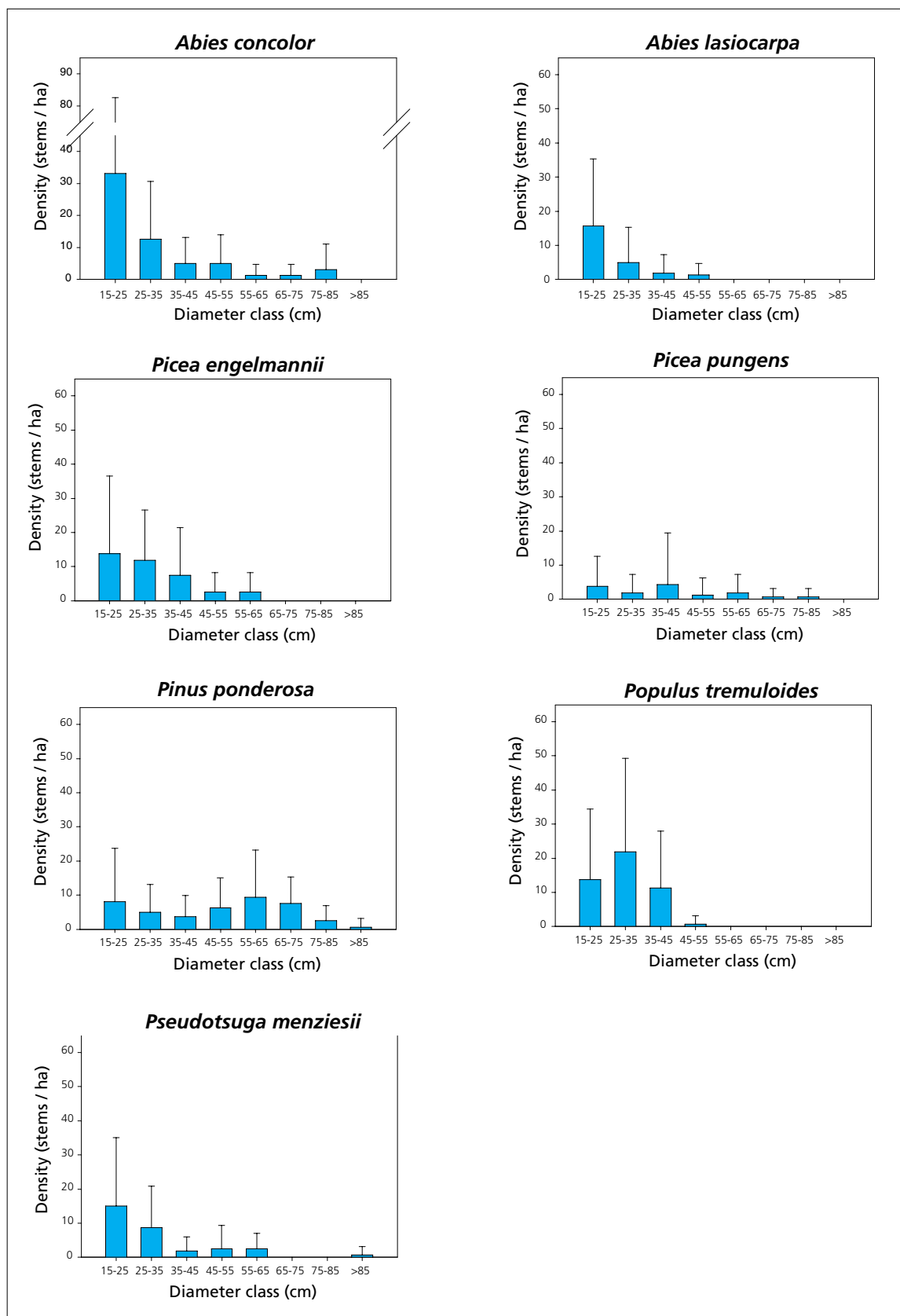


Figure 6. Size structure of each overstory tree species. Error bars represent one standard deviation.

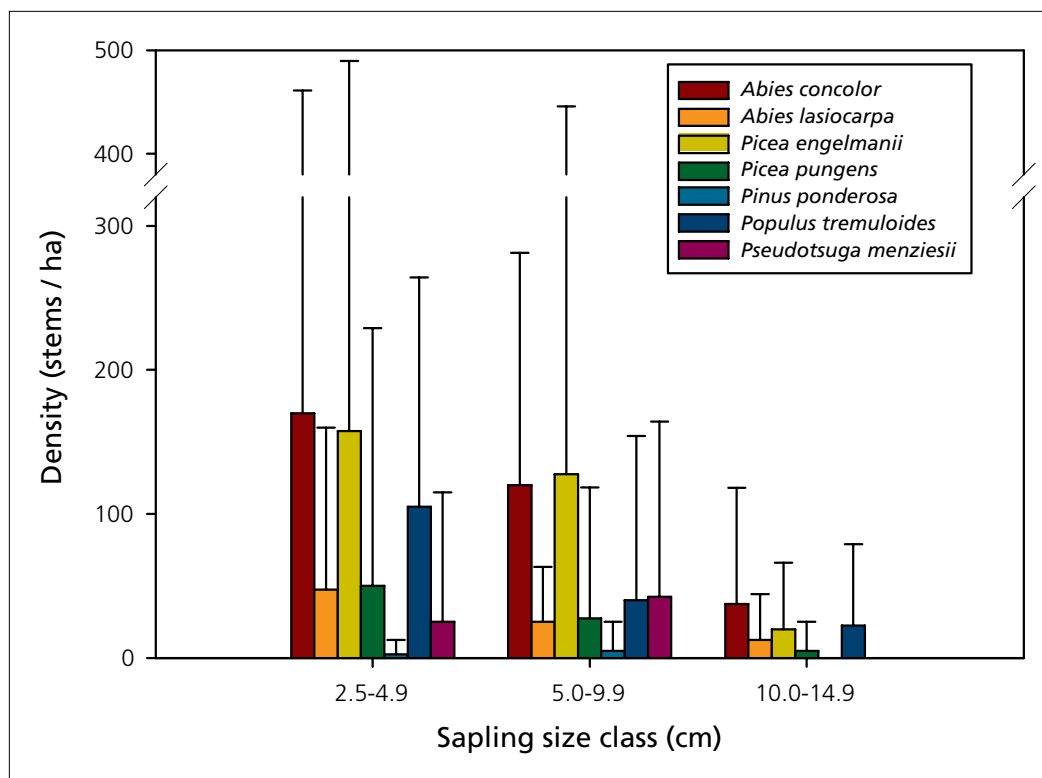


Figure 7. Density of the six most abundant sapling species. Error bars represent one standard deviation.

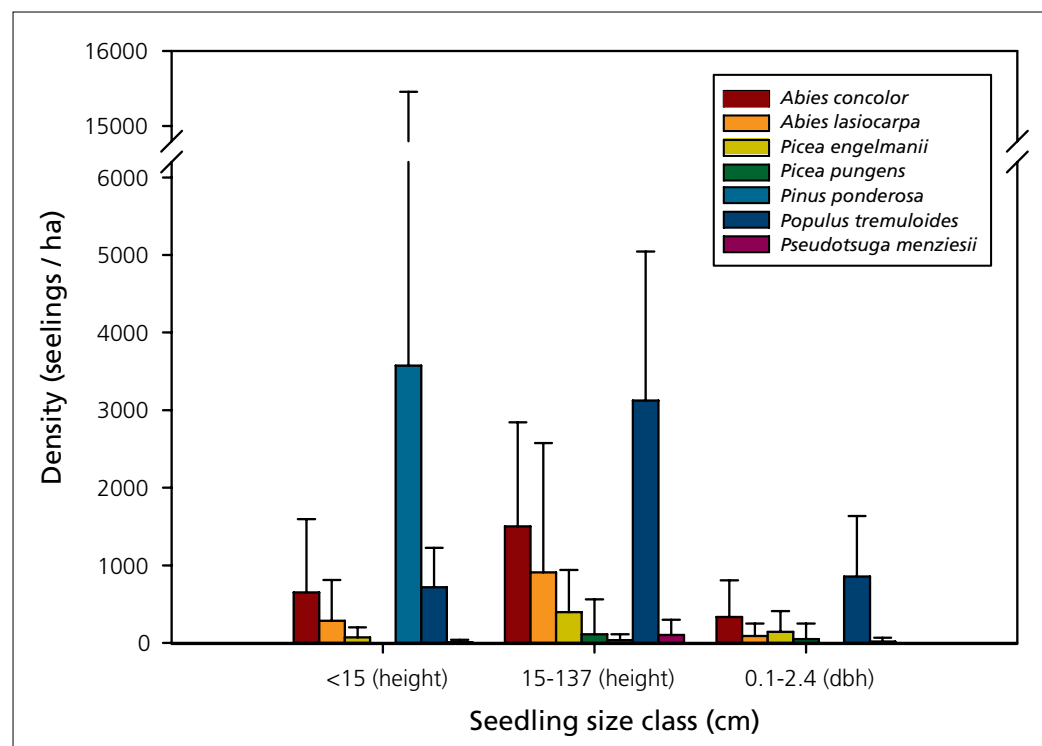


Figure 8. Density of seedlings by species. The two smallest size classes are measured by height; the largest size class is measured by diameter. Error bars represent one standard deviation.

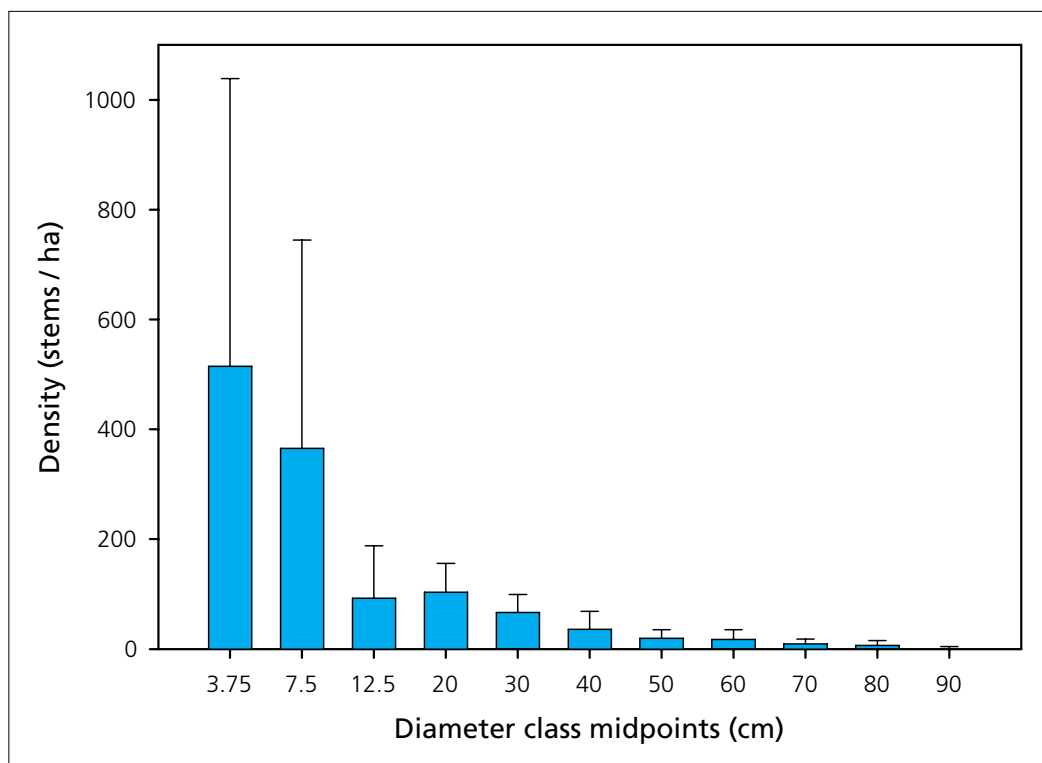


Figure 9. Size structure for overstory trees and saplings. Error bars represent one standard deviation.

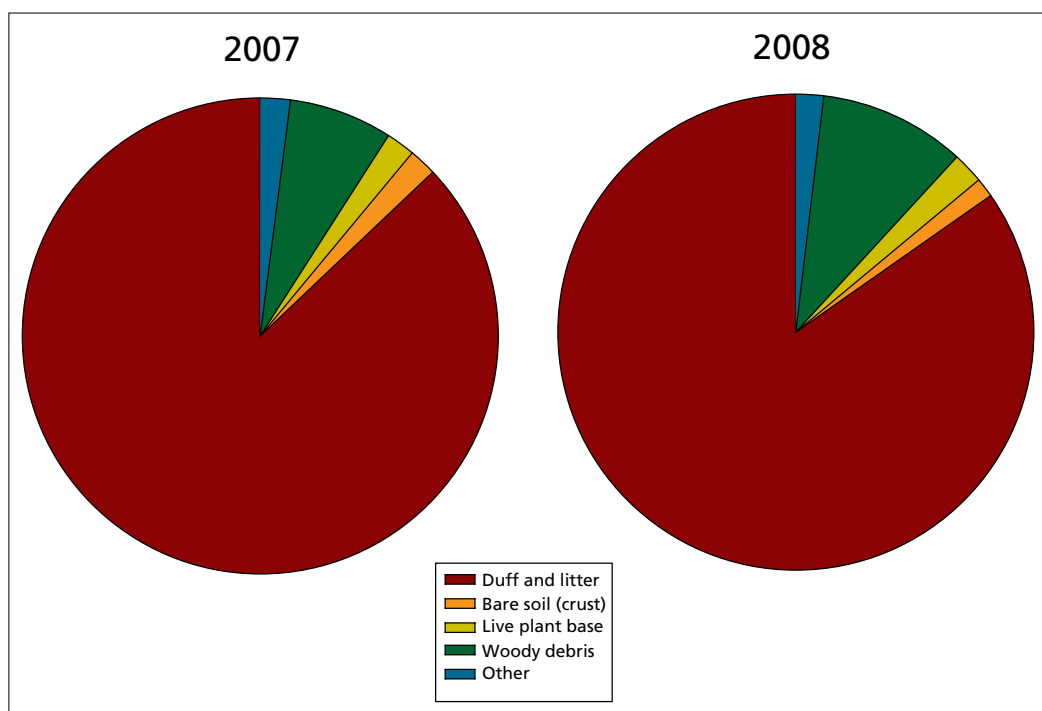


Figure 10. Mean cover of ground surface features in 2007 and 2008.

Table 5. Cover of ground surface features.

Surface feature	2007		2008	
	Mean cover (%)	(SD)	Mean cover (%)	(SD)
Live plant base	1.82	(1.66)	2.00	(1.52)
Dead woody base	0.51	(1.02)	0.60	(0.71)
Dead herbaceous base	n/a ^a	n/a	0.23	(0.21)
Bare soil	1.75	(2.67)	0.98	(0.89)
Duff and litter	80.97	(4.99)	79.73	(4.12)
Undifferentiated crust	0.00	(0.00)	0.26	(1.04)
Moss	0.46	(0.39)	0.33	(0.30)
Lichen	0.14	(0.25)	0.06	(0.06)
Cyanobacteria	0.00	(0.00)	0.00	(0.00)
Fine gravel (0.2 cm- 2cm)	0.14	(0.19)	0.20	(0.32)
Coarse gravel (2cm – 7.5 cm)	0.29	(0.30)	0.61	(1.09)
Cobble (7.5 cm – 25 cm)	0.24	(0.41)	0.47	(1.05)
Stone, bedrock (>25 cm)	0.65	(1.80)	0.35	(0.98)
Woody debris	6.54	(3.61)	9.36	(4.56)

Note: The surface feature components do not add up to 100% because the calculations were made from cover class midpoints, and estimations have observer errors.

^a Dead herbaceous base cover was not measured in 2007.

Discussion

These data represent the first year of baseline sampling for the Mixed-Conifer ecological site at GRCA, and a second year of sampling for shrub and herbaceous data. The monitoring data from the 16 plots demonstrate that the vegetation is highly variable among plots (fig. 11). The quadrat data showed that the herbaceous/shrub layer was sparse and co-dominated by perennial graminoids, forbs, and shrubs. Low quadrat frequencies, low abundances, and high standard deviations for individual species indicate heterogeneous composition (table 2). Species diversity indices indicate moderately high diversity and suggest heterogeneous understory vegetation on the landscape scale.

The changes in species abundances between the two years were generally small. A few species, such as *Carex rossii* and *Pteridium aquilinum*, showed relatively large decreases. The substantial changes that were evident were likely due to a late snowmelt in 2008 and differences in sampling time between years. Sampling began on July 6 in 2007 and on June 16 in 2008. Sampling time will become standardized in the future. Some of the observed changes may be the result of sampling error. Cover estimation may vary among individuals (and crews), similar species may occasionally be mis-identified, and the location of the quadrats will vary slightly from year to year. We strive to minimize these errors by ensuring that transect lines are as straight as possible, that quadrats are placed correctly, and that field crews are trained continuously on species identification and cover estimation.

Only one nonnative species was sampled—an encouraging result. It should be noted however that our sampling frame excluded moderately and severely burned areas and areas adjacent to roads and



Figure 11. Photopoints from two plots in the Mixed-Conifer ecological site. The plot on the left shows a dominance of *Pinus ponderosa* and *Populus tremuloides*, a sparse herbaceous/shrub layer, and a large amount of woody debris. The plot on the right shows a denser herbaceous layer and an absence of *Populus tremuloides*.

trails—areas that may be the most susceptible to the establishment of nonnative and other invasive species. Moreover, our monitoring was designed primarily to detect changes in condition of pre-dominant vegetation types, not to detect new nonnative species invasions. But the fact that 16 half hectare plots could be randomly placed on the landscape and contain only one nonnative species in low abundance is noteworthy.

Similar to the understory vegetation, the tree data also showed high heterogeneity in forest composition among plots. While the forest was dominated by *Pinus ponderosa*, *Abies concolor*, and *Picea engelmannii*, the composition of the overstory, sapling, and seedling layers was highly variable. Part of the high variation can be explained by the inclusion of high elevation spruce-fir forest in our sampling frame, but the high variation can also be attributed to the diversity in vegetation inherent in a topographically complex landscape.

The groundcover surface was predominantly duff and litter with large amounts of woody debris. These components act as fuel in wildland fires.

We plan to sample the quadrats and gap intercept transects annually for 3-5 years to determine the range of variability for key metrics. Power analysis will then be used to determine the total number of plots necessary to detect change in the key metrics. A temporal sampling design will then be implemented, with the installation of additional plots in subsequent years. Each year's data will be compared to the previously collected data to analyze changes through time in vegetation composition and structure and in soil stability and hydrological function. More thorough trend analyses will be conducted once sufficient data have been collected.

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Appendix A

Complete species list with mean foliar cover and frequency for herbaceous and shrub species in 2007 and 2008, and basal area of overstory trees and frequency of tree species (overstory, sapling, and seedling layers included) in 2007.

Table A1. Herbaceous and shrub species list.

Species	Common name	Family	2007		2008	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Achillea millefolium</i>	western yarrow	Asteraceae	0.035	37.50	0.029	37.50
<i>Agoseris glauca</i>	pale agoseris	Asteraceae	<.001	6.25	<.001	6.25
<i>Agrostis scabra</i>	rough bentgrass	Poaceae	0.002	12.50	0.001	12.50
<i>Amelanchier alnifolia</i>	Saskatoon serviceberry	Rosaceae	<.001	6.25	<.001	6.25
<i>Amelanchier utahensis</i>	Utah serviceberry	Rosaceae	0.003	6.25	0.001	6.25
<i>Androsace septentrionalis</i>	pygmy rock jasmine	Primulaceae	0.001	12.50	0.001	18.75
<i>Antennaria marginata</i>	white margin pussytoes	Asteraceae	0.039	37.50	0.064	37.50
<i>Antennaria parvifolia</i>	small leaf pussytoes	Asteraceae	0.035	56.25	0.027	50.00
<i>Aquilegia coerulea</i>	Colorado blue columbine	Ranunculaceae	0.003	6.25	0.003	6.25
<i>Arenaria fendleri</i>	Fendler's sandwort	Caryophyllaceae	0.004	12.50	0.003	12.50
<i>Arenaria lanuginosa</i>	spreading sandwort	Caryophyllaceae	0.003	12.50	0.001	12.50
<i>Bahia dissecta</i>	ragleaf bahia	Asteraceae	<.001	6.25	<.001	6.25
<i>Blepharoneuron tricholepis</i>	pine dropseed	Poaceae	0.011	18.75	0.006	18.75
<i>Brickellia grandiflora</i>	mountain brickellbush	Asteraceae	0.011	6.25	0.010	6.25
<i>Bromus anomalus</i>	nodding brome	Poaceae	0.001	12.50	0.002	12.50
<i>Bromus ciliatus</i>	fringed brome	Poaceae	0.139	100.00	0.161	100.00
<i>Carex rossii</i>	Ross' sedge	Cyperaceae	0.682	100.00	0.452	100.00
<i>Carex siccata</i>	dry-spike sedge	Cyperaceae	0.966	87.50	0.519	81.25
<i>Castilleja austromontana</i>	Rincon Indian paintbrush	Scrophulariaceae	0.002	12.50	0.002	12.50
<i>Castilleja linarifolia</i>	Wyoming Indian paintbrush	Scrophulariaceae	<.001	6.25	<.001	6.25
<i>Ceanothus fendleri</i>	Fendler's ceanothus	Rhamnaceae	0.002	18.75	0.005	18.75
<i>Chamerion angustifolium</i>	fireweed	Onagraceae	0.061	50.00	0.053	50.00

Table A1, continued.

Species	Common name	Family	2007		2008	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Chenopodium album</i>	lambsquarters	Chenopodiaceae	0.060	12.50	0.033	18.75
<i>Chenopodium graveolens</i>	fetid goosefoot	Chenopodiaceae	0.020	6.25	0.005	6.25
<i>Chenopodium leptophyllum</i>	narrowleaf goosefoot	Chenopodiaceae	0	0	<.001	6.25
<i>Chimaphila umbellata</i>	common pipsissewa	Pyrolaceae	0.001	6.25	0.002	12.50
<i>Cirsium wheeleri</i>	Wheeler's thistle	Asteraceae	0.011	25.00	0.009	25.00
<i>Collinsia parviflora</i>	blue-eyed Mary	Scrophulariaceae	0	0	<.001	12.50
<i>Conyza canadensis</i>	Canadian horseweed	Asteraceae	<.001	6.25	0	0
<i>Corallorrhiza maculata</i>	spotted coralroot	Orchidaceae	0.001	25.00	<.001	12.50
<i>Elymus canadensis</i>	Canada wildrye	Poaceae	0.026	12.50	0.028	12.50
<i>Elymus elymoides</i>	squirreltail	Poaceae	0.028	75.00	0.012	62.50
<i>Erigeron divergens</i>	spreading fleabane	Asteraceae	0.011	18.75	0.015	12.50
<i>Erigeron formosissimus</i>	beautiful fleabane	Asteraceae	0.035	31.25	0.072	43.75
<i>Erigeron speciosus</i>	aspen fleabane	Asteraceae	0.023	25.00	0.030	18.75
<i>Eriogonum racemosum</i>	redroot buckwheat	Polygonaceae	0.003	25.00	0.006	25.00
<i>Euphorbia brachycera</i>	horned spurge	Euphorbiaceae	<.001	6.25	0	0
<i>Fragaria virginiana</i>	Virginia strawberry	Rosaceae	0.242	100.00	0.315	100.00
<i>Fritillaria atropurpurea</i>	spotted fritillary	Liliaceae	0	0	<.001	6.25
<i>Gayophytum diffusum</i>	spreading groundsmoke	Onagraceae	0.002	12.50	0.006	31.25
<i>Geranium caespitosum</i>	piney-woods geranium	Geraniaceae	0.001	6.25	0.001	6.25
<i>Geranium richardsonii</i>	Richardson's geranium	Geraniaceae	0.081	25.00	0.145	25.00
<i>Goodyera oblongifolia</i>	western rattlesnake plantain	Orchidaceae	0.040	81.25	0.053	81.25
<i>Helioeris multiflora</i>	Showy goldeneye	Asteraceae	<.001	6.25	0	0
<i>Hesperostipa comata</i>	needle and thread	Poaceae	0.003	6.25	0.001	6.25
<i>Heterotheca villosa</i>	hairy false goldenaster	Asteraceae	0.001	6.25	0.001	6.25
<i>Hieracium fendleri</i>	yellow hawkweed	Asteraceae	0.011	56.25	0.018	68.75
<i>Hymenoxys subintegra</i>	Arizona rubberweed	Asteraceae	0.001	6.25	<.001	6.25
<i>Juniperus communis</i>	common juniper	Cupressaceae	0.836	68.75	0.939	62.50
<i>Kelloggia galioides</i>	milk kelloggia	Rubiaceae	0.001	6.25	0.004	6.25
<i>Koeleria macrantha</i>	prairie junegrass	Poaceae	0.001	12.50	0.001	6.25

Table A1, continued.

Species	Common name	Family	2007		2008	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Ligusticum porteri</i>	Porter's licorice root	Apiaceae	0.064	43.75	0.045	43.75
<i>Lotus utahensis</i>	Utah bird's-foot trefoil	Fabaceae	0.042	50.00	0.032	56.25
<i>Lotus wrightii</i>	Wright's deerveitch	Fabaceae	0.002	12.50	0.001	6.25
<i>Lupinus hillii</i>	hill lupine	Fabaceae	0.001	12.50	0.001	12.50
<i>Mahonia repens</i>	creeping barberry	Berberidaceae	0.069	68.75	0.099	68.75
<i>Maianthemum stellatum</i>	starry false solomon's-seal	Liliaceae	<.001	6.25	<.001	6.25
<i>Muhlenbergia montana</i>	mountain muhly	Poaceae	0.017	25.00	0.017	31.25
<i>Oreochrysum parryi</i>	Parry's goldenrod	Asteraceae	0.034	50.00	0.050	43.75
<i>Orthilla secunda</i>	sidebells wintergreen	Pyrolaceae	0.009	25.00	0.005	25.00
<i>Osmorhiza depauperata</i>	blunt-fruit sweet-cicely	Apiaceae	0.006	25.00	0.009	18.75
<i>Packera multilobata</i>	lobeleaf groundsel	Asteraceae	0.008	31.25	0.017	37.50
<i>Packera wernerifolia</i>	hoary groundsel	Asteraceae	0.004	18.75	0.004	18.75
<i>Pascopyrum smithii</i>	western wheatgrass	Poaceae	<.001	6.25	0.001	6.25
<i>Pedicularis centranthera</i>	dwarf lousewort	Scrophulariaceae	0.114	87.50	0.150	87.50
<i>Penstemon barbatus</i>	beardlip penstemon	Scrophulariaceae	0.019	18.75	0.018	18.75
<i>Penstemon virgatus</i>	upright blue penstemon	Scrophulariaceae	0.005	31.25	0.020	18.75
<i>Phacelia heterophylla</i>	variable-leaf scorpionweed	Hydrophyllaceae	0.011	25.00	0.010	25.00
<i>Poa fendleriana</i>	muttongrass	Poaceae	0.178	100.00	0.179	100.00
<i>Polygonum douglasii</i>	Douglas' knotweed	Polygonaceae	0.001	18.75	0	0
<i>Pseudocymopterus montanus</i>	alpine false springparsley	Apiaceae	0.013	43.75	0.008	37.50
<i>Pseudognaphalium macounii</i>	Macoun's cudweed	Asteraceae	0.008	12.50	0.001	18.75
<i>Pseudostellaria jamesiana</i>	tuber starwort	Caryophyllaceae	0.036	43.75	0.065	37.50
<i>Pteridium aquilinum</i>	western bracken fern	Dennstaedtiaceae	0.254	37.50	0.063	31.25
<i>Pyrola chlorantha</i>	green flowered wintergreen	Pyrolaceae	0.001	18.75	<.001	6.25
<i>Pyrola picta</i>	white veined wintergreen	Pyrolaceae	0.003	25.00	0.006	25.00
<i>Robinia neomexicana</i>	New Mexico locust	Fabaceae	0.404	12.50	0.236	12.50
<i>Rubus idaeus</i>	western red raspberry	Rosaceae	0.011	18.75	0.007	18.75

Table A1, continued.

Species	Common name	Family	2007		2008	
			Foliar cover (%)	Plot frequency (%)	Foliar cover (%)	Plot frequency (%)
<i>Sambucus nigra</i>	common elderberry	Caprifoliaceae	0.003	6.25	0.001	6.25
<i>Senecio wootonii</i>	Wooton's ragwort	Asteraceae	0.001	12.50	0.003	18.75
<i>Silene scouleri</i>	simple campion	Caryophyllaceae	0.001	25.00	0.003	18.75
<i>Solidago velutina</i>	threenerve goldenrod	Asteraceae	0.029	12.50	0.071	12.50
<i>Solidago wrightii</i>	Wright's goldenrod	Asteraceae	0.019	6.25	0.024 ^a	6.25
<i>Sorbus dumosa</i>	Arizona mountain ash	Rosaceae	0.008	6.25	0.006	6.25
<i>Symphoricarpos oreophilus</i>	mountain snowberry	Caprifoliaceae	0.037	6.25	0.065	6.25
<i>Taraxacum officinale</i> ^a	common dandelion	Asteraceae	0.003	12.50	0.003	12.50
<i>Thalictrum fendleri</i>	meadow-rue	Ranunculaceae	0.007	6.25	0.009	6.25
<i>Thlaspi montanum</i>	alpine pennycress	Brassicaceae	0.003	18.75	0.004	31.25
Unknown 07072007-1			<.001	6.25	0	0
Unknown 19062008-1			0	0	<.001	6.25

^a Nonnative species.

Table A2. Tree species list.

Species	Common name	Family	Basal area (m ² /ha)	Plot frequency (%)
<i>Abies concolor</i>	white fir	Pinaceae	5.82	93.75
<i>Abies lasiocarpa</i>	subalpine fir	Pinaceae	1.25	56.25
<i>Picea engelmannii</i>	Engelmann spruce	Pinaceae	3.38	68.75
<i>Picea pungens</i>	blue spruce	Pinaceae	2.06	25.00
<i>Pinus ponderosa</i>	ponderosa pine	Pinaceae	9.44	87.50
<i>Populus tremuloides</i>	quaking aspen	Salicaceae	3.41	100.00
<i>Pseudotsuga menziesii</i>	Douglas fir	Pinaceae	2.87	75.00