



Integrated Upland Monitoring in Cedar Breaks National Monument

Annual Report 2011 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2013/695.N



ON THE COVER

Monitoring spruce-fir forests at Cedar Breaks National Monument. NPS photo.

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Executive Summary

The goal of the Northern Colorado Plateau Network (NCPN) integrated upland monitoring effort is to provide park managers with status and trend information on vegetation and soil attributes. This information is intended to provide early warning of resource degradation and determine natural variability of upland resources.

This report summarizes NCPN upland monitoring at Cedar Breaks National Monument (NM) during 2011. It outlines goals and objectives of NCPN upland monitoring, methods of the upland monitoring protocol, and procedures for defining and mapping target populations for monitoring, and describes the results of this year's efforts and plans for future monitoring. This was the third year of monitoring forests and meadows above the rim at Cedar Breaks NM, and eight plots were visited. Early monitoring data describe status of vegetation; interpretation is limited until additional data are acquired and more rigorously analyzed after at least five years of monitoring are complete.

Acknowledgements

S. Topp and S. Karinen conducted field work. A. Wight provided maps and managed spatial data. L. Houghton helped assemble summary data. D. Perkins improved this report with his thoughtful review. Data management was provided by H. Thomas. D. Perry assisted with administrative details. M. Harrison provided logistical assistance.

1 Introduction

Uplands represent the vast majority of land area in national park units of the Northern Colorado Plateau Network (NCPN). These upland areas include rock outcrops, badlands, shrublands, grasslands, woodlands, forests, and subalpine meadows, with local vegetation determined by soil type and depth, topography, climate, and disturbance history.

Upland vegetation supplies most regional primary productivity, which translates to energy for other trophic levels. The condition of upland vegetation influences soil stability and nutrient cycling, which, in turn, determines potential above-ground production of native plant species and the propensity for invasion by non-native species. Vegetation also provides habitat for various organisms. The ability of uplands to retain soil and nutrients, absorb and release water, and buffer high-runoff precipitation events also influences conditions in riparian areas.

Many upland ecosystems of the northern Colorado Plateau are characterized by low resistance and resilience. Even moderate disturbances can affect vegetative composition and structure, and recovery to pre-disturbance conditions can be relatively slow. Natural disturbance regimes of the region include extreme climatic events, fire, insect and disease outbreaks, herbivory, and trampling (Miller 2005).

Grazing, which has been a traditional land use throughout much of the plateau, has resulted in shifts in vegetation composition (Harris et al. 2003) and ecological states (Miller et al. 2011) that persist for many decades or longer. Fire-regime alteration (Whelan 1995) and invasion of exotic plants (Bock et al. 1986) have additionally contributed to these shifts. Increasing recreational use and unauthorized social trailing threaten the integrity of upland systems through soil surface disturbance and resulting increases in soil erosion by water and wind.

Additional pressure inside parks may also result from land use in adjacent areas. Global climate change is expected to change levels and seasonality of dominant precipitation

events (Garfin et al. 2010), and we are only beginning to understand the implications for plateau ecosystems (Munson et al. 2011a,b). Additional information on characteristics of Colorado Plateau ecosystems and ecological threats to the region is provided in Miller (2005).

The overall goal of the NCPN integrated upland monitoring program is to determine long-term trends in vegetation, soil stability, and hydrologic function in the context of changes in other ecological drivers, stressors, and processes. Monitoring will increase fundamental understanding of upland systems and provide managers with early warning of undesirable change and information for management decisions. Specific objectives of upland monitoring at Cedar Breaks National Monument are described below.

Determine status and trends in plant communities, including:

- overall species richness
- cover of vegetation by dominant species and lifeform
- density of shrubs by size class
- basal area and density of tree species
- canopy closure
- fuel volume and litter/duff depth
- frequency of exotic invasive species

Determine status and trends in soil stability, including:

- cover of biological soil crusts by morphological group (cyanobacteria, lichen, moss, and undifferentiated crust)
- cover of other surface features (e.g., litter, rock, bare ground)

Evaluation of upland monitoring data relative to other vital signs will help facilitate identification of drivers and distinguishing “natural” from anthropogenic change. Local weather station data can be used to interpret responses, whereas remote sensing can be used to determine change in vegetation at larger scales caused by land use or climate change. Historical upland monitoring data sets may be integrated with data collected by NCPN to allow earlier detection of trends.

2 Methods

2.1 Integrated upland monitoring in Cedar Breaks National Monument

2.1.1 Resource issues driving upland monitoring

Discussion with Cedar Breaks National Monument (NM) staff identified high-elevation meadows, spruce-fir forests, and aspen (*Populus tremuloides*) stands as the highest priorities for long-term monitoring. Management issues of concern included expansion and contraction of vegetation types, recovery of spruce-fir forests from beetle kill, sudden aspen decline (SAD), and the spread of smooth brome (*Bromus inermis*) invasion.

Currently, the area above the rim in Cedar Breaks NM is dominated by a mixture of meadows and spruce-fir forest. Although there are large patches of forest in many areas, there are also islands and fingers of forest interspersed throughout the meadows. Determining how climate change will affect certain community types and reposition their distribution across the landscape is of interest to resource managers. Spruce-fir forests, especially Engelmann spruce (*Picea engelmannii*) within the forests, have been heavily attacked by bark beetles, creating a high percentage of dead trees throughout these forests. Tracking recovery of these forests is an important management priority due to the extent of the affected area.

Although aspen stands make up a relatively small part of high-elevation vegetation in Cedar Breaks NM, they are of particular concern due to the threat of SAD. Finally, smooth brome is an invasive exotic perennial grass that is present along roadsides and has expanded into other areas of the monument. Although Cedar Breaks NM actively treats some areas to remove this species, there is concern that it is displacing native grasses and forbs in the meadows.

2.1.2 Mapping and selecting target populations

2.1.2.1 Accessibility

An accessibility map was created for Cedar Breaks NM based on road and trail access.

Steep slopes ($\geq 50\%$) and areas isolated due to steep slopes (e.g., mesa tops) were considered inaccessible for upland monitoring. Accessibility in Cedar Breaks NM was derived using the NCPN LAM system (Landscape Accessibility Model; <http://science.nature.nps.gov/im/units/ncpn/Tools.cfm>).

2.1.2.2 Selecting and mapping target vegetation types

Defining the target population typically involves determining the ecological sites that correspond to the resource of interest. Dixie National Forest (DNF) mapped soils for Cedar Breaks NM but did not include associated ecological sites (USFS unpublished). Instead, broad categories of vegetation are associated with each soil map unit. Comparing the DNF soil map to the draft NCPN vegetation map showed that the priority vegetation types were not well distinguished by soil map units. Therefore, ecological sites and soil map units were not incorporated into the survey design for Cedar Breaks NM.

Due to issues with the soil survey and the relatively small area of the monument, we decided to use a simple mapping process for Cedar Breaks NM. Stratification of the sampling frame was minimized by using the natural barrier of the breaks to distinguish high elevations in the monument. Within the accessible area, all target vegetation types (subalpine meadow, spruce-fir, and aspen; Figure 2-1) were included in the sampling frame using their associated vegetation map units (Figure 2-2). This represented 88% (or 548 ha) of the accessible area of the monument above the rim.

2.1.3 Selection of monitoring locations

A 65-m buffer was applied to roads, trails, the park boundary, non-target vegetation, and inaccessible areas. Using the remaining map area, monitoring plots were selected using the Generalized Random Tessellated Stratified (GRTS) method (Stevens and Olsen 2004) to create a spatially balanced design. Coordinates corresponded to the centroid of a plot (see Figure 2-2). Plots were established in ascending order of plot number. If a plot was rejected (e.g., due to transects' crossing a road or trail), the next sequentially ordered plot was used.



Figure 2-1. Examples of dominant vegetation types monitored in Cedar Breaks National Monument.

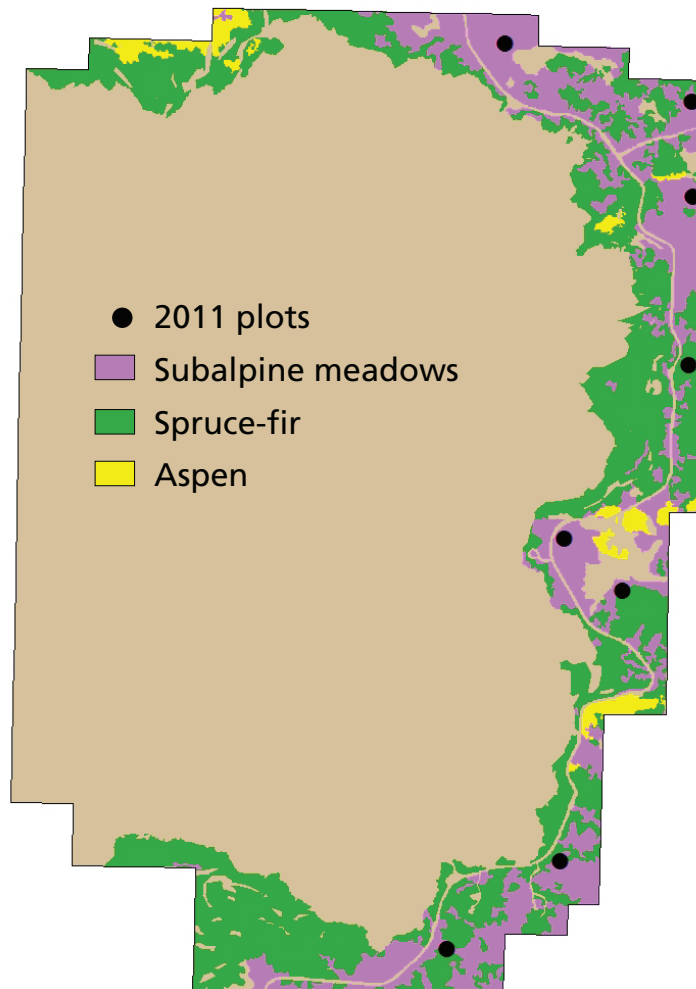


Figure 2-2. Location of monitoring plots in Cedar Breaks National Monument, 2011. Colors illustrate predicted vegetation types in the sampling frame above the rim.

Combining all target vegetation types in the sampling frame allows plots to fall near the boundary of different vegetation types so that expansion and contraction of communities can be monitored.

2.1.4 Revisit design

A rotating-panel revisit design (Figure 2-3) was created that samples eight plots each year for a total of 28 plots over seven years. Plots are sampled for two consecutive years in order to detect year-to-year differences (due to temperature, precipitation, etc.) and rested for five years. Every seven years, the sampling scheme repeats itself. The number of plots in each vegetation type should approximately represent the area of each vegetation type in the sampling frame.

2.2 Integrated upland monitoring procedures

2.2.1 Response design

The response design (methods used to collect observations) for integrated upland monitoring in NCPN parks is based largely on rangeland monitoring procedures recommended by Herrick and colleagues (2005) and standard forest, woodland, and fuels procedures (NPS 2003; Brown 1974).

Panel	Year						
	1	2	3	4	5	6	7
1	4	4					
2		4	4				
3			4	4			
4				4	4		
5					4	4	
6						4	4
7	4						4

Figure 2-3. Number of plots sampled each year based on a 7-year rotating panel revisit design for long-term upland monitoring at Cedar Breaks National Monument.

At each plot, observations are recorded along three parallel, 50-m transects spaced 25 m apart (Figure 2-4). Photos of each transect are taken from the origin and end. A point-intercept method is used to record percent cover of understory (<2 m) plant species and ground-cover attributes at 0.5-m intervals along each transect. All species, and the number of shrubs (by species and height class) and tree seedlings (by species), are recorded in a 1-m belt upslope of each transect. Density of exotic perennial species in the 1-m belt was discontinued beginning in the 2011 field season. Instead, frequency of all exotic species (annual and perennial) is recorded using 1×1-m quadrats placed every 5 m along each transect.

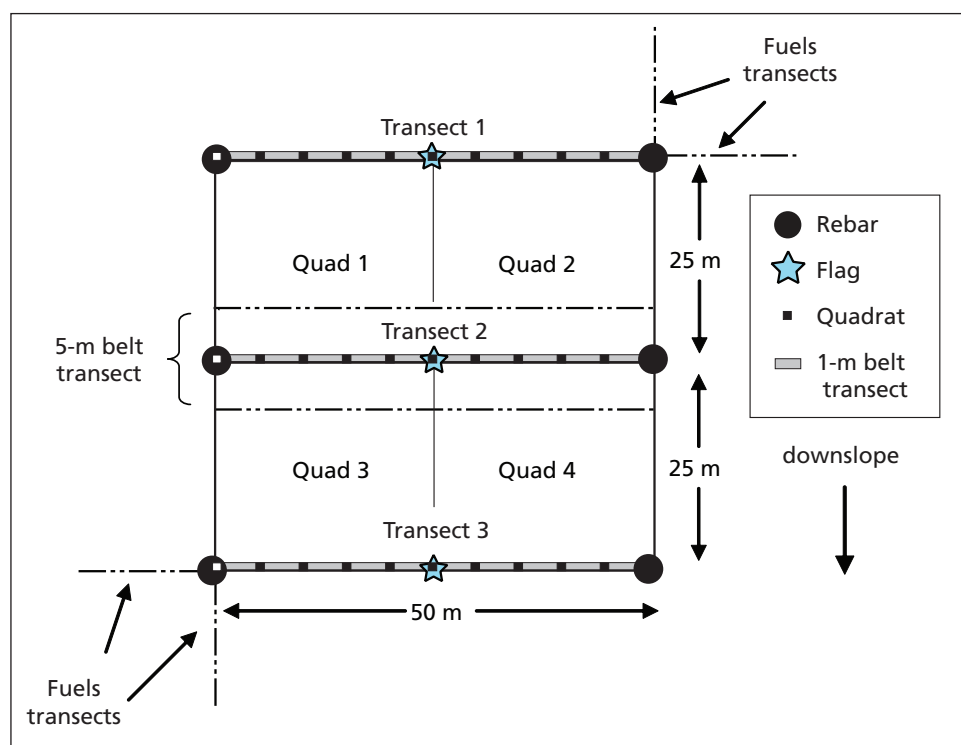


Figure 2-4. Plot layout for upland monitoring of forests and subalpine meadows.

Saplings (2.5–15-cm diameter) are identified to species, and density is tallied in a 5-m belt transect centered on Transect 2. All overstory trees (>15 cm diameter) in Quadrant 1 are identified to species, tagged with unique numbers, and measured for diameter. The diameter of all trees is measured at breast height. Crown health and class of trees are also recorded. Crown health describes the percent of live foliage for each tree. Crown class describes the relative position of each live tree in the canopy. The NCPN uses the following crown classes (Figure 2-5):

Dominant. Trees have crowns extending above the general level of the main canopy of adjacent trees and receive full light from above and partly from the sides.

Codominant. Trees have crowns forming the general level of the main canopy of adjacent trees and receive full light from above and comparatively little from the sides.

Intermediate. Trees have crowns extending into the lower portion of the main canopy of adjacent trees, but are shorter in height than the codominants. They receive little direct light from above and none from the sides. Intermediate crown-classed trees usually have small crowns that are crowded on the sides.

Overtopped/Suppressed. Trees have crowns entirely below the general level of the canopy of adjacent trees, and receive no direct light from above or from the sides.

Overstory canopy closure is measured every 10 m along the transects using a concave spherical densiometer. Fuels are measured using Brown's planar method (Brown 1974) along four 50-ft transects that extend beyond the plot on two corners. Counts of fine woody fuels and diameters of coarse woody fuels are recorded to derive volumes of each fuel class, and depth of litter and duff are measured. Disturbances observed on and around the site are also recorded. Beginning in 2011, an "exotic species walk" was added to search for other exotic plants present in plots.

All measures recorded along transects are sub-samples scaled to the plot level. The plot-level measures are the primary values used in summaries and statistical analyses.

2.3 Database

All observations recorded in the field are stored in an NCPN Access database. Quality assurance and quality control (QA/QC) procedures include domain checking in data-entry procedures, checks for missing values, and logic checks. All spatial data used in selecting monitoring locations, the sampling frame map, and the GRTS-generated sampling locations are GIS-ArcMap shape files and are stored with the Access database on NCPN servers.

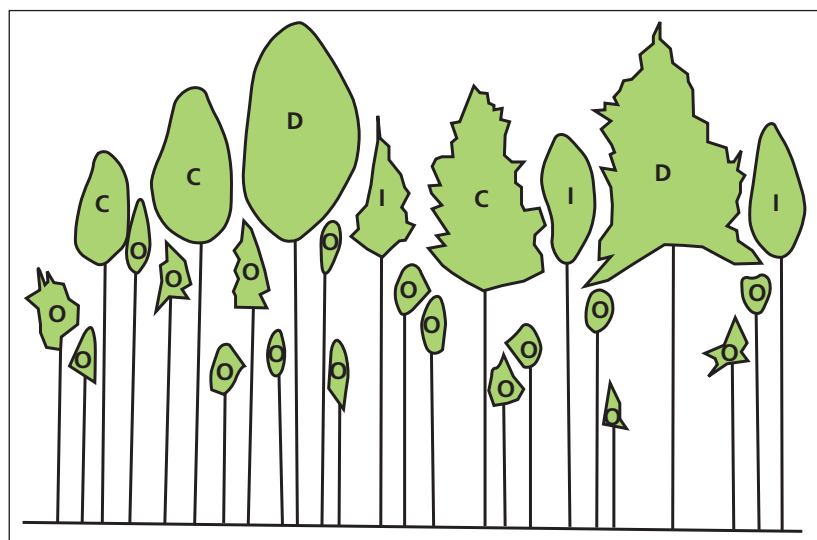


Figure 2-5. The relative positions of trees using four classes for crown classification. D =Dominant, C = Codominant, I = Intermediate, and O = Overtopped/Suppressed.

3 Results

3.1 Monitored plots

In July 2011, eight plots were monitored as part of the long-term revisit design. Four of these plots were newly established.

3.2 Summaries

Status and trend assessments are more meaningful after many years of monitoring, and as the number of monitoring plots increases. More intensive evaluation of monitoring data is slated to commence after five full years of monitoring are complete.

For this annual report, plot-level summaries of the measures in Chapter 1 were generated for each monitoring plot, then summarized for the entire area above the rim. Summaries are simply a mean and the range (minimum, maximum) for a measured attribute. Qualitative assessments of summary measures could be misleading, given the small sample sizes. The reader is cautioned not to draw wide-reaching conclusions from these preliminary summaries.

3.2.1 Species richness

Eighty-two species were detected during monitoring in 2011. Species richness by lifeform is reported in Table 3-1. Recorded species were compared to the NPSpecies database to determine first-time observations in Cedar Breaks NM. No new species were detected in the park in 2011.

3.2.2 Overstory canopy closure and understory cover by lifeform and dominant species

Overstory canopy closure and percent cover of live and total vegetation in the understory by lifeform are shown in Table 3-2. Live cover includes photosynthetic and live woody tissue. Total cover additionally includes dead plants, dead parts of live plants, and senesced tissue that was alive earlier in the growing season.

Live and total percent cover of dominant understory species are shown in Table 3-3.

Dominant species were selected using species frequently detected in plots. For each plot, the percent cover of all understory species and additional species recorded in the 1-m belt are included in an electronic appendix that accompanies this report (cebr11_species.xls).

3.2.3 Shrub density

Density of shrub species is shown in Table 3-4. Shrubs were uncommon, with the exception of alpine prickly currant (*Ribes montigenum*) and red elderberry (*Sambucus racemosa*) at a couple of plots.

3.2.4 Tree density

Density of live seedlings, saplings, and overstory trees, and crown class of live overstory trees, are shown in Table 3-5. Density, dbh, and crown health for all overstory trees >15 cm dbh are shown in Table 3-6.

3.2.5 Exotic species

Percent cover and frequency of detection of exotic plant species are shown in Table 3-7. Three exotic species were detected at monitoring plots through cover and frequency sampling. Kentucky bluegrass (*Poa pratensis*) was detected at all plots, with frequency as high as 93.3%. Common dandelion (*Taraxacum officinale*) was detected at all plots except one, but cover tended to be low. Smooth brome was detected at one plot (#107), with a frequency of 63%.

Beginning in 2011, NCPN upland sampling methods also included an “exotic species walk” to search for other exotic plants present in plots. A list of all exotic species detected, and descriptions of the number of plants, size of invasions, and approximate locations, are included in an electronic appendix that accompanies this report (cebr11_exotics.xls).

3.2.6 Threatened and endangered species

Although Cedar Breaks NM does not have any populations of federally listed threatened or endangered plant species within its borders, at least 18 species of special concern exist within the monument (Fertig 2009). None of these species was detected in monitoring plots in 2011, and the NCPN does not specifically monitor them in the monument.

3.2.7 Surface features

Surface-feature cover is shown in Table 3-8. The dominant surface cover at plots was undifferentiated crust, litter, or small rocks.

3.2.8 Fuels

Fuel volumes and depth of litter and duff are reported in Table 3-9. Fuels ranged from nothing in meadow plots to substantial amounts of sound, 1,000-hr fuels in forest plots with significant tree mortality.

Table 3-1. Mean (range) number of plant species detected per monitoring plot, Cedar Breaks National Monument, 2011.

Vegetation	Mean number of species detected
Tree	1.4 (0–3)
Shrub	1.0 (0–3)
Perennial grass	7.6 (5–12)
Annual grass	0
Forb/Herb	22.5 (17–29)
Total	32.5 (24–44)

Table 3-2. Mean (range) percent overstory canopy closure, and percent cover of understory vegetation, Cedar Breaks National Monument, 2011.

Vegetation	Percent	Percent cover	
		Live	Total
Overstory canopy closure	13.4 (0–48.2)	-	-
Total understory		59.8 (43.7–78.0)	62.4 (46.0–79.3)
Tree		7.3 (0–30.3)	8.4 (0–33.7)
Shrub		3.1 (0–7.3)	3.2 (0–7.7)
Perennial grass		14.5 (3.3–26.7)	16.7 (4.0–31.3)
Annual grass		0	0
Forb/Herb		44.0 (24.3–71.0)	44.3 (24.7–71.0)

Table 3-3. Mean (range) percent cover of dominant understory species, Cedar Breaks National Monument, 2011.

Scientific name	Common name	Lifeform	Duration	Nativity	No. of plots with species present*	Percent cover	
						Live	Total
<i>Abies lasiocarpa</i>	subalpine fir	Tree	Perennial	Native	5	4.5 (0-22.3)	4.9 (0-23.0)
<i>Achillea millefolium</i>	common yarrow	Forb	Perennial	Native	8	6.0 (2.7-10.3)	6.0 (2.7-10.3)
<i>Agoseris glauca</i>	pale agoseris	Forb	Perennial	Native	3	0.7 (0-4.7)	0.8 (0-5.0)
<i>Arenaria fendleri</i>	Fendler's sandwort	Forb	Perennial	Native	3	1.5 (0-6.7)	1.5 (0-6.7)
<i>Bromus ciliatus</i>	fringed brome	Graminoid	Perennial	Native	4	0.5 (0-1.7)	0.6 (0-2.0)
<i>Delphinium barbeyi</i>	subalpine larkspur	Forb	Perennial	Native	2	1.3 (0-6.7)	1.4 (0-8.0)
<i>Elymus trachycaulus</i>	slender wheatgrass	Graminoid	Perennial	Native	6	1.0 (0-4.3)	1.3 (0-4.7)
<i>Erigeron ursinus</i>	bear daisy	Forb	Perennial	Native	7	3.6 (0-9.3)	3.6 (0-9.7)
<i>Mertensia arizonica</i>	aspen bluebell	Forb	Perennial	Native	5	3.0 (0-8.3)	3.0 (0-8.7)
<i>Osmorhiza depauperata</i>	blunt sweet-cicely	Forb	Perennial	Native	3	0.4 (0-1.7)	0.4 (0-1.7)
<i>Penstemon rydbergii</i>	Rydberg's penstemon	Forb	Perennial	Native	4	9.5 (0-35.3)	9.5 (0-36.0)
<i>Picea engelmannii</i>	Engelmann spruce	Tree	Perennial	Native	5	2.8 (0-7.0)	3.6 (0-10.3)
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	3	0.3 (0-1.7)	0.3 (0-2.0)
<i>Ribes montigenum</i>	alpine prickly currant	Shrub	Perennial	Native	5	3.1 (0-7.3)	3.2 (0-7.7)
<i>Solidago multiradiata</i>	Rocky Mountain goldenrod	Forb	Perennial	Native	6	1.8 (0-7.3)	1.8 (0-7.3)
<i>Stipa lettermanii</i>	Letterman's needlegrass	Graminoid	Perennial	Native	8	2.5 (0.3-7.0)	3.0 (0.3-9.3)
<i>Thalictrum fendleri</i>	Fendler's meadow-rue	Forb	Perennial	Native	3	1.6 (0-11.3)	1.6 (0-11.3)
<i>Trifolium longipes</i>	longstalk clover	Forb	Perennial	Native	8	5.1 (0.7-16.3)	5.2 (0.7-16.3)

* 8 plots were monitored in 2011.

Table 3-4. Density of shrub species per hectare, Cedar Breaks National Monument, 2011.

Scientific name	Common name	No. of plots with species present*	Density (number of shrubs/ha)		
			Mean	Minimum	Maximum
<i>Rubus idaeus</i>	American red raspberry	1	8	0	67
<i>Sambucus racemosa</i>	red elderberry	2	33	0	200

* 8 plots were monitored in 2011.

Table 3-5. Mean (range) density of live seedlings, saplings, and overstory trees, and crown class of live overstory trees, Cedar Breaks National Monument, 2011.

Scientific name	Common name	No. of plots with species detected*	Density of trees by dbh class (no. of trees/ha)					Crown class			
			Seedling	Sapling		Tree		% O	% I	% C	% D
			<2.5 cm	2.5–5.0 cm	5.1–10.0 cm	10.1–15.0 cm	>15 cm				
<i>Abies lasiocarpa</i>	subalpine fir	5	1,292 (0–6,933)	185 (0–920)	85 (0–440)	5 (0–40)	46 (0–128)	3 (0–13)	62 (0–100)	35 (0–100)	0
<i>Picea engelmannii</i>	Engelmann spruce	5	75 (0–200)	70 (0–360)	60 (0–320)	45 (0–280)	30 (0–96)	0	69 (25–100)	31 (0–75)	0
<i>Populus tremuloides</i>	Quaking aspen	1	450 (0–3,600)	0	0	0	0	0	0	0	0

* 8 plots were monitored in 2011.

Crown class codes: O=Overtopped, I=Intermediate, C=Codominant, D=Dominant.

Table 3-6. Mean (range) density, diameter at breast height (dbh), and crown health for all trees >15 cm dbh, Cedar Breaks National Monument, 2011.

Scientific name	Common name	Density (no. of trees/ha)	dbh (cm)	Crown health				
				% 1	% 2	% 3	% 4	% 5
<i>Abies lasiocarpa</i>	subalpine fir	62 (0–128)	26.5 (22.9–29.5)	38 (13–88)	25 (0–50)	0	10 (0–29)	26 (0–50)
<i>Picea engelmannii</i>	Engelmann spruce	84 (0–304)	37.3 (28.8–42.3)	43 (7–67)	0	4 (0–14)	0	53 (33–79)

Crown health codes: 1=90–100% live foliage, 2=50–89% live foliage, 3=16–49% live foliage, 4=0.1–15% live foliage, 5=standing dead.

Table 3-7. Mean (range) percent cover and frequency of exotic plant species detected in Cedar Breaks National Monument, 2011.

Scientific name	Common name	Lifeform	Duration	No. of plots with exotic species detected*	Percent cover		Frequency of detection (%)
					Live	Total	
<i>Bromus inermis</i>	smooth brome	Graminoid	Perennial	1	2.0 (0–16.3)	2.4 (0–19.3)	7.9 (0–63.3)
<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	8	6.3 (0.3–16.0)	6.8 (0.3–18.0)	51.7 (20.0–93.3)
<i>Taraxacum officinale</i>	common dandelion	Forb	Perennial	7	0.7 (0–3.7)	0.7 (0–3.7)	21.7 (0–60.0)

* 8 plots were monitored in 2011.

Table 3-8. Mean (range) percent cover of surface features, Cedar Breaks National Monument, 2011.

Surface feature	Percent cover
Crust, undifferentiated	17.8 (2.3–35.0)
Cyanobacteria	0
Lichen	0
Moss	0.1 (0–0.3)
Bare soil	3.1 (0–11.0)
Litter	51.3 (22.7–78.3)
Woody debris	2.1 (0–6.3)
Small rock	11.0 (1.0–23.0)
Large rock	0.7 (0–2.3)
Bedrock	0.04 (0–0.3)

Table 3-9. Mean (range) fuel volume and depth of litter and duff, Cedar Breaks National Monument, 2011.

Fuel volume (tons/acre)					Depth (cm)	
Total	1-hr	10-hr	100-hr	1000-hr	Litter	Duff
				Sound Rotten		
7.9 (0–24.9)	0.05 (0–0.1)	0.4 (0–1.1)	0.5 (0–1.9)	6.2 (0–21.4) 0.9 (0–5.8)	0.8 (0.1–1.6)	0.5 (0–1.2)

*A piece of fuel is rotten when it is obviously punky or can be easily kicked apart at the intersection point; otherwise it is considered sound.

4 Discussion

In general, data from 2011 were fairly similar to those from the previous two years. Half of the plots monitored in 2011 were newly established, and it is important to remember that any differences between years could be due to the different suite of plots sampled, rather than actual changes on the landscape. This variation will be accounted for in status and trend analyses after plots have been revisited; it is too early to draw conclusions from these preliminary data.

In 2012, eight plots will be monitored according to the full operational monitoring design, including four plots that will be newly established. Continued discussion will occur with Cedar Breaks National Monument resource staff to ensure that park expectations and needs are satisfied by NCPN integrated upland monitoring. A status and trend report will be produced after five years of monitoring are completed.

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