



Integrated Upland Monitoring in Timpanogos Cave National Monument

Annual Report 2010 (Non-sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2012/526.N



ON THE COVER

Northern Colorado Plateau Network crew monitoring the subalpine meadow at Timpanogos Cave 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 determine natural variability of upland resources and provide early warning of resource degradation.

This report summarizes NCPN upland monitoring at Timpanogos Cave National Monument (NM) during 2010. 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 second year of monitoring subalpine meadows, mixed conifer forests, and Gambel oak (*Quercus gambelii*) shrublands at Timpanogos Cave NM, and a total of three plots were visited. Early monitoring data describe status of vegetation; interpretation is limited until additional data are acquired and more rigorously analyzed.

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.

Upland ecosystems of the Colorado Plateau, where the majority of NCPN park units are located, tend to be dominated by shrubs, perennial grasses, and small trees. Although these life forms play an integral role in defining the structure and function of Colorado Plateau ecosystems (Whitford 2002), it is the highly-pinnacled biological soil crusts that make these these dryland systems unique. Biological soil crusts are biotic communities composed of cyanobacteria, algae, micro-fungi, mosses, and lichens that occur on and within the upper few millimeters of the soil surface (Belnap et al. 2003). Their presence stabilizes the soil surface and reduces susceptibility to wind and water erosion (Williams et al. 1995). They also contribute to nutrient cycling by fixing C (Lange 2003) and N (Evans and Lange 2003; Belnap 2002) and affect the availability of nutrients to plants (Harper and Belnap 2001). Biological soil crusts are particularly sensitive to disturbances that affect the soil surface, such as trampling and off-road vehicle use (Rosentreter and Belnap 2003).

In the basins neighboring the Colorado Plateau, where several NCPN park units are located, biological soil crusts also play an important role but are less dramatically pin-

nacled. In the forests, shrublands, and meadows of the mountain regions surrounding the Colorado Plateau, where numerous NCPN park units are located, the role of biological soil crusts is less important because much of the soil surface is covered by vegetation and litter.

Many upland ecosystems of the region 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 threatens 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 the integrated upland monitoring protocol are described below.

Determine status and trends in plant communities, including:

- overall species richness
- cover of vegetation by dominant species and life form
- 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 (litter, rock, bare ground, etc.)

- soil aggregate stability
- canopy-gap size (as an indicator of wind erosion potential)

Determine status and trends in hydrologic function, including:

- basal-gap size

Evaluation of upland monitoring data relative to other vital signs will help us to identify drivers and distinguish “natural” from anthropogenic change. Local weather-station data can be used to interpret responses, and 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 the NCPN to allow earlier detection of trends.

2 Methods

2.1 Integrated Upland Monitoring at Timpanogos Cave National Monument

2.1.1 Resource issues driving upland monitoring

Through discussion with Timpanogos Cave National Monument (NM) resource management staff, subalpine meadows, mixed conifer forests, and Gambel oak (*Quercus gambelii*) shrublands were identified as priority communities for long-term upland monitoring (Figure 2-1).

2.1.2 Accessibility

Areas that posed safety threats, were inaccessible within budgetary limitations, and/or were anthropogenic in nature were filtered out of the sampling frame. Areas located on slopes of $\geq 50\%$ and/or isolated by steep slopes were eliminated. Accessibility and slope features were generated using the Landscape Accessibility Model (<http://science.nature.nps.gov/im/units/ncpn/Tools.cfm>). The total accessible area in Timpanogos Cave NM was approximately 14 ha.

2.1.3 Selection of monitoring locations

Due to the small area of the monument and the steep slopes over much of that area, opportunities for upland monitoring at Timpanogos Cave NM were limited. During a field visit in October 2008, one location in each priority vegetation type was identified with gentle slopes and enough area upon which to fit an upland monitoring plot (Figure 2-2). There is no sampling frame for Timpanogos Cave NM and, therefore, no inference beyond the individual plots.

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 others (2005) and standard forest, woodland, and fuels procedures (NPS 2003; Brown 1974). 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.

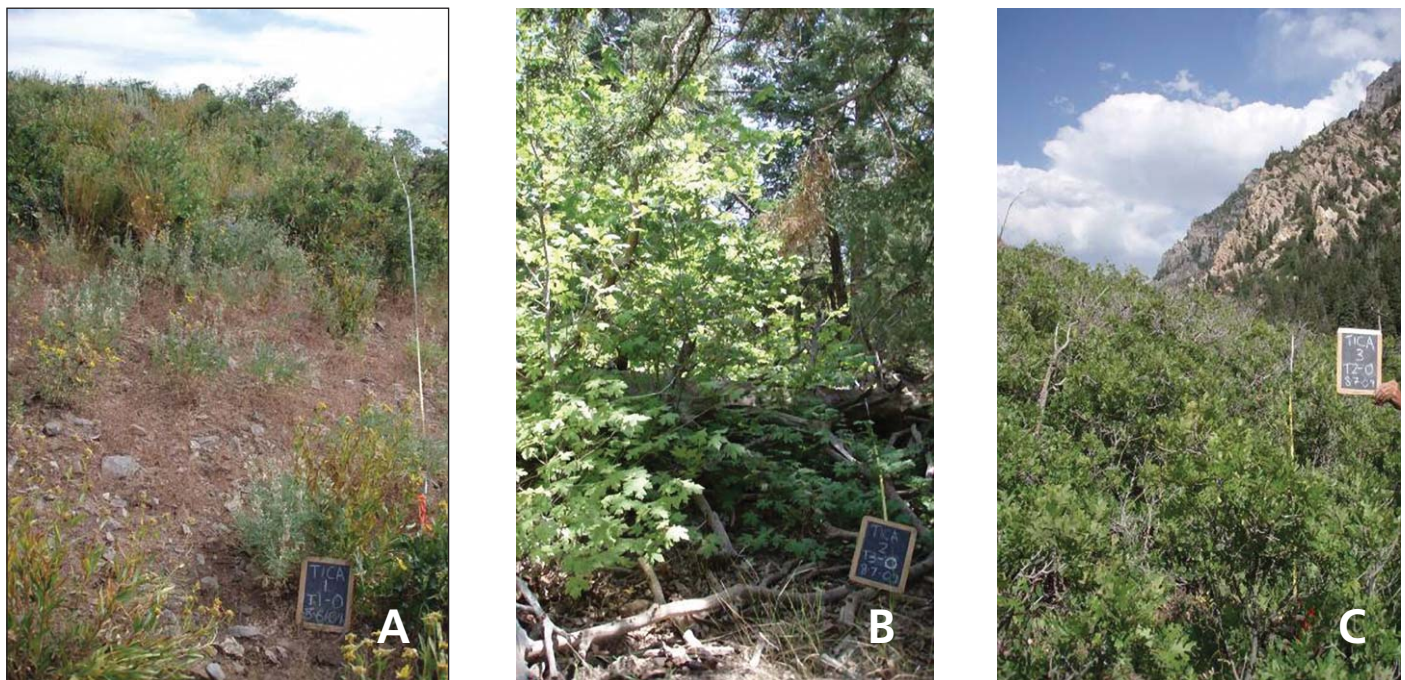


Figure 2-1. Vegetation types monitored at Timpanogos Cave National Monument. (A) Subalpine meadow, (B) Mixed conifer forest, (C) Gambel oak shrubland.

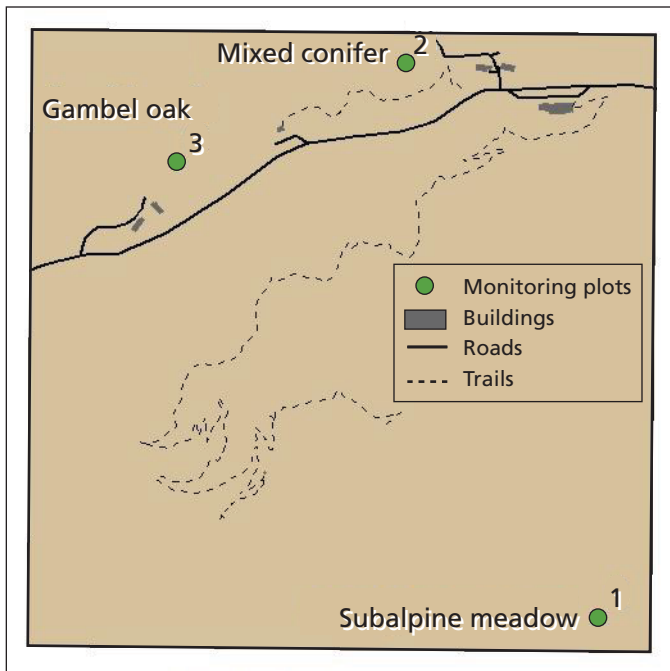


Figure 2-2. Location of upland monitoring plots at Timpanogos Cave National Monument.

2.2.1.1 Forests and subalpine meadows

At each plot, observations are recorded along three parallel, 50-m transects spaced 25 m apart (Figure 2-3). Photos are taken at the origin and end of each transect. 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. The number of shrubs (by species and height class), tree seedlings (by species), and exotic perennials (by species) are recorded in a 1-m belt upslope of each transect. In the subalpine meadow, all species are also recorded in the 1-m belt. 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. 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 15-m 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.

2.2.1.2 Gambel oak/mixed montane shrublands

Gambel oak/mixed montane shrub systems are structurally different than other vegetation types on the Colorado Plateau, and their dense, tall vegetation is not easily sampled using standard upland methods. This vegetation type is sampled using three 20-m transects (Figure 2-4), with photos taken at the origin and end of each transect. Point-intercept cover is collected at 0.25-m intervals, and fuel measurements are collected along the three existing transects. Within the 20 × 20-m plot, species and diameter are recorded for all mature trees and exceptionally large individuals of Gambel oak. Density of shrubs, trees, and exotic perennial species is not recorded in this vegetation type. Disturbances on and off the monitoring plot are recorded using the same methods as for other vegetation types.

Cover of shrub species in oak plots was no longer measured using the line-intercept method in 2010. It was determined during methods testing in previous years that this measurement was repetitive of cover measures using the point-intercept method.

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 are stored with the Access database on NCPN servers.

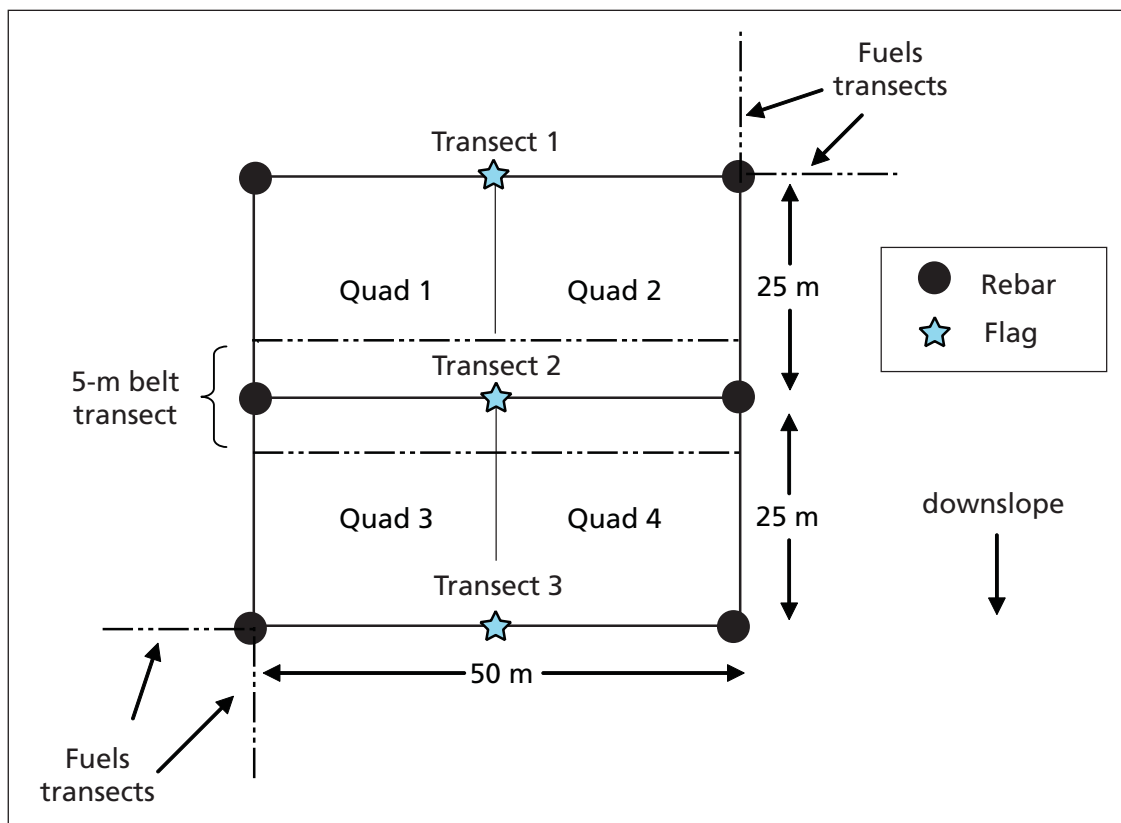


Figure 2-3. Plot layout for upland monitoring of forests and subalpine meadows.

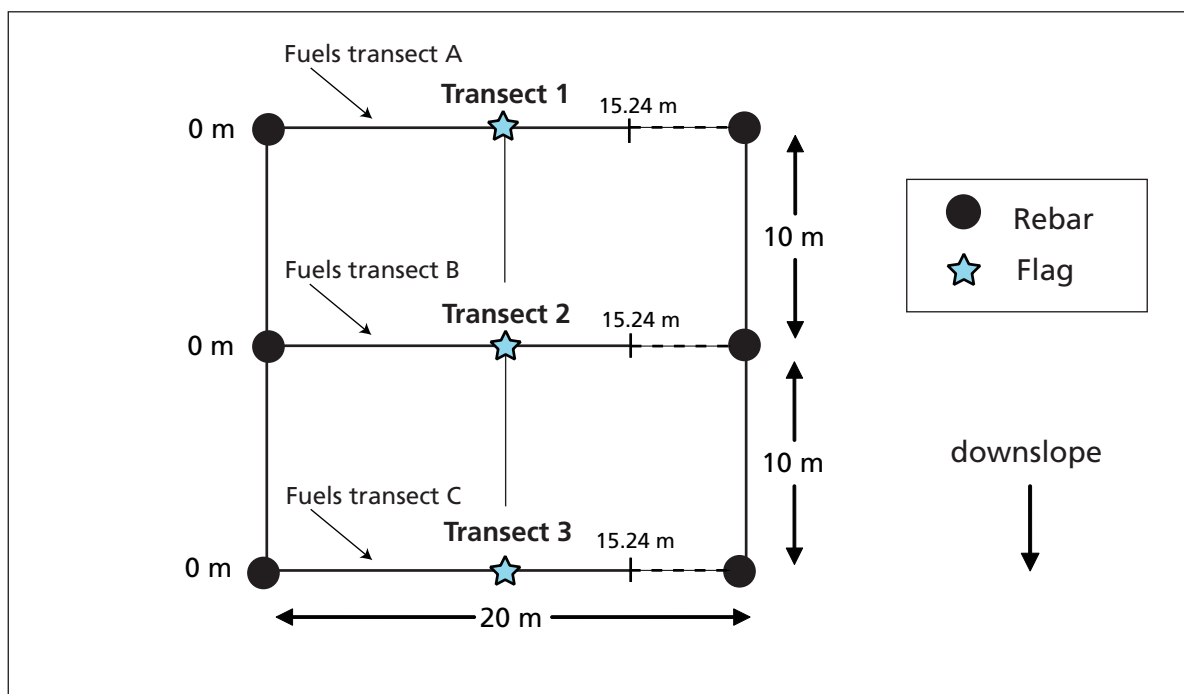


Figure 2-4. Plot layout for upland monitoring of Gambel oak/mixed montane shrublands.

3 Results

3.1 Monitored Plots

In August 2010, three plots were monitored as part of the long-term revisit design (see Figure 2-2).

3.2 Summaries

Status and trend assessments are more meaningful after many years of monitoring. More intensive evaluation of monitoring data is slated to commence after five full years of monitoring. For this annual report, summaries of the measures listed in Chapter 1 were generated for each monitoring plot.

3.2.1 Species richness

Forty-four species were detected during monitoring in 2010. Species richness by life form is reported in Table 3-1 (see next page). Recorded species were compared to the NPSpecies database to determine first-time observations in Timpanogos NM. No new species were detected in the monument in 2010.

3.2.2 Overstory canopy closure and understory cover by life form and dominant species

Overstory canopy closure and percent cover of live and total vegetation in the understory by life form is 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 all understory species for each plot is shown in Table 3-3. Fourteen additional species were detected in the 1-m belt of the subalpine meadow plot (Table 3-4). Cover of these species was low (< 5%) and was not detected by point-intercept sampling.

Threatened and endangered plant species are not common in the areas of Timpanogos Cave NM monitored by the network, and the NCPN does not specifically monitor them in this park. No threatened or endangered species were found on any plots in 2010.

3.2.3 Shrub density

Big sagebrush (*Artemisia tridentata*) was the only shrub counted in the subalpine meadow plot, at a density of 1,000 shrubs/ha. Shrub density was not measured for Gambel oak, mountain snowberry (*Symphoricarpos oreophilus*), or Woods' rose (*Rosa woodsii*) because the multi-stemmed nature of these shrubs species does not allow for repeatable density counts. No shrubs were detected in the 1-m belts at the mixed conifer plot.

3.2.4 Tree density

Density of live seedlings, saplings, and overstory trees is shown in Table 3-5. Density, dbh, crown class, and crown health for all overstory trees of >15 cm dbh are shown in Table 3-6. 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 network uses the following crown classes (Figure 3-1):

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.

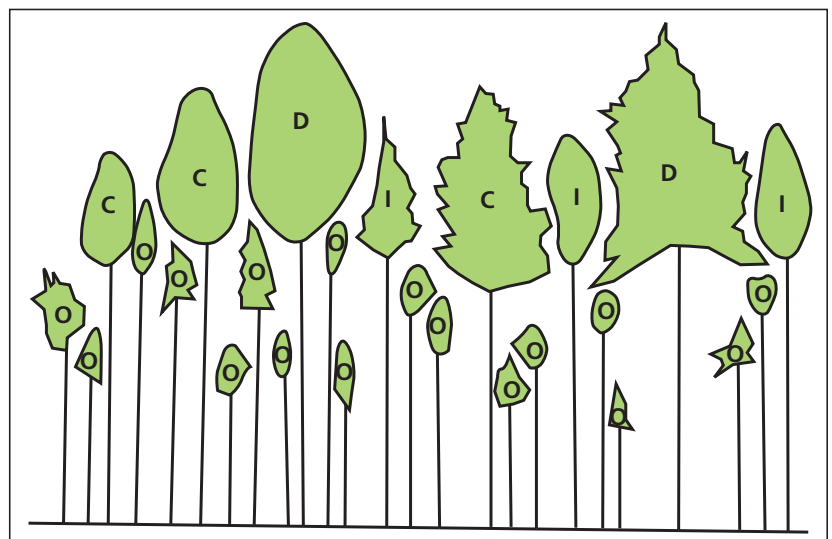


Figure 3-1. The relative positions of trees using four classes for crown classification. D =Dominant, C = Codominant, I = Intermediate, and O = Overtopped/Suppressed.

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.

3.2.5 Exotic species

Four exotic species were detected in plots: prickly lettuce (*Lactuca serriola*) and yellow salsify (*Tragopogon dubius*) in the subalpine meadow plot (see Table 3-4), and cheatgrass (*Bromus tectorum*) and smooth brome (*Bromus inermis*) in the mixed conifer plot (see Table 3-3). No exotics were detected in the Gambel oak plot. Smooth brome was also detected in the 1-m belt at the mixed conifer plot at a density of 133 plants/ha.

In 2010, NCPN upland sampling methods did not include an invasive species walk; therefore, lack of detection does not mean that other exotic species were not present in plots. In 2011, methods will be added to include early detection of exotics.

3.2.6 Surface features

Surface-feature cover is shown in Table 3-7. Litter was the dominant surface cover at all plots.

3.2.7 Fuels

Fuel volumes and depth of litter and duff are reported in Table 3-8. The mixed conifer plot was the only plot with substantial woody fuels. Fuels were not measured in the subalpine meadow.

Table 3-1. Number of plant species detected per monitoring plot by life form and vegetation type, Timpanogos Cave National Monument, 2010.

Vegetation type	Number of species detected					
	Total	Tree	Shrub	Perennial grass	Annual grass	Forbs/Herb
Subalpine meadow	34	1	4	6	0	23
Mixed conifer	10	3	2	4	1	0
Gambel oak	2	0	1	0	0	1

Table 3-2. Overstory canopy closure, and percent cover of understory vegetation by life form, Timpanogos Cave National Monument, 2010.

Vegetation type	Overstory canopy closure	Total*		Tree		Shrub		Perennial grass		Annual grass		Forbs/Herb	
		Live	Total	Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Subalpine meadow	4.6	67.0	74.7	0	0	34.7	39.3	6.0	6.3	0	0	40.3	45.3
Mixed conifer	74.2	39.3	51.3	29.0	34.0	6.0	7.7	5.7	8.7	0	4.0	0	0
Gambel oak	na	76.3	78.8	0	0	62.1	65.4	0	0	0	0	28.8	29.2

*Total understory cover (< 2 m) for subalpine meadow and mixed conifer; total vegetation cover at all canopy heights for Gambel oak.

Table 3-3. Percent cover of understory species by vegetation type, Timpanogos Cave National Monument, 2010.

Scientific name	Common name	Life form	Duration	Nativity	Percent cover*	
					Live	Total
Subalpine meadow						
<i>Agastache urticifolia</i>	nettle-leaf horsemint	Forb	Perennial	Native	11.7	12.7
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	1.0	2.0
<i>Aster foliaceus</i>	alpine leafybract aster	Forb	Perennial	Native	0.3	0.3
<i>Bromus carinatus</i>	mountain brome	Graminoid	Perennial	Native	4.0	4.0
<i>Carex hoodii</i>	Hood's sedge	Graminoid	Perennial	Native	0.7	0.7
<i>Collomia linearis</i>	small collomia	Forb	Annual	Native	0.3	0.3
<i>Crepis acuminata</i>	mountain hawksbeard	Forb	Perennial	Native	0	0.3
<i>Cryptantha torreyana</i>	Torrey's cryptanth	Forb	Annual	Native	0	0.7
<i>Descurainia pinnata</i>	western tansymustard	Forb	Annual	Native	0.3	0.3
<i>Elymus trachycaulus</i>	slender wheatgrass	Graminoid	Perennial	Native	0.3	0.3
<i>Gayophytum ramosissimum</i>	branching groundsmoke	Forb	Annual	Native	1.0	3.3
<i>Gilia</i> sp.	gilia species	Forb		Native	0	0.3
<i>Hackelia floribunda</i>	showy stickseed	Forb	Perennial	Native	0.7	0.7
<i>Helianthella uniflora</i>	little sunflower	Forb	Perennial	Native	25.7	26.7
<i>Lithospermum ruderale</i>	western stoneseed	Forb	Perennial	Native	0.7	0.7
<i>Lupinus argenteus</i>	silvery lupine	Forb	Perennial	Native	3.3	3.3
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	16.3	18.0
<i>Rosa woodsii</i>	Woods' rose	Shrub	Perennial	Native	0.7	0.7
<i>Senecio serra</i>	tall ragwort	Forb	Perennial	Native	0.7	0.7
<i>Stipa lettermanii</i>	Letterman's needlegrass	Graminoid	Perennial	Native	1.0	1.3
<i>Symphoricarpos oreophilus</i>	mountain snowberry	Shrub	Perennial	Native	21.0	23.3
<i>Viguiera multiflora</i>	showy goldeneye	Forb	Perennial	Native	0.3	0.3
Mixed conifer						
<i>Abies concolor</i>	white fir	Tree	Perennial	Native	6.7	9.0
<i>Acer grandidentatum</i>	bigtooth maple	Tree	Perennial	Native	10.7	11.0
<i>Bromus inermis</i>	smooth brome	Graminoid	Perennial	NonNative	1.0	1.0
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	NonNative	0	4.0
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	Tree	Perennial	Native	12.7	15.7
<i>Mahonia repens</i>	Oregon-grape	DwarfShrub	Perennial	Native	0.3	0.3
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	4.7	6.7
<i>Poa secunda</i>	Sandberg's bluegrass	Graminoid	Perennial	Native	0	0.7
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	5.7	7.3
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	0	0.3
Gambel oak						
<i>Apocynum androsaemifolium</i>	spreading dogbane	Forb	Perennial	Native	28.8	29.2
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	62.1	65.4

*Understory cover (< 2 m) for subalpine meadow and mixed conifer; cover at all canopy heights for Gambel oak.

Table 3-4. Additional species detected in the subalpine meadow plot, Timpanogos Cave National Monument, 2010.

Scientific name	Common name	Life form	Duration	Nativity
<i>Allium</i> sp.	onion species	Forb	Perennial	Native
<i>Arabis holboellii</i>	Holboell's rockcress	Forb	Perennial	Native
<i>Calochortus nuttallii</i>	sego-lily	Forb	Perennial	Native
<i>Chenopodium fremontii</i>	Fremont's goosefoot	Forb	Annual	Native
<i>Collinsia parviflora</i>	blue-eyed Mary	Forb	Annual	Native
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native
<i>Epilobium brachycarpum</i>	autumn willow-herb	Forb	Annual	Native
<i>Galium aparine</i>	cleavers	Forb	Annual	Native
<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	NonNative
<i>Melica bulbosa</i>	oniongrass	Graminoid	Perennial	Native
<i>Petradoria pumila</i>	rock goldenrod	Forb	Perennial	Native
<i>Polygonum douglasii</i>	Douglas' knotweed	Forb	Annual	Native
<i>Populus tremuloides</i>	quaking aspen	Tree	Perennial	Native
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	NonNative

Table 3-5. Density of live seedlings, saplings, and overstory trees by vegetation type, Timpanogos Cave National Monument, 2010.

Scientific name	Common name	Density of trees by dbh class (no. of trees/ha)				
		Seeding	Sapling			Tree
		<2.5 cm	2.5–5.0 cm	5.1–10.0 cm	10.1–15.0 cm	>15 cm*
Subalpine meadow	none	0	0	0	0	0
Mixed conifer						
<i>Abies concolor</i>	white fir	133	0	120	0	16
<i>Acer grandidentatum</i>	bigtooth maple	400	0	0	0	0
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	0	0	40	120	304
Gambel oak		na	na	na	na	0

* This category also includes Gambel oak >10 cm dbh.

Table 3-6. Density, diameter at breast height (dbh), crown class, and crown health for all trees >15 cm dbh by vegetation type, Timpanogos Cave National Monument, 2010.

Vegetation type	Scientific name	Common name	Density (no. of trees/ha)	Dbh (cm)	Crown class				Crown health				
					% O	% I	% C	% D	% 1	% 2	% 3	% 4	% 5
Subalpine meadow	none		0	na									
Mixed conifer	<i>Abies concolor</i>	white fir	80	22.2	0	0	20	0	0	20	0	0	80
	<i>Acer grandidentatum</i>	bigtooth maple	0	na									
	<i>Juniperus scopulorum</i>	Rocky Mountain juniper	304	23.1	0	53	47	0	100	0	0	0	0
Gambel oak	none		0	na									

Crown class codes: O=Overtopped, I=Intermediate, C=Codominant, D=Dominant. 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. Percent cover of surface features by vegetation type, Timpanogos Cave National Monument, 2010.

Vegetation type	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Subalpine meadow	3.7	0	0	0	4.3	82.0	0	6.3	1.7	0
Mixed conifer	0	0	0	0.3	0	75.3	6.7	4.0	12.3	0
Gambel oak	0	0	0	0	0	77.9	0.4	6.3	13.3	0

Table 3-8. Fuel volume and depth of litter and duff by vegetation type, Timpanogos Cave National Monument, 2010.

Vegetation type	Fuel volume (tons/acre)						Depth (cm)		
	Total	1-hr	10-hr	100-hr	1000-hr		Litter	Duff	
					Sound	Rotten			
Subalpine meadow	na	na	na	na	na	na	na	na	
Mixed conifer	11.1	0.3	0.9	5.4	0.9	3.5	0.7	1.1	
Gambel oak	1.0	0.2	0.8	0	0	0	2.7	0.1	

4 Discussion

In general, data from 2010 were similar to data from the previous year. In 2011, all three plots will be revisited. After 3–5 years of data have been collected, a long-term revisit schedule will begin

with plots sampled every 3–5 years. Further discussion will occur with Timpanogos Cave NM 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 full years of monitoring.

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