



Integrated Upland Monitoring in Timpanogos Cave National Monument

Annual Report 2011 (Non-Sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2013/714.N



ON THE COVER

The steep slopes of American Fork Canyon at Timpanogos Cave National Monument. NPS photo.

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March 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Witwicki, D. 2013. Integrated upland monitoring in Timpanogos Cave National Monument: annual report 2011 (non-sensitive version). Natural Resource Technical Report NPS/NCPN/NRTR—2013/714.N. National Park Service, Fort Collins, Colorado.

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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 Timpanogos Cave 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 subalpine meadows, mixed conifer forests, and Gambel oak (*Quercus gambelii*) shrublands at Timpanogos Cave NM, and three 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

B. Condie and B. Gottung conducted field work. A. Wight provided maps and managed spatial data. L. Houghton helped assemble summary data. D. Perkins and C. McKinney improved this report with their thoughtful review. Data management was provided by H. Thomas. D. Perry assisted with administrative details.

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 precipita-

tion 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 Timpanogos Cave 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 at Timpanogos Cave National Monument

2.1.1 Resource issues driving upland monitoring

Discussion with Timpanogos Cave NM resource management staff identified subalpine meadows, mixed conifer forests, and Gambel oak (*Quercus gambelii*) shrublands as priority communities for long-term 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 at Timpanogos Cave NM was approximately 14 ha.

2.1.3 Selection of monitoring locations

Due to the small area of the monument and steep slopes over much of the area, opportunities for upland monitoring at Timpanogos Cave NM were extremely limited. During a field visit in October 2008, one location in each priority vegetation type was identified with gentle slopes and enough area to fit an upland monitoring plot (Figure 2-2). There is no sampling frame for the monument 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 colleagues (2005) and standard forest, woodland, and fuels procedures (USDI 2003; Brown 1974). All measures recorded along transects are subsamples scaled to the plot level.

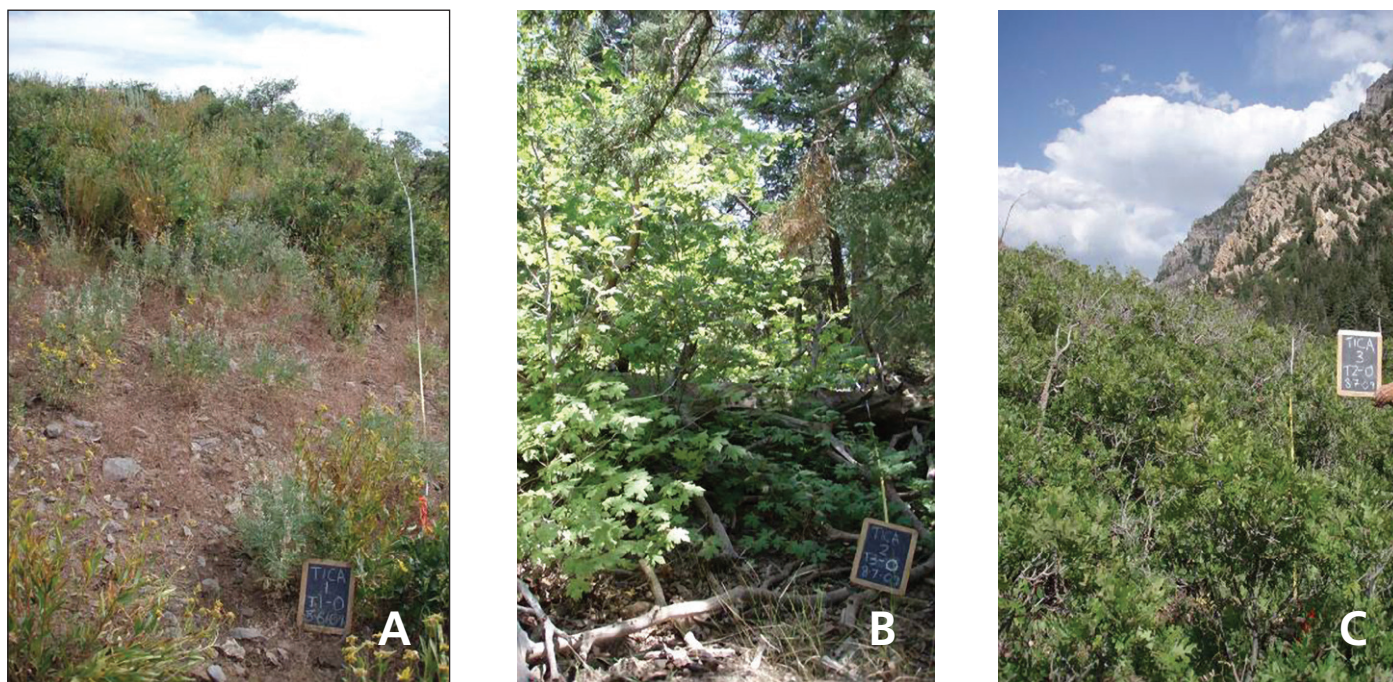


Figure 2-1. Vegetation types monitored at Timpanogos Cave National Monument. (A) Subalpine meadow, (B) Mixed conifer forest, (C) Gambel oak shrubland.

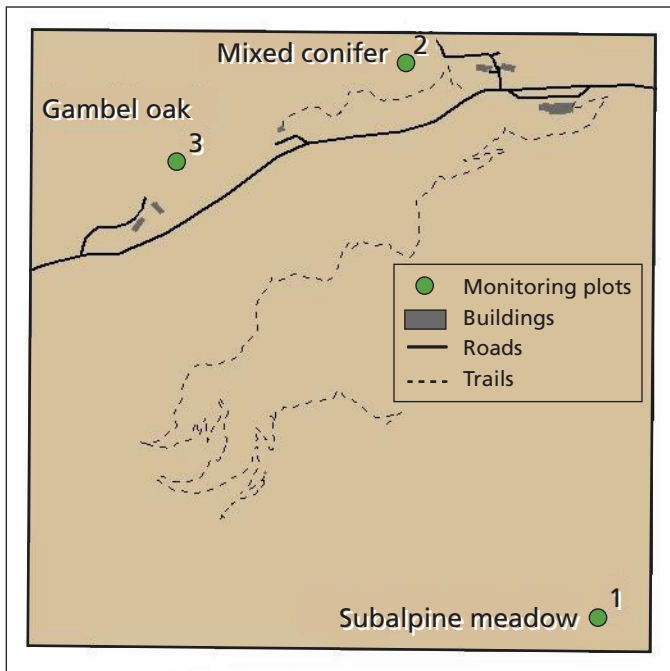


Figure 2-2. Location of upland monitoring plots at Timpanogos Cave National Monument.

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 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. Density of shrubs (by species and height class) and tree seedlings (by species) is recorded in a 1-m belt upslope of each transect. In the subalpine meadow, all species are also recorded in the 1-m belt. Density monitoring 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.

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 (dbh). Crown health and class of trees are also recorded in forest plots. 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 2-4):

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.

2.2.1.2 Gambel oak/mixed montane shrublands

Gambel oak/mixed montane shrub systems are structurally different from other vegetation types on the Colorado Plateau, and the dense, tall vegetation is not easily sampled using standard upland methods. This vegetation type is sampled using three 20-m transects (Figure 2-5), with photos taken at the origin and end of each transect. Point-intercept cover is collected at 0.25-m intervals, and exotic frequency is collected at smaller intervals along transects. Within the 20×20-m plot, species and diameter are recorded for all mature trees and exceptionally large

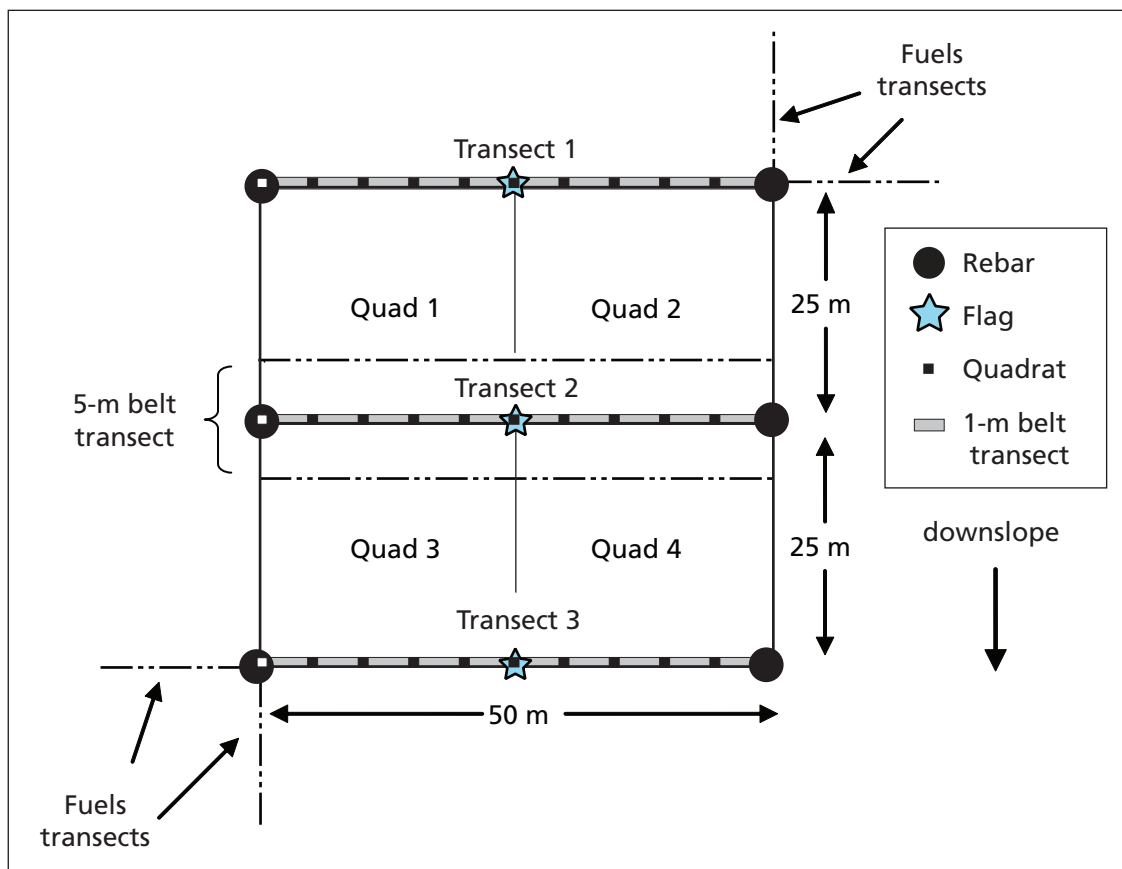


Figure 2-3. Plot layout for upland monitoring of forests and subalpine meadows.

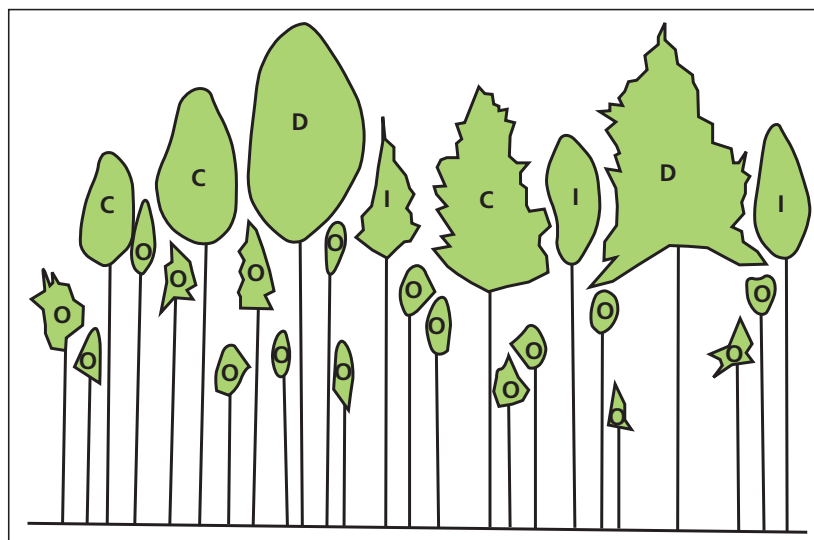


Figure 2-4. The relative positions of trees using four classes for crown classification. D = Dominant, C = Codominant, I = Intermediate, and O = Overtopped/Suppressed.

individuals of Gambel oak. Fuel measurements (beginning in 2011) and density of shrubs and trees are not recorded in this vegetation type. Disturbances and exotic plants on and around the monitoring plot are recorded using the same methods as the other vegetation types.

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.

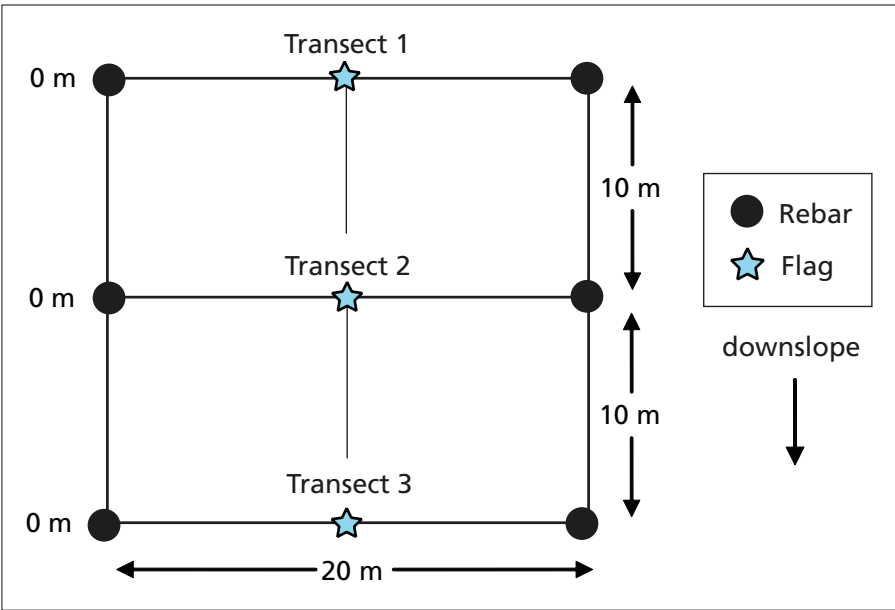


Figure 2-5. Plot layout for upland monitoring of Gambel oak/mixed montane shrublands.

3 Results

3.1 Monitored plots

In July 2011, 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 are complete. For this annual report, summaries of the measures listed in Chapter 1 were generated for each monitoring plot.

3.2.1 Species richness

Forty-five 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 Timpanogos National Monument. Two new species, thickspike wheatgrass (*Elymus lanceolatus*) and mountain valerian (*Valeriana acutiloba*), were detected in the monument 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 all understory species for each plot are shown in Table 3-3. Twelve 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.

No threatened or endangered species or other plants of special concern were found on any plots in 2011. Timpanogos Cave NM is not known to contain any federally listed

threatened or endangered plant species. Plants of special concern 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.

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 shrub 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, and crown class of 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 of exotic plant species is included in Table 3-3. Frequency of detection of exotic plant species is shown in Table 3-7.

A total of six exotic plant species were detected through cover and frequency sampling. Cheatgrass (*Bromus tectorum*) and smooth brome (*Bromus inermis*) were detected in the mixed conifer plot, and cheatgrass had the highest frequency of detection of any exotic plant species (over 50%). The remaining exotic plant species were detected with low cover and frequency. Prickly lettuce (*Lactuca serriola*), Kentucky bluegrass (*Poa pratensis*), and yellow salsify (*Tragopogon dubius*) were detected in the subalpine meadow, and Japanese brome (*Bromus japonicus*), prickly lettuce (*Lactuca serriola*), and Dalmatian toadflax (*Linaria dalmatica*) were detected in the Gambel oak plot.

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 (tica11_exotics.xls).

3.2.6 Surface features

Surface-feature cover is shown in Table 3-8. 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 3-9. The mixed conifer plot was the only plot with substantial woody fuels. Fuels were not measured in the subalpine meadow or Gambel oak plots.

Table 3-1. Number of plant species detected per monitoring plot by lifeform and vegetation type, Timpanogos Cave National Monument, 2011.			
Number of species detected	Vegetation type		
	Subalpine meadow	Mixed conifer	Gambel oak
Tree	1	3	0
Shrub	4	2	1
Perennial grass	8	5	0
Annual grass	0	1	1
Forbs/Herb	20	1	3
Total	33	12	5

Table 3-2. Percent overstory canopy closure, and percent cover of understory vegetation by lifeform, Timpanogos Cave National Monument, 2011.													
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	7.2	84.7	86.3	0.3	0.3	39.3	42.7	6.3	6.7	0	0	62.3	63.0
Mixed conifer	71.8	39.0	48.0	29.3	33.7	6.7	8.0	2.3	3.7	0.7	5.3	0.7	0.7
Gambel oak	na	80.8	83.8	0	0	61.7	67.5	0	0	0	0	37.1	37.5

*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, 2011.

Scientific name	Common name	Lifeform	Duration	Nativity	Percent cover*	
					Live	Total
Subalpine meadow						
<i>Abies concolor</i>	white fir	Tree	Perennial	Native	0.3	0.3
<i>Agastache urticifolia</i>	nettle-leaf horsemint	Forb	Perennial	Native	20.3	20.7
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	1.7	2.3
<i>Aster foliaceus</i>	alpine leafybract aster	Forb	Perennial	Native	0.7	0.7
<i>Bromus carinatus</i>	mountain brome	Graminoid	Perennial	Native	5.0	5.3
<i>Collomia linearis</i>	small collomia	Forb	Annual	Native	0.3	0.3
<i>Cryptantha torreyana</i>	Torrey's cryptanth	Forb	Annual	Native	0.3	1.0
<i>Elymus trachycaulus</i>	slender wheatgrass	Graminoid	Perennial	Native	0.3	0.3
<i>Epilobium brachycarpum</i>	autumn willow-herb	Forb	Annual	Native	5.0	5.0
<i>Galium multiflorum</i>	shrubby bedstraw	Forb	Perennial	Native	9.3	9.7
<i>Hackelia floribunda</i>	showy stickseed	Forb	Perennial	Native	0.3	0.7
<i>Helianthella uniflora</i>	little sunflower	Forb	Perennial	Native	33.3	33.3
<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	Nonnative	0.7	0.7
<i>Lupinus argenteus</i>	silvery lupine	Forb	Perennial	Native	7.3	7.3
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	22.0	23.7
<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	1.0
<i>Symphoricarpos oreophilus</i>	mountain snowberry	Shrub	Perennial	Native	19.7	20.7
<i>Thalictrum fendleri</i>	Fendler's meadow-rue	Forb	Perennial	Native	0.3	0.3
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	Nonnative	0.3	0.3
<i>Valeriana acutiloba</i>	mountain valerian	Forb	Perennial	Native	0.3	0.3
Mixed conifer						
<i>Abies concolor</i>	white fir	Tree	Perennial	Native	6.0	8.0
<i>Acer grandidentatum</i>	bigtooth maple	Tree	Perennial	Native	9.3	10.0
<i>Aster ascendens</i>	Pacific aster	Forb	Perennial	Native	0.7	0.7
<i>Bromus inermis</i>	smooth brome	Graminoid	Perennial	NonNative	0.3	0.3
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	NonNative	0.7	5.3
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	Tree	Perennial	Native	16.7	18.7
<i>Mahonia repens</i>	Oregon grape	Dwarf Shrub	Perennial	Native	0.3	0.3
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	0.7	1.3
<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	Nonnative	0.7	0.7
<i>Poa secunda</i>	Sandberg's bluegrass	Graminoid	Perennial	Native	0	0.7
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	6.3	7.7
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	0.7	0.7
Gambel oak						
<i>Apocynum androsaemifolium</i>	spreading dogbane	Forb	Perennial	Native	37.1	37.5
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	61.7	67.5

*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, 2011.

Scientific name	Common name	Lifeform	Duration	Nativity
<i>Allium</i> sp.	onion species	Forb	Perennial	Native
<i>Calochortus nuttallii</i>	sego-lily	Forb	Perennial	Native
<i>Carex hoodii</i>	Hood's sedge	Graminoid	Perennial	Native
<i>Chenopodium fremontii</i>	Fremont's goosefoot	Forb	Annual	Native
<i>Crepis acuminata</i>	mountain hawkbeard	Forb	Perennial	Native
<i>Elymus lanceolatus</i>	thickspike wheatgrass	Graminoid	Perennial	Native
<i>Gayophytum ramosissimum</i>	branching groundsmoke	Forb	Annual	Native
<i>Lathyrus pauciflorus</i>	fewflower pea	Forb	Perennial	Native
<i>Melica bulbosa</i>	oniongrass	Graminoid	Perennial	Native
<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	Nonnative
<i>Stipa nelsonii</i>	Columbia needlegrass	Graminoid	Perennial	Native
<i>Viguiera multiflora</i>	showy goldeneye	Forb	Perennial	Native

Table 3-5. Density of live seedlings, saplings, and overstory trees, and crown class of overstory trees by vegetation type, Timpanogos Cave National Monument, 2011.

Vegetation type	Scientific name	Common name	Density of trees by dbh class (no. of trees/ha)					Crown class		
			Seedling <2.5 cm	Sapling			Tree >15 cm*	%D	%C	%I
				2.5–5.0 cm	5.1–10.0 cm	10.1–15.0 cm				
Subalpine meadow	<i>Abies concolor</i>	white fir	67	0	0	0	0			
Mixed conifer	<i>Abies concolor</i>	white fir	0	0	40	80	16	0	100	0
	<i>Acer grandidentatum</i>	bigtooth maple	600	0	0	0	0			
	<i>Juniperus scopulorum</i>	Rocky Mountain juniper	67	80	0	80	272	5.9	35.3	58.8
Gambel oak	<i>Quercus gambelii</i>	Gambel oak	na	na	na	na	0			

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

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

Table 3-6. Density, diameter at breast height (dbh), and crown health for all trees >15 cm dbh by vegetation type, Timpanogos Cave National Monument, 2011.

Vegetation type	Scientific name	Common name	Density (no. of trees/ha)	Dbh (cm)	Crown health				
					%1	%2	%3	%4	%5
Subalpine meadow	none		0	na					
Mixed conifer	<i>Abies concolor</i>	white fir	32	24.6	0	50	0	0	50
	<i>Acer grandidentatum</i>	bigtooth maple	0	na					
	<i>Juniperus scopulorum</i>	Rocky Mountain juniper	272	22.7	29.4	64.7	5.9	0	0
Gambel oak	none		0	na					

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. Frequency of exotic plant species detected by vegetation type, Timpanogos Cave National Monument, 2011.

Vegetation type	Scientific name	Common name	Lifeform	Duration	Frequency of detection (%)
Subalpine meadow	<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	6.7
	<i>Poa pratensis</i>	Kentucky bluegrass	Graminoid	Perennial	3.3
	<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	3.3
Mixed conifer	<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	53.3
Gambel oak	<i>Bromus japonicus</i>	Japanese brome	Graminoid	Annual	6.7
	<i>Lactuca serriola</i>	prickly lettuce	Forb	Annual	6.7
	<i>Linaria dalmatica</i>	Dalmatian toadflax	Forb	Perennial	6.7

Table 3-8. Percent cover of surface features by vegetation type, Timpanogos Cave National Monument, 2011.

Surface feature	Vegetation type		
	Subalpine meadow	Mixed conifer	Gambel oak
Crust, undifferentiated	7.0	0	0.4
Cyanobacteria	0	0	0
Lichen	0	0	0
Moss	0	0	0
Bare soil	4.0	0	0
Litter	75.7	75.7	78.8
Woody debris	0.7	3.3	0.8
Small rock	9.0	5.7	5.4
Large rock	1.0	14.7	13.8
Bedrock	0	0	0

Table 3-9. Fuel volume and depth of litter and duff by vegetation type, Timpanogos Cave National Monument, 2011.

Vegetation type	Fuel volume (tons/acre)						Depth (cm)	
	Total	1-hr	10-hr	100-hr	1,000-hr		Litter	Duff
					Sound*	Rotten*		
Subalpine meadow	na	na	na	na	na	na	na	na
Mixed conifer	6.5	0.1	1.5	1.9	2.6	0.4	2.6	0.5
Gambel oak	na	na	na	na	na	na	na	na

*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 similar to those from the previous two years. The plots will be rested in 2012 and 2013, and revisited in 2014. Further discussion will occur with Timpanogos

Cave 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 full years of monitoring are complete.

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NPS 153/120181, March 2013

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