



Integrated Upland Monitoring in Timpanogos Cave National Monument

Annual Report 2009 (Non-sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2010/391.N



ON THE COVER

American Fork Canyon, Timpanogos Cave National Monument. NPS photo.

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Contents

Figures v

Tables v

Executive Summary vii

1 Introduction 1

2 Methods.....3

 2.1 Integrated upland monitoring at Timpanogos Cave NM.....3

 2.2 Integrated upland monitoring procedures 3

 2.3 Database 3

3 Results.....7

 3.1 Monitored plots.....7

 3.2 Vegetation type summaries 7

4 Discussion 13

5 Literature Cited.....15

Appendix A. Supplemental Information 17

Figures

Figure 2-1. Vegetation types monitored at Timpanogos Cave National Monument. 4

Figure 2-2. Location of upland monitoring plots at Timpanogos Cave National Monument. 4

Figure 2-3. Plot layout for upland monitoring of forests and subalpine meadows. 5

Figure 2-4. Plot layout for upland monitoring of Gambel oak/mixed montane shrublands. 5

Figure 3-1. The relative positions of trees using four classes for crown classification 7

Tables

Table 2-1. Plot-level measures for each vegetation type..... 6

Table 3-2. Percent cover of overstory, and understory vegetation by life form, Timpanogos Cave NM, 2009. 8

Table 3-1. Number of plant species detected per monitoring plot by life form and vegetation type, Timpanogos Cave NM, 2009. 8

Table 3-3. Percent cover of understory species by vegetation type, Timpanogos Cave NM, 2009. 9

Table 3-5. Density of live seedlings, saplings, and overstory trees by vegetation type, Timpanogos Cave NM, 2009. 10

Table 3-4. Additional species detected in the subalpine meadow plot, Timpanogos Cave NM, 2009... 10

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 NM, 2009. 11

Table 3-7. Percent cover of surface features by vegetation type, Timpanogos Cave National Monument, 2009. 11

Table 3-8. Fuel volume and depth of litter and duff by vegetation type, Timpanogos Cave NM, 2009. 11

Table A. Physical attributes of upland monitoring plots in Timpanogos Cave National Monument, 2009 17

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.

In 2009, the NCPN initiated upland monitoring at Timpanogos Cave National Monument (NM). This report 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.

1 Introduction

Uplands represent the vast majority of land area in national parks of the Colorado Plateau. Plateau uplands include rock outcrops, badlands, shrublands, grasslands, woodlands, and forests, 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, 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 riparian conditions.

Upland ecosystems of the Colorado Plateau are characterized by low resistance and resilience. Even moderate disturbances can affect vegetative composition and structure, and recovery to pre-disturbance conditions is relatively slow. 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 2005). Increasing recreational use and unauthorized social trailing threatens the integrity of upland systems through soil disturbance and resulting increases in soil erosion by water and wind. Global climate change is expected to change levels and seasonality of dominant precipitation events, with unknown implications for plateau systems.

The Northern Colorado Plateau Network (NCPN), as part of the National Park Service's Inventory and Monitoring Program, has identified plant communities, hydrologic function, soil stability, biological soil crust (BSC), and nutrient cycling as important components to understanding the health of upland systems (O'Dell et al. 2005). The indicators that apply to these components are listed below.

- Plant communities: species and functional group composition and diversity, and vegetation structure
- Hydrologic function: basal-gap size, cover and development of BSC, and infiltration rate

- Soil stability: cover of vegetation, litter, and BSC, and soil aggregate stability
- Biological soil crust: BSC cover
- Nutrient cycling is not currently measured

The goals of NCPN upland monitoring are to increase fundamental understanding of upland systems and provide managers with early warning of undesirable change. These goals will be accomplished partly through sampling design and data analysis. Evaluation of upland monitoring data relative to other vital signs will facilitate identification of drivers and distinguish “natural” from anthropogenic change. This effort will document the variability in upland systems while providing information needed for resource management decisions.

Specific objectives of the NCPN integrated upland monitoring protocol are:

- To determine annual status and trends in ground cover (live and standing dead vegetation, litter, rock, biological soil crust, and bare ground); vegetation by life form; soil aggregate stability; hydrologic function; and nutrient cycling;
- To determine annual status and trends in cover of biological soil crusts by morphological group; and
- To determine annual status and trends in cover of exotic plants in upland areas.

2 Methods

2.1 Integrated upland monitoring at Timpanogos Cave NM

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 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 >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 monument's small area, much of it consisting of steep slopes, opportunities for upland monitoring at Timpanogos Cave NM were extremely limited. During a field visit in October 2008, one location with gentle slopes and enough area to fit an upland monitoring plot was identified for priority vegetation type (Figure 2-2). There is no sampling frame for TICA, 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 assessment procedures (Herrick et al. 2004) and standard forest, woodland, and fuels procedures (NPS 2003; Brown 1974), with modifications by Miller and others (2007).

2.2.1.1 Forests and subalpine meadows

At each plot, observations were recorded along three parallel, 50-m transects spaced 25 m apart (Figure 2-3). A point-intercept method was used to record percent cover of understory (<2 m) and ground-cover attributes at 0.5-m intervals along each transect (Table 2-1). The number of shrubs (by species and height class) and exotic perennials (by species) was recorded in a 1-m belt upslope of each transect. In the subalpine meadow, all species were also recorded in the 1-m belt. Saplings were identified to species, and density was tallied in a 5-m belt transect centered on Transect 2. Within Quadrant 1, species and dbh (diameter at breast height) were recorded for all mature trees. Overstory cover was recorded along each transect using a concave spherical densiometer. Fuels were measured using Brown's planar method (Brown 1974) along four 15-m transects that extend beyond the plot on two corners. All measures recorded along transects were sub-samples scaled to the plot level. The plot-level measures were the primary values used in summaries and statistical analyses. Disturbances observed on and around the site were also recorded.

2.2.1.2 Gambel oak/mixed montane shrublands

Gambel oak/mixed montane shrublands are structurally different from other vegetation types on the Colorado Plateau, and the dense, tall vegetation is not easily sampled using standard upland methods. Therefore, plot size was reduced to 20 × 20 m, point-intercept was collected at 0.25-m intervals, and fuel measurements were collected along the three existing transects (Figure 2-4). Shrubs were recorded by species along each transect, using a line-intercept method. Within the 20 × 20-m plot, species and dbh were recorded for all mature trees and *Quercus gambelii* (Gambel oak). Density was not recorded in this vegetation type.

2.3 Database

All observations recorded in the field are stored in an Access database maintained by the NCPN. 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 2-1. Vegetation types monitored at Timpanogos Cave National Monument.

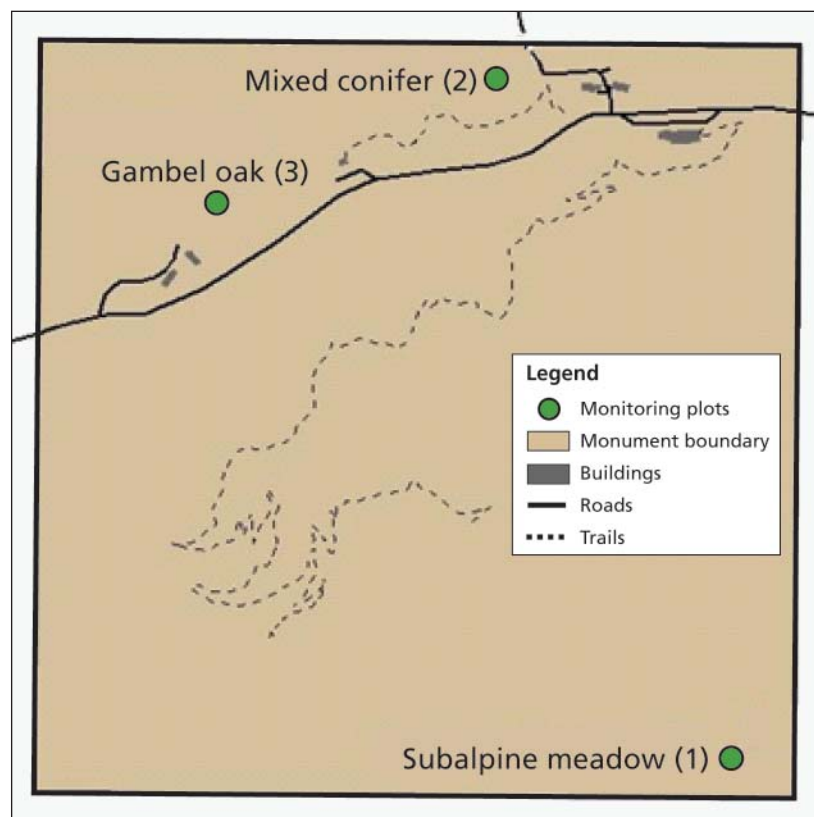


Figure 2-2. Location of upland monitoring plots at Timpanogos Cave National Monument.

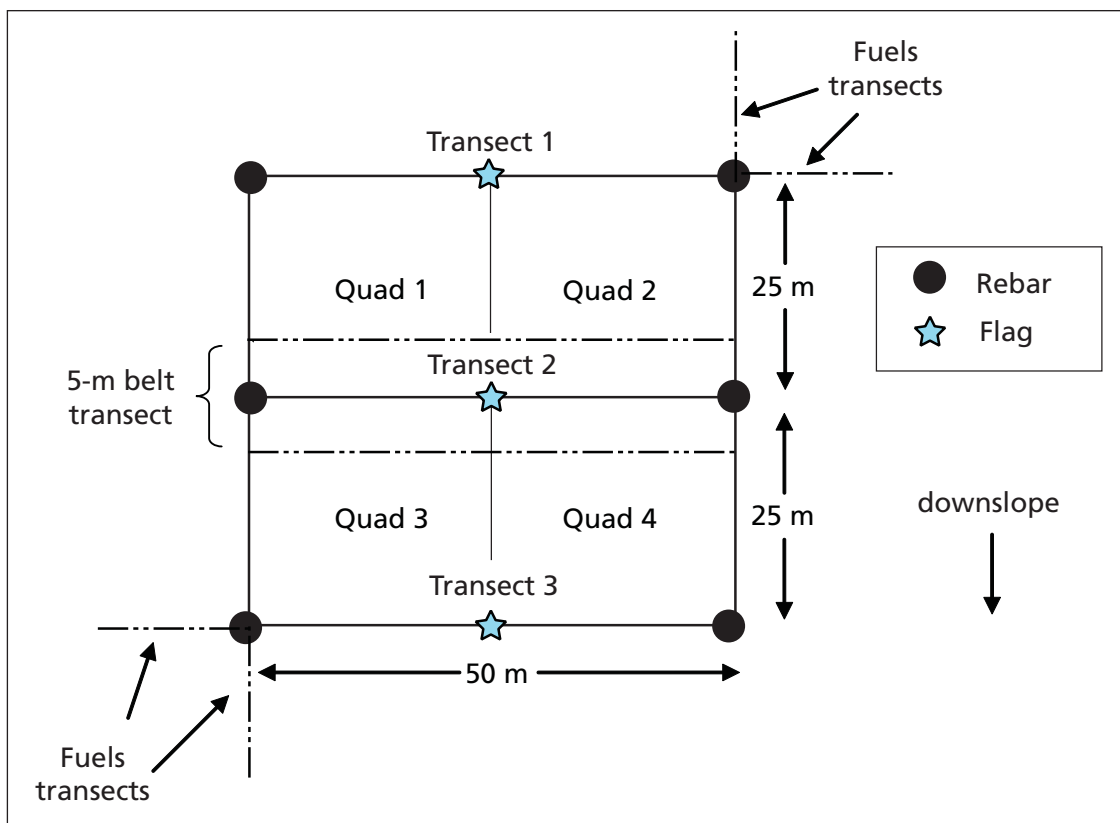


Figure 2-3. Plot layout for upland monitoring of forests and subalpine meadows.

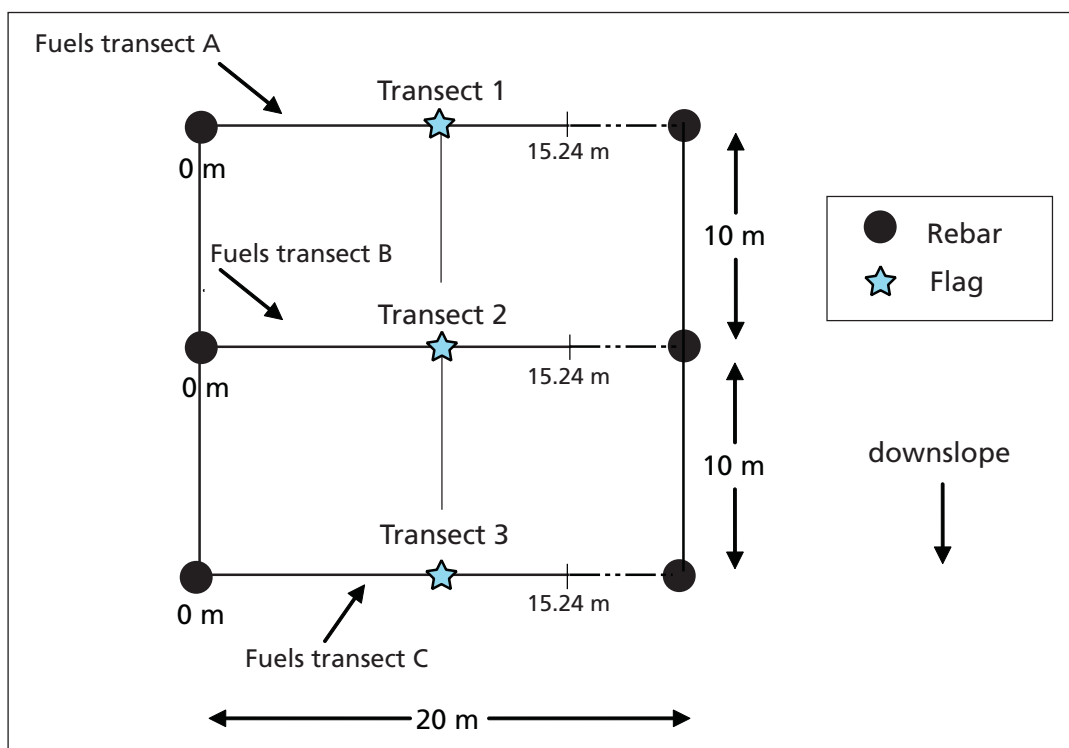


Figure 2-4. Plot layout for upland monitoring of Gambel oak/mixed montane shrublands.

Table 2-1. Plot-level measures for each vegetation type.

Measure	Attribute/Context	Sampling method/Spatial scale(s) of observation		
		Subalpine meadow	Forest	Gambel oak
Plant species richness	Number of species detected	Point-intercept for understory, 1-m belt transects for all species, 5-m belt transect for saplings, ¼ plot for trees	Point-intercept for understory, 1-m belt transects for shrubs & tree seedlings, 5-m belt transect for saplings, ¼ plot for trees	Point-intercept for understory, entire plot for trees
Percent cover	Life form (trees, shrubs, annual and perennial grasses, forbs/herbs)	Point-intercept along all three transects (150 m)	Point-intercept along all three transects (150 m)	Point-intercept along all three transects (60 m)
	Individual plant species	Point-intercept along all three transects (150 m)	Point-intercept along all three transects (150 m)	Point-intercept along all three transects (60 m)
	Overstory canopy cover	15 point samples across plot	15 point samples across plot	
	Surface features (undifferentiated crust, cyanobacteria, lichen, moss, bare soil, litter, woody debris, small and large rock, bedrock)	Point-intercept along all three transects (150 m)	Point-intercept along all three transects (150 m)	Point-intercept along all three transects (60 m)
Density	Disturbance features (livestock and wildlife scat, ant mound, wildlife excavation, tracks from wildlife, livestock, humans, bicycles, or motor vehicles, other).	Point-intercept along all three transects (150 m)	Point-intercept along all three transects (150 m)	Point-intercept along all three transects (60 m)
	Individual tree species and total tree density	Quadrant 1 for trees; one 5-m belt for saplings	Quadrant 1 for trees; one 5-m belt for saplings	Entire plot for trees
	Individual tree seedlings, shrubs, and exotic perennials by species; and total tree seedlings, shrubs, and exotic perennials combined by group	1-m belt transects upslope of all 3 transects	1-m belt transects upslope of all 3 transects	
Fuel loading	Woody fuel volumes; duff and litter depth		Four ~15-m transects	Three ~15-m transects

3 Results

3.1 Monitored plots

In August 2009, three plots were established and monitored as part of the long-term revisit design (see Figure 2-2). Appendix A lists physical attributes of individual plots visited in 2009.

3.2 Vegetation type 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 Table 2-1 were generated for each monitoring plot.

3.2.1 Species richness

Species richness by life form is reported in Table 3-1 (tables begin on page 8). Recorded species were compared to the NPSpecies database to determine first-time observations in Timpanogos Cave NM. No new species were detected in the monument in 2009.

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

Percent cover of overstory, and 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 are shown in Table 3-3. Shrub species in the Gambel oak plot were additionally measured using the line-intercept method. Gambel oak was the only shrub species detected, with a total cover of 76.1%.

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.

3.2.3 Shrub density

Big sagebrush (*Artemisia tridentata*) was the only shrub counted in the subalpine meadow plot, at a density of 933 shrubs/ha. Shrub density was not

measured for Gambel oak (*Quercus gambelii*) or mountain snowberry (*Symphoricarpos oreophilus*) because the multi-stemmed nature of these shrubs species does not allow for repeatable density counts. No shrubs were detected in the 1-m belt 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 a tree in the canopy. The NCPN uses the following crown classes (Figure 3-1):

- **Dominant:** Crowns extend above the general level of the main canopy of adjacent trees. They receive full light from above and partial light from the sides.
- **Codominant:** Crowns form the general level of the main canopy of adjacent trees. They receive full light from above and comparatively little from the sides.
- **Intermediate:** Crowns extend 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.

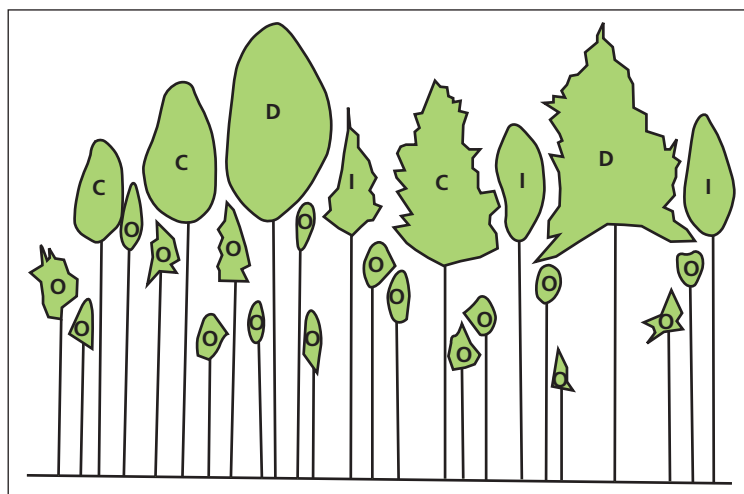


Figure 3-1. The relative positions of trees using four classes for crown classification. D=Dominant, C=Codominant, I=Intermediate, O=Overtopped.

- *Overtopped*: Crowns are 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: cheatgrass (*Bromus tectorum*) and yellow salsify (*Tragopogon dubius*) in the subalpine meadow plot, cheatgrass and smooth brome (*Bromus inermis*) in the mixed conifer plot, and Japanese chess (*Bromus japonicus*) in the Gambel oak plot. Smooth brome was also detected in the 1-m belt at the mixed conifer plot at a density of 67 plants/ha.

NCPN upland sampling methods are not intended as an early detection survey; therefore, lack of detection does not mean that other exotic species were not present in plots.

3.2.6 Threatened and endangered species

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 2009.

3.2.7 Surface features

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

3.2.8 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 NM, 2009.

Vegetation type	Number of species detected					
	Tree	Shrubs	Perennial grasses	Annual grasses	Forbs/Herbs	Total
Subalpine meadow	0	3	8	1	25	37
Mixed conifer	3	2	3	1	1	10
Gambel oak	0	1	0	1	1	3

Table 3-2. Percent cover of overstory, and understory vegetation by life form, Timpanogos Cave NM, 2009.

Vegetation type	Overstory	Tree		Shrubs		Perennial grasses		Annual grasses		Forbs/Herbs	
		Live	Total	Live	Total	Live	Total	Live	Total	Live	Total
Subalpine meadow	4.6	0	0	39.7	41.3	8.0	8.0	0	0	48.7	51.0
Mixed conifer	67.2	22.7	25.3	9.0	9.3	3.0	3.7	0.3	3.7	0.3	0.3
Gambel oak	na	0	0	70.0	72.5	0	0	0	0.4	19.2	19.2

Table 3-3. Percent cover of understory species by vegetation type, Timpanogos Cave NM, 2009.

Scientific name	Common name	Life form	Duration	Nativity	Percent cover	
					Live	Total
Subalpine meadow						
<i>Agastache urticifolia</i>	nettle-leaf horsemint	Forb	Perennial	Native	17.7	18.0
<i>Artemisia tridentata</i>	big sagebrush	Shrub	Perennial	Native	0.7	0.7
<i>Bromus carinatus</i>	mountain brome	Graminoid	Perennial	Native	4.7	4.7
<i>Carex hoodii</i>	Hood's sedge	Graminoid	Perennial	Native	1.0	1.0
<i>Collomia linearis</i>	small collomia	Forb	Annual	Native	0.3	0.3
<i>Conyza canadensis</i>	Canadian horseweed	Forb	Annual	Native	0.3	0.3
<i>Cryptantha torreyana</i>	Torrey's cryptanth	Forb	Annual	Native	0.3	0.3
<i>Elymus spicatus</i>	bluebunch wheatgrass	Graminoid	Perennial	Native	1.0	1.0
<i>Galium aparine</i>	cleavers	Forb	Annual	Native	0	1.7
<i>Galium bifolium</i>	twin-leaf bedstraw	Forb	Annual	Native	0	2.3
<i>Gayophytum ramosissimum</i>	branching groundsmoke	Forb	Annual	Native	3.7	3.7
<i>Hackelia floribunda</i>	showy stickseed	Forb	Perennial	Native	0.3	0.3
<i>Helianthella uniflora</i>	little sunflower	Forb	Perennial	Native	25.7	25.7
<i>Lathyrus pauciflorus</i>	fewflower pea	Forb	Perennial	Native	0.3	0.3
<i>Lupinus argenteus</i>	silvery lupine	Forb	Perennial	Native	6.7	6.7
<i>Melica bulbosa</i>	oniongrass	Graminoid	Perennial	Native	0.3	0.3
<i>Polygonum douglasii</i>	Douglas' knotweed	Forb	Annual	Native	0.3	0.3
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	17.7	17.7
<i>Senecio serra</i>	tall ragwort	Forb	Perennial	Native	0.7	0.7
<i>Stipa lettermanii</i>	Letterman's needlegrass	Graminoid	Perennial	Native	0.7	0.7
<i>Stipa nelsonii</i>	Columbia needlegrass	Graminoid	Perennial	Native	0.3	0.3
<i>Symphoricarpos oreophilus</i>	mountain snowberry	Shrub	Perennial	Native	25.0	26.7
<i>Thalictrum fendleri</i>	Fendler's meadow-rue	Forb	Perennial	Native	0.3	0.3
<i>Viguiera multiflora</i>	showy goldeneye	Forb	Perennial	Native	1.0	1.0
Mixed conifer forest						
<i>Abies concolor</i>	white fir	Tree	Perennial	Native	6.7	7.7
<i>Acer grandidentatum</i>	bigtooth maple	Tree	Perennial	Native	8.0	8.3
<i>Apocynum androsaemifolium</i>	spreading dogbane	Forb	Perennial	Native	0.3	0.3
<i>Bromus inermis</i>	smooth brome	Graminoid	Perennial	Non-native	0.3	0.3
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	Non-native	0.3	3.7
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	Tree	Perennial	Native	9.7	11.3
<i>Mahonia repens</i>	Oregon-grape	DwarfShrub	Perennial	Native	0.7	0.7
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native	2.3	3.0
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	8.3	8.7
<i>Stipa hymenoides</i>	Indian ricegrass	Graminoid	Perennial	Native	0.3	0.3
Gambel oak shrubland						
<i>Apocynum androsaemifolium</i>	spreading dogbane	Forb	Perennial	Native	19.2	19.2
<i>Bromus japonicus</i>	Japanese chess	Graminoid	Annual	Non-native	0	0.4
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	70.0	72.5

Table 3-4. Additional species detected in the subalpine meadow plot, Timpanogos Cave NM, 2009.

Scientific name	Common name	Life form	Duration	Nativity
<i>Arabis holboellii</i>	Holboell's rockcress	Forb	Perennial	Native
<i>Bromus tectorum</i>	cheatgrass	Graminoid	Annual	Non-native
<i>Calochortus nuttallii</i>	sego-lily	Forb	Perennial	Native
<i>Chenopodium fremontii</i>	Fremont's goosefoot	Forb	Annual	Native
<i>Crepis acuminata</i>	mountain hawksbeard	Forb	Perennial	Native
<i>Descurainia pinnata</i>	western tansymustard	Forb	Annual	Native
<i>Elymus trachycaulus</i>	slender wheatgrass	Graminoid	Perennial	Native
<i>Lithospermum ruderae</i>	western stone seed	Forb	Perennial	Native
<i>Machaeranthera canescens</i>	hoary aster	Forb	Perennial	Native
<i>Penstemon humilis</i>	low beardtongue	Forb	Perennial	Native
<i>Poa fendleriana</i>	muttongrass	Graminoid	Perennial	Native
<i>Tragopogon dubius</i>	yellow salsify	Forb	Biennial	Non-native

Table 3-5. Density of live seedlings, saplings, and overstory trees by vegetation type, Timpanogos Cave NM, 2009.

Scientific name	Common name	Density of trees by dbh class (no. of trees/ha)				
		Seedling	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 forest						
<i>Abies concolor</i>	white fir	67	0	80	40	16
<i>Acer grandidentatum</i>	bigtooth maple	133	0	0	0	0
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	4,933	40	0	120	288
Gambel oak shrubland						
none		0	0	0	0	0

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 NM, 2009.

Scientific name	Common name	Density (no. of trees/ha)	Dbh (cm)	Crown class				Crown health				
				%D	%C	%I	%O	1	2	3	4	5
Subalpine meadow												
none		0	-	-	-	-	-	-	-	-	-	-
Mixed conifer												
<i>Abies concolor</i>	white fir	80	22.2	0	20	0	0	0	20	0	0	80
<i>Acer grandidentatum</i>	bigtooth maple	0	na	-	-	-	-	-	-	-	-	-
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	288	23.3	0	100	0	0	100	0	0	0	0
Gambel oak												
none		0	-	-	-	-	-	-	-	-	-	-

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

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, 2009.

Vegetation type	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
Subalpine meadow	5.3	0	0	0	8.3	76.7	0	9.0	0.3	0
Mixed conifer	0	0	0	0	1.3	74.3	6.0	4.7	12.0	0
Gambel oak	0	0	0	0	0.4	81.3	0.8	6.7	10.8	0

Table 3-8. Fuel volume and depth of litter and duff by vegetation type, Timpanogos Cave NM, 2009.

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	7.6	0.2	1.4	4.1	1.5	0.4	2.0	0.5
Gambel oak	0.2	0.2	0	0	0	0	3.6	0

4 Discussion

This was the first year of monitoring at Timpanogos Cave NM. Early monitoring data describe conditions of sites inside the park that may be useful in understanding reference conditions of sites outside the park that are more intensively managed.

Species richness and cover varied greatly among the vegetation types. The subalpine plot was dominated by forbs. The overstory of the mixed conifer plot was primarily Rocky mountain juniper. Although numerous white firs were detected in the plot, the majority of these were dead, and few seedlings and saplings were detected. The Gambel oak plot was extremely homogenous, with a total of only three species detected. All of the exotic species detected in Timpanogos Cave NM had low cover, and could potentially be eradicated in the areas sampled if park managers so desired.

In the Gambel oak plot, shrub cover was measured using both the point-intercept method and the line-intercept method. Because total shrub cover was similar from both of these methods, the NCPN will only use the point-intercept method in the future.

In 2010, all three plots will be revisited. After 3–5 years of data are collected, a long-term revisit schedule will begin, with plots sampled every 3–5 years. Further discussion will occur with park 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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Appendix A. Supplemental Information

Table A. Physical attributes of upland monitoring plots in Timpanogos Cave National Monument, 2009.

Vegetation type	Plot ID	Elevation (m)	Percent slope	Azimuth (degrees)
Subalpine	1	2,435	30	53
Mixed conifer	2	1,729	34	84
Gambel oak	3	1,694	30	103

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