



Integrated Upland Monitoring in Bryce Canyon National Park

Annual Report 2010 (Non-sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2012/524.N



ON THE COVER

Ponderosa pine forest in Bryce Canyon National Park. NPS photo.

Integrated Upland Monitoring in Bryce Canyon National Park

Annual Report 2010 (Non-sensitive Version)

Natural Resource Technical Report NPS/NCPN/NRTR—2012/524.N

Prepared by

Dana Witwicki
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

Editing and Design

Alice Wondrak Biel
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

January 2012

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

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Northern Colorado Plateau Network website, <http://www.nature.nps.gov/im/units/ncpn>, as well as at the Natural Resource Publications Management web site, <http://www.nature.nps.gov/publications/nrpm>.

Please cite this publication as:

Witwicki, D. 2012. Integrated upland monitoring in Bryce Canyon National Park: Annual report 2010 (non-sensitive version). Natural Resource Technical Report NPS/NCPN/NRTR—2012/524.N. National Park Service, Fort Collins, Colorado.

Contents

Figures..... v

Tables vii

Executive Summary ix

1 Introduction..... 1

2 Methods..... 3

 2.1 Integrated Upland Monitoring in Bryce Canyon National Park 3

 2.2 Integrated Upland Monitoring Procedures 5

 2.3 Database 5

3 Results..... 7

 3.1 Monitored Plots..... 7

 3.2 Vegetation Type Summaries 7

4 Discussion..... 17

5 Literature Cited 19

Figures

Figure 2-1. Examples of vegetation types monitored in Bryce Canyon National Park	4
Figure 2-2. Sampling frame and location of monitoring plots in Bryce Canyon National Park, 2010	5
Figure 2-3. Number of pinyon-juniper (A) and mixed conifer (B) plots sampled each year based on five-year rotating panel revisit designs for long-term upland monitoring at Bryce Canyon National Park.	5
Figure 2-4. Plot layout for upland monitoring of forests and woodlands.	6
Figure 3-1. The relative positions of trees using four classes for crown classification.....	8
Figure 3-2. Non-metric multidimensional scaling (NMS) ordination of plots from the two vegetation types monitored in Bryce Canyon National Park in 2010.....	15

Tables

Table 3-1. Mean (range) number of plant species detected per monitoring plot by life form and vegetation type, Bryce Canyon NP, 2010.	9
Table 3-2. Mean (range) overstory canopy closure, and percent cover of vegetation by life form for each vegetation type, Bryce Canyon NP, 2010.	10
Table 3-3. Mean (range) percent cover of dominant species by vegetation type, Bryce Canyon NP, 2010.	10
Table 3-4. Density of shrub species per hectare by vegetation type, Bryce Canyon NP, 2010.	11
Table 3-5. Mean (range) density of live seedlings, saplings, and overstory trees by vegetation type, Bryce Canyon NP, 2010.	12
Table 3-6. Mean (range) density, diameter at breast height (dbh), crown class, and crown health for all trees >15 cm dbh by vegetation type, Bryce Canyon NP, 2010.	13
Table 3-7. Mean (range) percent cover of surface features by vegetation type, Bryce Canyon NP, 2010.	14
Table 3-8. Mean (range) fuel volume and depth of litter and duff by vegetation type, Bryce Canyon NP, 2010.	14

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 in Bryce Canyon National Park (NP) in 2010. 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.

Upland monitoring was initiated at Bryce Canyon NP in 2010. Based on discussions with park resource staff, pinyon-juniper woodlands and mixed conifer forests were selected for monitoring. The sampling frame was delineated using the elevation zone where each vegetation type occurs in the park. Ten pinyon-juniper and eight mixed conifer plots were established and monitored in 2010. One of the pinyon-juniper plots was excluded from the monitoring summaries because a spring was discovered along one of the transects.

In this report, measures were summarized for each vegetation type. The only analysis performed was an ordination of species cover. Results of this ordination indicated good separation between the vegetation types. Early monitoring data describe status of vegetation types. Interpretation will be 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 a couple of NCPN park units are located, biological soil crusts also play an important role but are less dramatically pinnacled. 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 of the region's upland ecosystems 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 may persist for many decades or longer. Fire-regime alteration (Whelan 1995) and exotic-plant invasion (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 (e.g., litter, rock, bare ground)

- 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 in Bryce Canyon National Park

2.1.1 Resource issues driving upland monitoring

Park resource management staff identified pinyon-juniper (PJ) woodlands and mixed conifer forests as the highest priority for long-term monitoring. PJ woodlands occur at lower elevations in the park, primarily below the rim, and vary depending on elevation and aspect. At the lowest elevations, PJ woodlands have an understory of Wyoming big sagebrush, bunchgrass, and/or sparse vegetation. As elevation increases, PJ woodlands mix with Gambel oak and mixed montane shrubs, and with ponderosa pine at the highest elevations in its range. Mixed conifer forests occur in high-elevation areas in the southern half of the park and are dominated by white fir, Douglas-fir, and ponderosa pine.

The overall goal of monitoring these vegetation types is to provide information on the natural variability of upland resources not already monitored through the fire effects program and early warning of system degradation.

2.1.2 Mapping and selecting target populations

2.1.2.1 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>).

2.1.2.2 Selection of target vegetation types

Defining the target population typically involves determining the ecological sites that correspond to the resource of interest. An ecological site is defined by a combination of soil properties (texture, depth, water-holding capacity), geology, landform, climatic regime, and potential vegetation.

The spatial extent of ecological sites is largely determined by soil map units within a soil survey, although the location of an ecological site within a soil map unit is not explicit. The National Resource Conservation Service (NRCS) mapped soils for Bryce Canyon NP within the Panguitch Soil Survey (USDA NRCS 1990). However, because the NRCS did not have permission to dig soil pits within the park for this soil survey, the accuracy of soil map units within the park is questionable. When compared to the draft NCPN vegetation map, there was quite a bit of discrepancy between the vegetation map units and the soil survey. Due to these problems with the soil survey, ecological sites were not used in Bryce Canyon NP. Instead, the sampling frame was stratified by elevation.

2.1.2.3 Mapping of target vegetation types

A sampling frame was created using elevation zones dominated by PJ woodland and high-elevation mixed conifer forest (see Figure 2-1). For PJ woodlands, this included accessible areas at elevations of 2,300 m and below (Figure 2-2). For mixed conifer forests, this included accessible areas at elevations above 2,600 m (Figure 2-2).

2.1.3 Selection of monitoring locations

Monitoring plots were selected using the Reversed Randomized Quadrant Recursive Raster (RRQRR) method (Theobald et al. 2007) to create a spatially balanced design within the sampling frame. RRQRR provides an ordered list of centroids for all possible monitoring plots in the sampling frame. The sampling frame was buffered by 65 m, and any points within the buffer were not used for monitoring. This reduced the number of points rejected for overlapping roads, trails, or the park boundary. Within each vegetation type, plots were established in ascending order of plot number. If a plot was rejected (e.g., due to incorrect vegetation type), the next sequentially ordered plot was used.

2.1.4 Revisit design

A rotating-panel revisit design (Figure 2-3) was created that samples 10 PJ plots and 8 mixed conifer plots each year. A total of 25 PJ plots and 20 mixed conifer plots are sampled over five years. Plots are sampled for two consecutive years (in order to detect annual

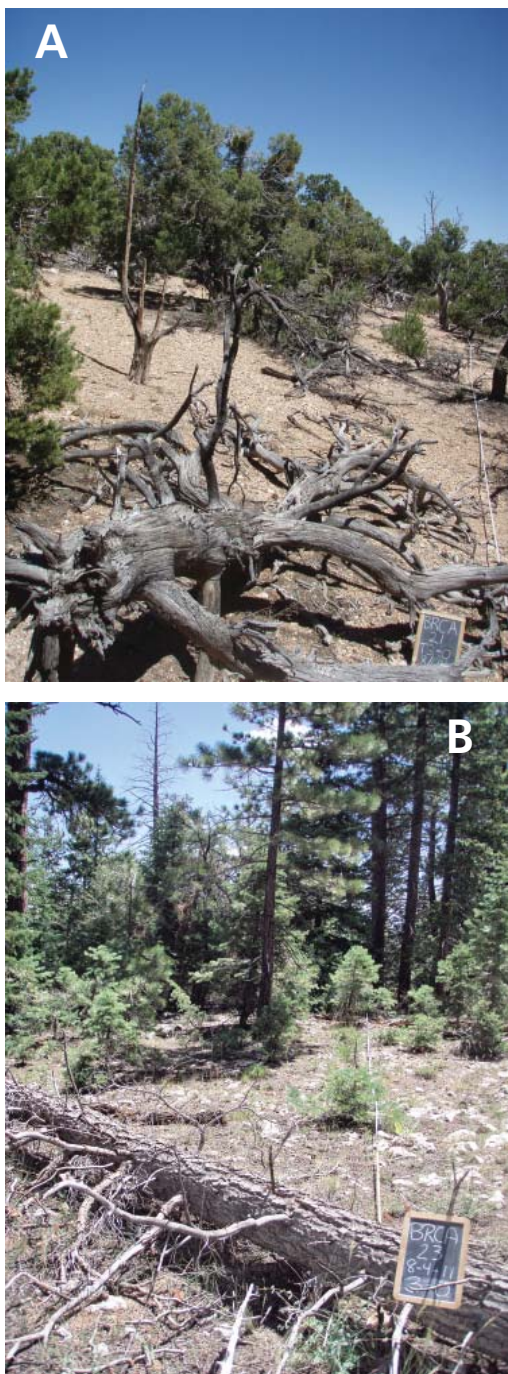


Figure 2-1. Examples of vegetation types monitored in Bryce Canyon National Park. A) Pinyon-juniper woodland. B) Mixed conifer forest.

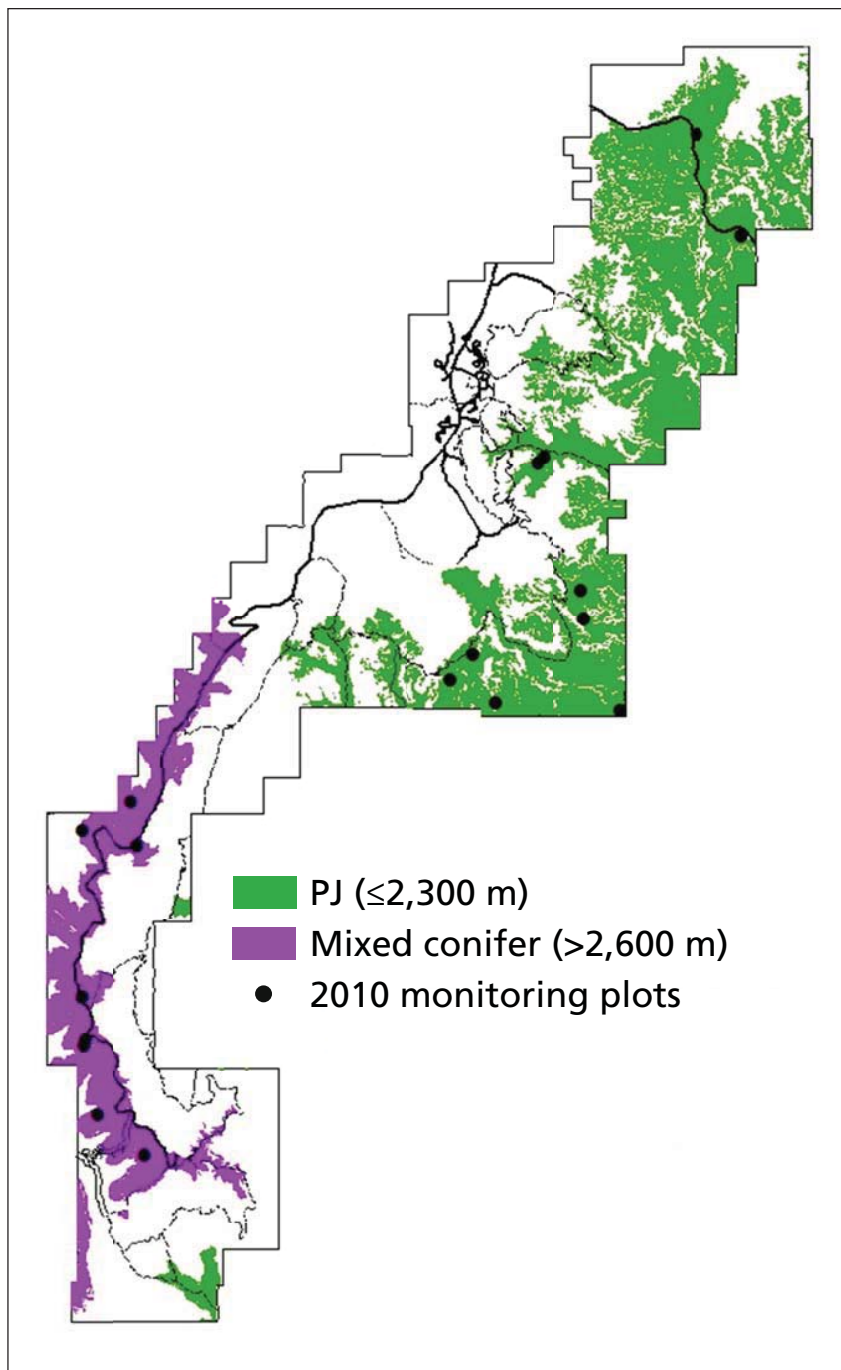


Figure 2-2. Sampling frame and location of monitoring plots in Bryce Canyon National Park, 2010.

A. Pinyon-juniper (2,300 m and below)

Panel	Year									
	1	2	3	4	5	6	7	8	9	10
1	5	5				5	5			
2		5	5				5	5		
3			5	5				5	5	
4				5	5				5	5
5	5				5	5				5

B. Mixed Conifer (above 2,600 m)

Panel	Year									
	1	2	3	4	5	6	7	8	9	10
1	4	4				4	4			
2		4	4				4	4		
3			4	4				4	4	
4				4	4				4	4
5	4				4	4				4

Figure 2-3. Number of pinyon-juniper (A) and mixed conifer (B) plots sampled each year based on five-year rotating panel revisit designs for long-term upland monitoring at Bryce Canyon National Park.

variation due to temperature, precipitation, etc.) and rested for three years. The sampling scheme repeats itself every five years.

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 on standard forest, woodland, and fuels procedures (USDI 2003; Brown 1974). Pinyon-juniper woodlands are sampled using woodland methods, while mixed conifer forests are sampled using forest methods.

At each plot, observations are recorded along three parallel, 50-m transects spaced 25 m apart (Figure 2-4). Photos are taken at the origin and end of each transect. A

point-intercept method is used to record percent cover of plant species and ground-cover attributes at 0.5-m intervals along each transect. Density 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. 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 over-story trees (>15-cm diameter) in Quadrant 1 are identified to species, tagged with unique numbers, and measured for diameter. Diameter of trees is typically measured at breast height (dbh). Crown class and health of trees are also recorded in forest plots. Overstory canopy closure is recorded along each transect using a concave spherical densiometer in forest plots.

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. Depth of litter and duff is also recorded. Disturbances observed on and around the site are recorded at each plot. Soil stability is also recorded at woodland (in this case, PJ) plots.

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.

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, and the RRQRR-generated sampling locations are GIS-ArcMap shape files and are stored with the Access database on NCPN servers.

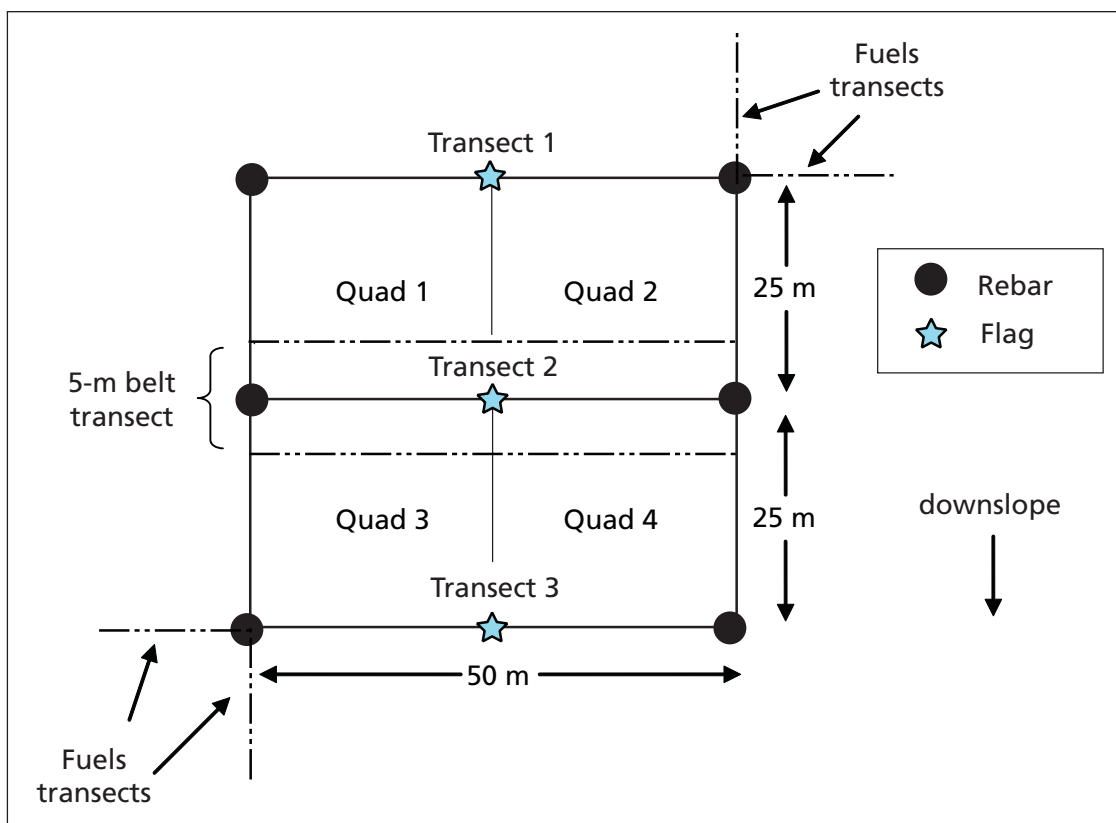


Figure 2-4. Plot layout for upland monitoring of forests and woodlands.

3 Results

3.1 Monitored Plots

In July 2010, eighteen plots were established and monitored as part of the long-term revisit design, including 10 in PJ woodland and eight in mixed conifer forest (see Figure 2-2). Each plot was sampled using the suite of measures appropriate for that vegetation type.

Only nine PJ plots, instead of the 10 original plots, were included in this report. One plot contained a spring with riparian vegetation for approximately 10 m along a transect. Re-bar was removed from this plot in 2010, and it will not be included in the long-term data set.

3.2 Vegetation Type 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 have been completed.

For this annual report, plot-level summaries of the measures listed in Chapter 1 were generated for each monitoring plot, then summarized by vegetation type. Summaries are simply a mean and the range (minimum, maximum) for a measured attribute. Given the limited data, measures were not statistically compared among vegetation types. The reader is cautioned not to draw wide-reaching conclusions from this initial set of results.

The only statistical assessment provided is a multivariate assessment of the similarity of vegetation conditions within and among vegetation types (see Section 3.2.9). Data from 2010 were ordinated using NMS (non-metric multidimensional scaling), which involves scaling plots on the basis of similarity (or dissimilarity) of species composition and cover. Plots are distributed in multivariate space, typically along 1–3 axes, and within this space, plots with similar composition are located closer together and correlated with dominant species.

3.2.1 Species richness

Sixty-one species were detected during monitoring: 36 species in PJ plots and 37 species in mixed conifer plots. Species richness by life form is reported for each vegetation type in Table 3-1 (tables begin on page 9). Recorded species were compared to the NPSpecies database to determine first-time observations in Bryce Canyon NP; no new species were detected in 2010.

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

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

Overstory canopy closure and percent cover of live and total vegetation 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 dominant understory species is shown in Table 3-3. Dominant species were selected using species frequently detected in plots. The percent cover of all species recorded for each plot is included in an electronic appendix that accompanies this report (brca10_species.xls).

3.2.3 Shrub density

Density of shrub species for all vegetation types is shown in Table 3-4.

3.2.4 Tree density

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

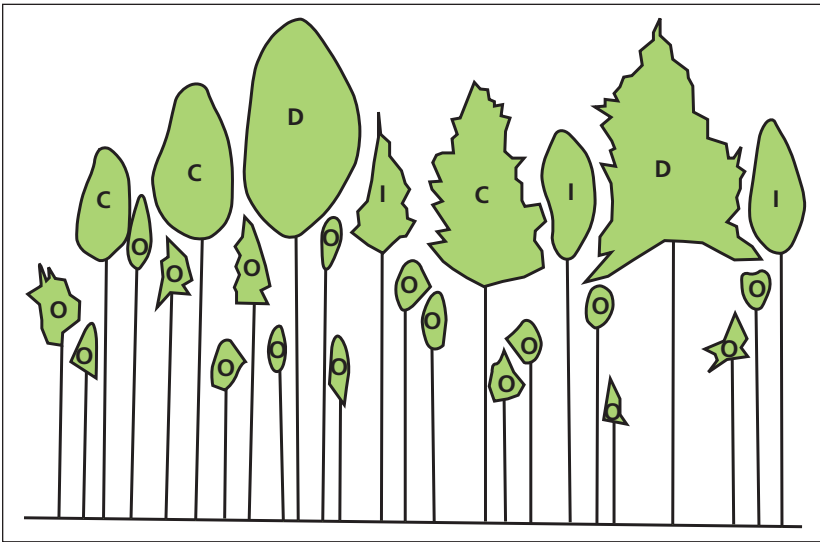


Figure 3-1. The relative positions of trees using four classes for crown classification. D=Dominant, C=Codominant, I=Intermediate, and O=Overtopped/Suppressed.

Crown health classes that describe the percent of live foliage for each tree were additionally recorded for mixed conifer plots and used to indicate standing dead trees at PJ plots. Crown classes that describe the relative position of a live tree in the canopy were recorded for mixed conifer plots. The NCPN 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.

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

Only one exotic species, yellow salsify (*Tragopogon dubius*), was detected at one mixed conifer plot. This plot had 0.3% cover and a density of 200 plants per hectare. No exotic species were detected at PJ plots.

In 2010, NCPN upland sampling methods were not intended as an early detection survey; 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. The surface cover at PJ plots was dominated by litter, small rocks, and undifferentiated crust. Litter was the dominant surface cover at all mixed conifer plots.

3.2.7 Soil stability

At PJ sites, soil aggregate stability had a mean of 2.3 and a range of 1.8–3.1. Soil stability numbers range from 1 (least stable) to 6 (most stable) and are correlated with current erosion resistance and soil biotic integrity. They also usually reflect hydrologic function because stable soils are less likely to disperse and clog soil pores during rainstorms. The numbers are affected by soil texture, so it is important to limit comparisons to similar soils that have comparable amounts of sand, silt, and clay. Extremely sandy soils may not have maximum soil stability values of 6.

3.2.8 Fuels

Fuel volumes and depth of litter and duff are reported in Table 3-8. Mixed conifer plots had a greater volume of fuels than PJ plots, primarily because there were greater amounts of sound 1,000-hour fuels at these sites.

3.2.9 Plot ordinations

Non-metric multidimensional scaling ordination was performed using species with relative cover values of $\geq 10\%$ (Figure 3-2). Relative

cover is the percent cover of the species divided by the total vegetation cover on a plot. This requirement was imposed to emphasize dominant species. The direction and relative magnitude of correlations of species are shown in the graph. The species vector from the origin shows the direction of positive correlation.

The ordination illustrates the high degree of separation between the vegetation types and differences within vegetation types. Within the PJ sites, five of the plots were tightly correlated with pinyon pine (*Pinus edulis*), Utah juniper (*Juniperus osteosperma*), and greenleaf mountain mahogany (*Cercocarpus montanus*), which are associated with typi-

cal low-elevation PJ woodlands. The other four PJ plots were also associated with ponderosa pine (*Pinus ponderosa*) and greenleaf manzanita (*Arctostaphylos patula*) to varying degrees, which occur at higher-elevation PJ woodlands.

The mixed conifer sites were more tightly grouped than the PJ sites but were separated into two distinct groups. All mixed conifer plots were very strongly associated with white fir (*Abies concolor*) and strongly associated with Douglas-fir (*Pseudotsuga menziesii*) and Oregon grape (*Mahonia repens*). The four mixed conifer plots on the right side of the ordination were associated with greenleaf manzanita to varying degrees.

Table 3-1. Mean (range) number of plant species detected per monitoring plot by life form and vegetation type, Bryce Canyon NP, 2010.

Vegetation type	Number of species detected					
	Total	Tree	Shrub	Perennial grass	Annual grass	Forb/Herb
PJ	10.3 (7–18)	2.3 (2–3)	5.2 (3–9)	0.6 (0–3)	0	2.2 (1–5)
Mixed conifer	13.4 (9–18)	3.5 (2–4)	6.3 (3–9)	1.6 (0–4)	0	1.9 (0–3)

Table 3-2. Mean (range) overstory canopy closure, and percent cover of vegetation by life form for each vegetation type, Bryce Canyon NP, 2010.

Vegetation type	Overstory canopy closure	Percent cover							
		Total*		Tree		Shrub		Perennial grass	
		Live	Total	Live	Total	Live	Total	Live	Total
PJ	na	30.6 (19.7–45.7)	37.0 (24.3–50.3)	18.4 (10.0–33.3)	20.0 (10.0–33.7)	11.0 (3.0–19.7)	16.2 (3.0–37.0)	1.0 (0–8.0)	1.3 (0–9.7)
Mixed conifer	53.2 (34.9–78.5)	13.3 (6.3–23.7)	17.4 (9.0–26.3)	8.3 (1.7–18.7)	11.0 (3.3–20.7)	3.1 (0–7.0)	4.0 (0.3–7.3)	1.3 (0–5.3)	1.8 (0–8.0)

*Total vegetation cover at all canopy heights for PJ and total understory cover for mixed conifer

Table 3-3. Mean (range) percent cover of dominant species by vegetation type, Bryce Canyon NP, 2010.

Latin name	Common name	Life form	Duration	Nativity	No. of plots with species present*	Percent cover	
						Live	Total
						All canopy heights	
PJ							
<i>Arctostaphylos patula</i>	greenleaf manzanita	Shrub	Perennial	Native	5	4.2 (0–12.7)	7.3 (0–24.7)
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	Shrub	Perennial	Native	7	3.8 (0–12.0)	5.1 (0–14.7)
<i>Juniperus osteosperma</i>	Utah juniper	Tree	Perennial	Native	7	7.1 (0–14.7)	8.1 (0–15.0)
<i>Pinus edulis</i>	two-needle pinyon	Tree	Perennial	Native	8	8.2 (0–19.3)	8.8 (0–19.7)
<i>Pinus ponderosa</i>	ponderosa pine	Tree	Perennial	Native	4	3.3 (0–11.0)	3.3 (0–11.0)
<i>Purshia tridentata</i>	antelope bitterbrush	Shrub	Perennial	Native	6	0.4 (0–2.7)	0.7 (0–3.3)
<i>Quercus gambelii</i>	Gambel oak	Shrub	Perennial	Native	6	0.7 (0–2.0)	0.9 (0–3.3)
Mixed conifer						Understory cover	
<i>Abies concolor</i>	white fir	Tree	Perennial	Native	8	7.3 (1.7–17.7)	9.1 (2.7–19.3)
<i>Arctostaphylos patula</i>	greenleaf manzanita	Shrub	Perennial	Native	5	1.0 (0–3.0)	1.7 (0–5.3)
<i>Mahonia repens</i>	Oregon grape	Dwarf Shrub	Perennial	Native	7	1.2 (0–3.3)	1.2 (0–3.3)
<i>Pseudotsuga menziesii</i>	Douglas-fir	Tree	Perennial	Native	7	0.8 (0–2.3)	1.3 (0–3.3)
<i>Symphoricarpos oreophillus</i>	mountain snowberry	Shrub	Perennial	Native	5	0.3 (0–1.0)	0.4 (0–1.0)

* A total of 9 PJ and 8 mixed conifer plots were monitored in 2010.

Table 3-4. Density of shrub species per hectare by vegetation type, Bryce Canyon NP, 2010.

Scientific name	Common name	No. of plots with species present*	Density (number of shrubs/ha)		
			Mean	Minimum	Maximum
PJ					
<i>Amelanchier utahensis</i>	Utah serviceberry	1	22	0	200
<i>Arctostaphylos patula</i>	greenleaf manzanita	4	1,311	0	4,600
<i>Ceanothus martinii</i>	Utah mountain-lilac	2	237	0	1,467
<i>Cercocarpus montanus</i>	alder-leaf mountain mahogany	8	563	0	1,533
<i>Chrysothamnus parryi</i>	Parry's rabbitbrush	1	30	0	267
<i>Ephedra viridis</i>	Mormon tea	4	111	0	467
<i>Eriogonum corymbosum</i>	crisp-leaf wild buckwheat	1	7	0	67
<i>Mahonia fremontii</i>	Fremont's mahonia	2	30	0	200
<i>Purshia mexicana</i>	cliff-rose	1	37	0	333
<i>Purshia tridentata</i>	antelope bitterbrush	7	126	0	267
<i>Quercus gambelii</i>	Gambel oak	4	178	0	667
<i>Sambucus caerulea</i>	blue elderberry	1	7	0	67
<i>Shepherdia rotundifolia</i>	roundleaf buffaloberry	1	30	0	267
<i>Symphoricarpos oreophilus</i>	mountain snowberry	2	96	0	800
<i>Tetradymia canescens</i>	spineless horsebrush	3	59	0	267
Mixed conifer					
<i>Arctostaphylos patula</i>	greenleaf manzanita	6	533	0	1,933
<i>Ceanothus martinii</i>	Utah mountain-lilac	5	767	0	4,400
<i>Cercocarpus ledifolius</i>	curl-leaf mountain mahogany	1	17	0	133
<i>Chrysothamnus depressus</i>	dwarf rabbitbrush	1	58	0	467
<i>Chrysothamnus nauseosus</i>	rubber rabbitbrush	1	8	0	67
<i>Chrysothamnus parryi</i>	Parry's rabbitbrush	2	58	0	333
<i>Juniperus communis</i>	common juniper	3	75	0	467
<i>Pachystima myrsinites</i>	mountain-lover	3	1,050	0	5,133
<i>Purshia tridentata</i>	antelope bitterbrush	2	33	0	200
<i>Ribes cereum</i>	wax currant	5	508	0	3,200
<i>Ribes</i> sp.	currant	1	8	0	67
<i>Rosa woodsii</i>	Woods' rose	4	142	0	600
<i>Sambucus caerulea</i>	blue elderberry	1	8	0	67
<i>Symphoricarpos oreophilus</i>	mountain snowberry	8	2,475	267	4,133

* A total of 9 PJ and 8 mixed conifer plots were monitored in 2010.

Table 3-5. Mean (range) density of live seedlings, saplings, and overstory trees by vegetation type, Bryce Canyon NP, 2010.

Scientific name	Common name	No. of plots with species detected*	Density of trees by dbh class (no. of trees/ha)				Tree
			Seedling	Sapling			
			<2.5 cm	2.5–5.0 cm	5.1–10.0 cm	10.1–15.0 cm	
PJ							
<i>Juniperus osteosperma</i>	Utah juniper	7	133 (0–600)	53 (0–120)	31 (0–80)	27 (0–160)	85 (0–240)
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	2	7 (0–67)	9 (0–80)	4 (0–40)	9 (0–40)	0
<i>Pinus edulis</i>	two-needle pinyon	8	281 (0–667)	40 (0–160)	49 (0–320)	62 (0–160)	50 (0–176)
<i>Pinus ponderosa</i>	ponderosa pine	4	67 (0–333)	0	4 (0–40)	0	25 (0–96)
Mixed conifer							
<i>Abies concolor</i>	while fir	8	3,825 (733–10,533)	160 (0–560)	55 (0–280)	110 (0–520)	138 (0–464)
<i>Pinus flexilis</i>	limber pine	2	17 (0–133)	0	0	0	4 (0–32)
<i>Pinus ponderosa</i>	ponderosa pine	6	8 (0–67)	0	10 (0–80)	10 (0–80)	54 (0–272)
<i>Populus tremuloides</i>	quaking aspen	3	233 (0–1667)	0	0	10 (0–80)	0
<i>Pseudotsuga menziesii</i>	Douglas-fir	7	392 (0–1,000)	20 (0–120)	30 (0–80)	5 (0–40)	46 (0–96)

* A total of 9 PJ and 8 mixed conifer plots were monitored in 2010.

Table 3-6. Mean (range) density, diameter at breast height (dbh), crown class, and crown health for all trees >15 cm dbh by vegetation type, Bryce Canyon NP, 2010.

Scientific name	Common name	Density (no. of trees/ha)	dbh (cm)	Crown class			Crown health					
				% O	% I	% C	% D	% 1	% 2	% 3	% 4	% 5
PJ												
<i>Juniperus osteosperma</i>	Utah juniper	112 (0–336)	25 (20–31)	na	na	na	na	na	na	na	18 (0–38)	
<i>Pinus edulis</i>	two-needle pinyon	59 (0–176)	22 (19–24)	na	na	na	na	na	na	na	20 (0–50)	
<i>Pinus ponderosa</i>	ponderosa pine	30 (0–128)	43 (32–51)	na	na	na	na	na	na	na	13 (0–25)	
Mixed conifer												
<i>Abies concolor</i>	while fir	172 (32–512)	27 (21–41)	3 (0–13)	30 (0–75)	33 (0–83)	6 (0–50)	33 (0–78)	21 (0–63)	18 (0–44)	0.4 (0–3)	28 (0–100)
<i>Pinus flexilis</i>	limber pine	8 (0–48)	22 (21–23)	0	0	33 (0–67)	0	33 (0–67)	0	0	0	67 (0–100)
<i>Pinus ponderosa</i>	ponderosa pine	60 (0–288)	33 (20–50)	0	28 (0–100)	44 (0–100)	17 (0–100)	37 (0–100)	31 (0–100)	20 (0–100)	0	12 (0–50)
<i>Pseudotsuga menziesii</i>	Douglas-fir	104 (0–288)	29 (15–38)	0	30 (0–100)	32 (0–100)	0	31 (0–100)	7 (0–22)	22 (0–100)	2 (0–17)	38 (0–78)

Crown class is not recorded for dead trees.

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. Mean (range) percent cover of surface features by vegetation type, Bryce Canyon NP, 2010.

Vegetation type	Crust, undifferentiated	Cyanobacteria	Lichen	Moss	Bare soil	Litter	Woody debris	Small rock	Large rock	Bedrock
PJ	15.3 (1.7–34.7)	0.1 (0–1.0)	0	0.4 (0–1.7)	3.0 (0–6.0)	52.6 (36.0–80.7)	1.8 (0.3–4.0)	22.5 (10.3–43.7)	2.3 (0–4.7)	0.4 (0–3.0)
Mixed conifer	2.6 (0–8.7)	0	0.04 (0–0.3)	0.2 (0–1.3)	4.9 (0–14.0)	77.8 (65.7–84.7)	4.9 (0.7–9.7)	5.8 (1.7–12.0)	2.0 (0.3–4.0)	0

Table 3-8. Mean (range) fuel volume and depth of litter and duff by vegetation type, Bryce Canyon NP, 2010.

Vegetation type	Fuel volume (tons/acre)						Depth (cm)	
	Total	1-hr	10-hr	100-hr	1000-hr		Litter	Duff
					Sound	Rotten		
PJ	8.6 (1.1–48.5)	0.1 (0.01–0.3)	0.6 (0.1–1.0)	0.6 (0–1.6)	1.1 (0–2.9)	6.2 (0–47.4)	1.1 (0.3–2.1)	0.7 (0–3.4)
Mixed conifer	18.2 (1.4–39.1)	0.5 (0.1–1.1)	1.1 (0.5–2.1)	1.6 (0–5.0)	8.3 (0–20.5)	6.6 (0–21.6)	1.1 (0.7–1.5)	1.1 (0.2–2.7)

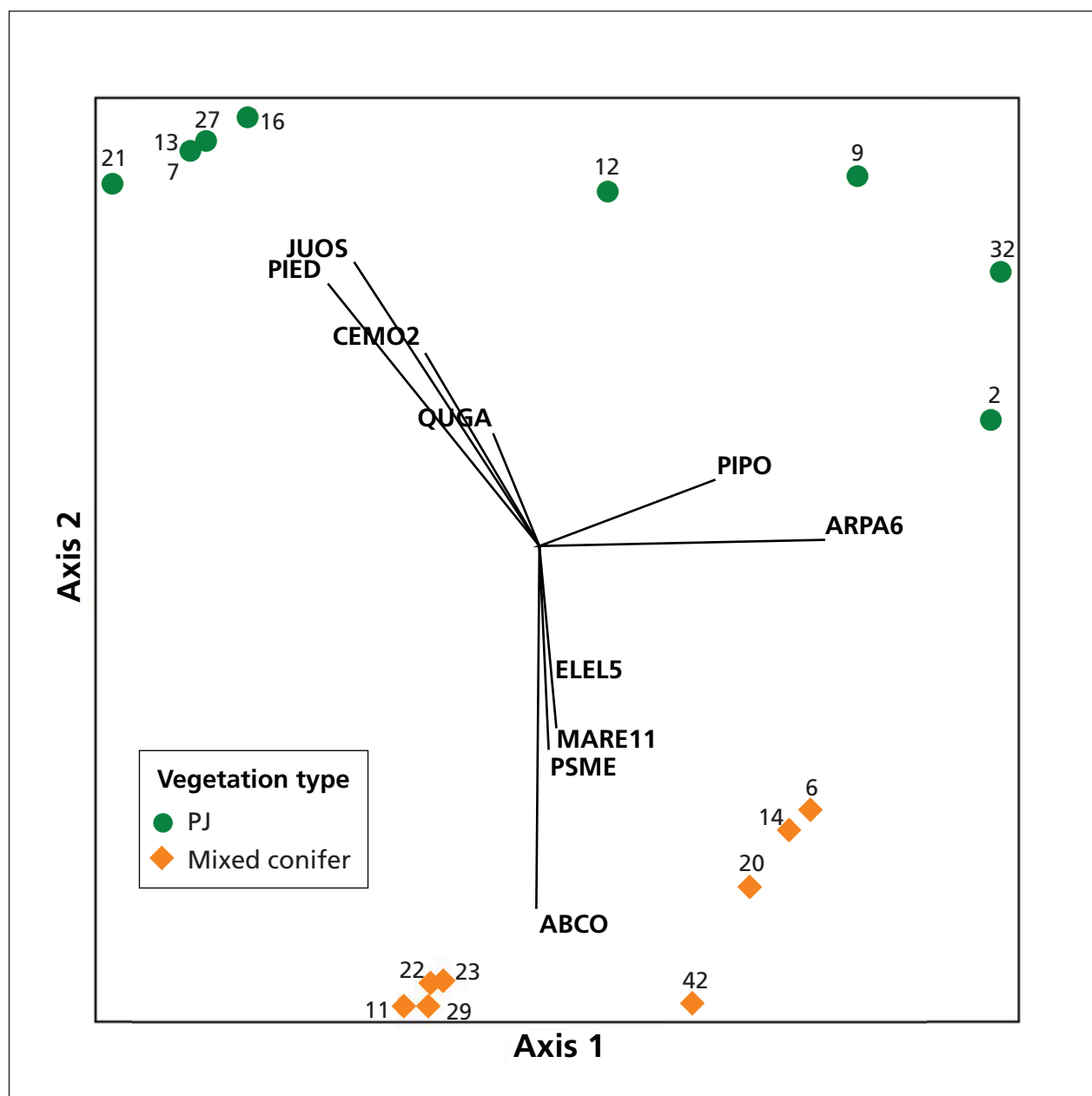


Figure 3-2. Non-metric multidimensional scaling (NMS) ordination of plots from the two vegetation types monitored in Bryce Canyon National Park in 2010. Points are labeled by Plot ID.

Species codes

ABCO = *Abies concolor* (white fir)

ARPA6 = *Arctostaphylos patula* (greenleaf manzanita)

CEMO2 = *Cercocarpus montanus* (alder-leaf mountain mahogany)

ELEL5 = *Elymus elymoides* (squirreltail)

JUOS = *Juniperus osteosperma* (Utah juniper)

MARE11 = *Mahonia repens* (Oregon grape)

PIED = *Pinus edulis* (two-needle pinyon pine)

PIPO = *Pinus ponderosa* (ponderosa pine)

PSME = *Pseudotsuga menziesii* (Douglas fir)

QUGA2 = *Quercus gambelii* (Gambel oak)

4 Discussion

This was the first year of monitoring at Bryce Canyon NP. Early monitoring data, which describe status and conditions of sites inside the park, may be useful in understanding reference conditions of more intensively managed sites outside the park. PJ and mixed conifer sites had similar species richness, with PJ sites dominated by tree and shrub cover and the understory of mixed conifer sites dominated by tree cover. Although litter and duff depths were similar in both vegetation types, fuel volumes were over two times higher at mixed conifer sites, primarily due to the presence of greater amounts of sound 1,000-hr fuels. Annual grasses were not detected in any plot, meaning that cheatgrass (*Bromus tectorum*), a common invasive annual grass, was not a significant component of either of these vegetation types in the park. In general, exotic plant species appeared to have little presence in the vegetation types monitored at the park.

In 2011, we plan to monitor 18 plots at Bryce Canyon NP, in accordance with the full operational monitoring design. One-half of the plots visited in 2010 will be revisited and the remaining plots will be established. 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 have been completed.

5 Literature Cited

- Belnap, J. 2002. Nitrogen fixation in biological soil crusts from southeast Utah, U.S.A. *Biology and Fertility of Soils* 35:128–135.
- Belnap, J., B. Budel, and O. L. Lange. 2003. Biological soil crusts: Characteristics and distribution. Pages 3–30 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.). Ecological studies series 150. Berlin: Springer-Verlag.
- Bock, C. E., J. H. Bock, K. L. Jepsen, and J. C. Ortega. 1986. Ecological effects of planting African lovegrass in Arizona. *National Geographic Research* 2(4):456–463.
- Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA Forest Service General Technical Report INT-16. Intermountain Forest and Range Experiment Station, Ogden, Utah.
- Evans, R. D., and O. L. Lange. 2003. Biological soil crusts and ecosystem nitrogen and carbon dynamics. Pages 263–279 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.). Ecological studies series 150. Berlin: Springer-Verlag.
- Garfin, G. M., J. K. Eischeid, M. T. Lenart, K. L. Cole, K. Ironside, and N. Cobb. 2010. Downscaling climate projections in topographically diverse landscapes of the Colorado Plateau in the arid southwestern United States. In C. van Riper III, B. F. Wakeling, and T. D. Sisk, eds., *The Colorado Plateau IV: Shaping conservation through science and management*. Tucson: The University of Arizona Press.
- Harper, K. T., and J. Belnap. 2001. The influence of biological soil crusts on mineral uptake by associated vascular plants. *Journal of Arid Environments* 47(3):347–357.
- Harris, T. A., G. P. Asner, and M. E. Miller. 2003. Changes in vegetation structure after long-term grazing in pinyon-juniper ecosystems: Integrating imaging spectroscopy and field studies. *Ecosystems* 6(4):368–383.
- Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford. 2005. Monitoring manual for grassland, shrubland, and savanna ecosystems. Published as 2 volumes. USDA Jornada Experimental Range, Las Cruces, New Mexico.
- Lange, O. L. 2003. Photosynthesis of soil-crust biota as dependent on environmental factors. Pages 217–240 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.). Ecological studies series 150. Berlin: Springer-Verlag.
- Miller, M. E. 2005. The structure and functioning of dryland ecosystems: Conceptual models to inform long-term ecological monitoring. U.S. Geological Survey Scientific Investigations Report 2005-5197.
- Miller, M. E., R. T. Belote, M. A. Bowker, and S. L. Garman. 2011. Alternative states of a semiarid grassland ecosystem: Implications for ecosystem services. *Ecosphere* 2(5):1–18.
- Munson, S. M., J. Belnap, C. D. Schelz, M. Moran, and T. W. Carolin. 2011a. On the brink of change: Plant responses to climate change on the Colorado Plateau. *Ecosphere* 2(6):1–15.
- Munson, S. M., J. Belnap, and G. S. Okin. 2011b. Responses of wind erosion to climate-induced vegetation changes on the Colorado Plateau. *Proceedings of the National Academy of Sciences of the USA* 108(10):3854–3859.
- National Park Service. 2003. Fire monitoring handbook. Fire Management Program Center, National Interagency Fire Center, Boise, Idaho.
- Rosentreter, R., and J. Belnap. 2003. Biological soil crusts of North America. Pages 31–51 in J. Belnap and O. L. Lange, eds., *Biological soil crusts: Structure, function, and management* (2nd ed.). Ecological studies series 150. Berlin: Springer-Verlag.
- Theobald, D. M., D. L. Stevens Jr., D. White, S. Urquhart, A. R. Olsen, and J. B. Norman. 2007. Using GIS to generate spatially balanced random survey designs for natural resource applications.

- Environmental Management
40:134–146.
- U.S. Department of Agriculture Natural Resources Conservation Service (USDA NRCS). 1990. Soil survey of Panguitch Area, Utah, parts of Garfield, Iron, Kane and Piute counties. Richfield, Utah.
- Whelan, R. J. 1995. The ecology of fire. Cambridge: Cambridge University Press.
- Whitford, W. G. 2002. Ecology of desert systems. San Diego, Calif.: Academic Press.
- Williams, J. D., J. P. Dombrowski, D. A. Gillette, and N. E. West. 1995. Microphytic crust influence on wind erosion. Transactions of the American Society of Agricultural Engineers 38:131–137.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 129/112410, January 2012

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™