



# Integrated Upland Monitoring in Bryce Canyon National Park

## *Annual Report 2011 (Non-Sensitive Version)*

Natural Resource Technical Report NPS/NCPN/NRTR—2013/683.N



## ON THE COVER

Measuring the diameter of a pinyon pine in a woodland, Bryce Canyon National Park. NPS photo.

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## *Annual Report 2011 (Non-Sensitive Version)*

Natural Resource Technical Report NPS/NCPN/NRTR—2013/683.N

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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 in Bryce Canyon National Park (NP) in 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.

In 2011, NCPN completed its second year of monitoring at Bryce Canyon NP. Eighteen plots were monitored, including ten pinyon-juniper and eight mixed conifer plots. Early monitoring data describe status of vegetation types, and interpretation is limited until additional data are acquired and more rigorously analyzed after at least five years of monitoring are complete.



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# 1 Introduction

Uplands represent the vast majority of land area in national park units of the 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 that, 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 dryland systems unique.

Biological soil crusts are biotic communities composed of cyanobacteria, algae, microfungi, 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) (Figure 1-1).

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

pinnacled. In the forests, shrublands, and meadows of the mountain regions surrounding the Colorado Plateau, where numerous NCPN park units are also located, biological soil crusts do not play an important role because much of the soil surface is covered by vegetation and litter.

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

Grazing, which has been a traditional land use throughout much of the plateau, has resulted in shifts in vegetation composition (Harris et al. 2003) and ecological states (Miller et al. 2011) that persist for many decades or longer. Fire-regime alteration (Whelan 1995) and invasion of exotic plants (Bock et al. 1986) have additionally contributed to these shifts. Increasing recreational use and unauthorized social trailing threatens the integrity of upland systems through soil-surface disturbance and resulting increases in soil erosion by water and wind. Additional pressure inside parks may also result from land use in adjacent areas. Global climate change is expected to change levels and seasonality of



Figure 1-1. Example of damage caused to biological soil crust by off-road vehicle use, Arches National Park.

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 loading
- 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

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

## 2 Methods

### 2.1 Integrated upland monitoring in Bryce Canyon National Park

#### 2.1.1 Resource issues driving upland monitoring

Park resource management staff identified two-needle pinyon (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) woodlands (hereafter referred to as pinyon-juniper [PJ]) and mixed-conifer forests as the highest priorities 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 (*Artemisia tridentata*), bunchgrass, and/or sparse vegetation. As elevation increases, PJ woodlands mix with Gambel oak (*Quercus gambelii*) and mixed montane shrubs, and with ponderosa pine (*Pinus ponderosa*) 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 (*Abies concolor*), Douglas-fir (*Pseudotsuga menziesii*), and ponderosa pine.

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

#### 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, land form, 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 National Park (NP) within the Panguitch Soil Survey (USDA NRCS 1990). However, because NRCS did not have permission to dig soil pits within the park for this survey, accuracy of soil map units within the park is questionable—there were obvious discrepancies between the soil survey and the vegetation map units shown on the draft NCPN vegetation map. 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 (Figure 2-1). This included accessible areas at elevations of 2,300 m and below for PJ woodlands and above 2,600 m for mixed-conifer forests (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 vegeta-



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

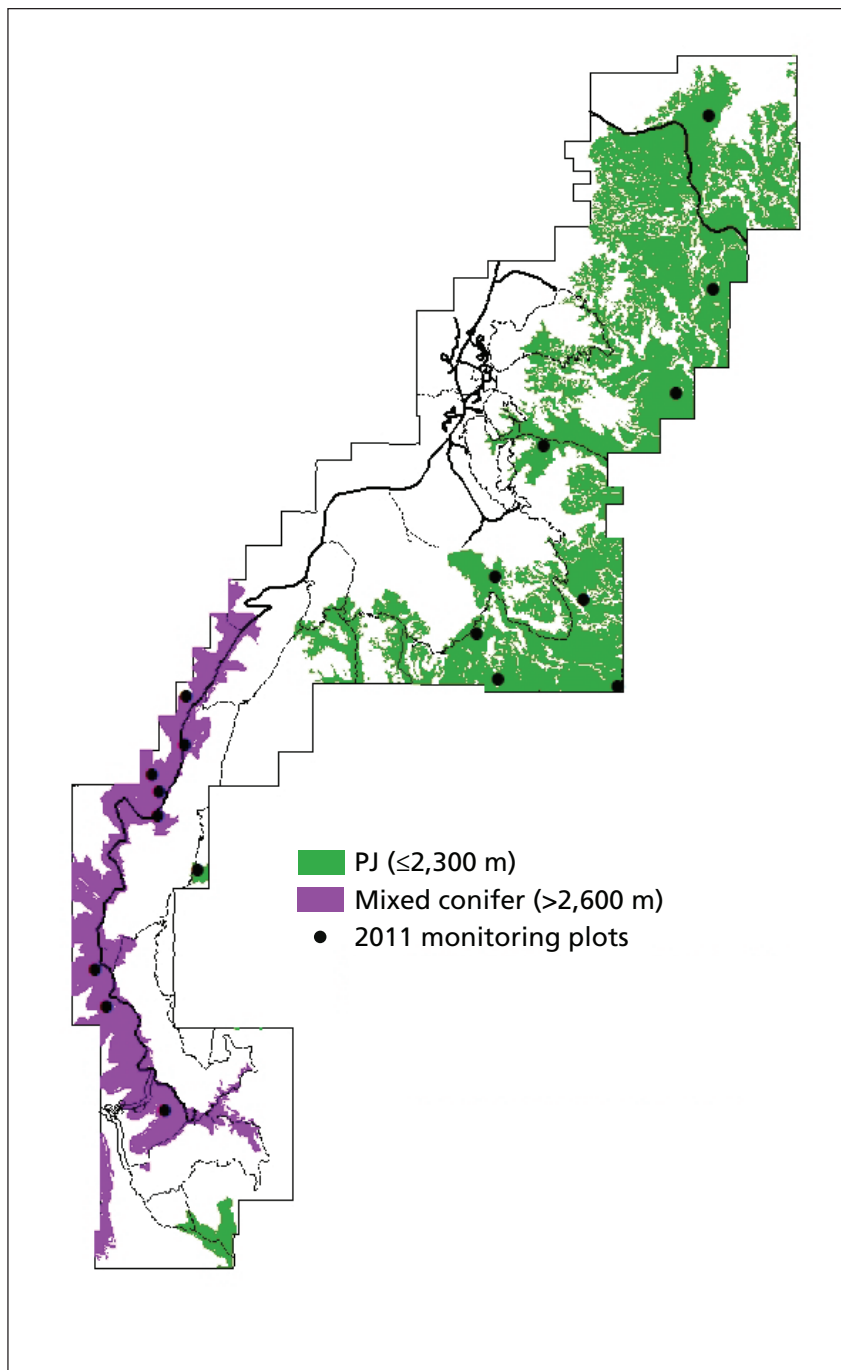


Figure 2-2. Sampling frame and location of monitoring plots in Bryce Canyon National Park, 2011.

tion 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.

The only vegetation types that were rejected in the PJ sampling frame were sagebrush and salt desert shrublands and grasslands found at low elevations in the park. Gambel oak shrublands and ponderosa pine forests were considered acceptable in the PJ sampling frame because they were usually mixed with two-needle pinyons and Utah junipers. No plots were rejected for incorrect vegetation in the mixed-conifer vegetation type.

#### 2.1.4 Revisit design

A rotating-panel revisit design (Figure 2-3) was created that samples ten PJ plots and eight 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 year-to-year differences due to temperature, precipitation, etc.) and rested for three years. The sampling scheme repeats 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 colleagues (2005) and standard forest, woodland, and fuels procedures (NPS 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 of each transect are taken from the origin and end. Photos of the soil surface are also taken at a specified point along each transect for woodland plots. 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. Vegetation cover is recorded in the understory (<2 m) in forests

### 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.

and at all heights for woodlands. Density of shrubs (by species and height class) and tree seedlings (by species) are recorded in a 1-m belt upslope of each transect. Density monitoring of exotic perennial species in the 1-m belt was discontinued beginning in the 2011 field season. Instead, frequency of all exotics species (annual and perennial) is recorded using 1 × 1-m quadrats placed every 5 m

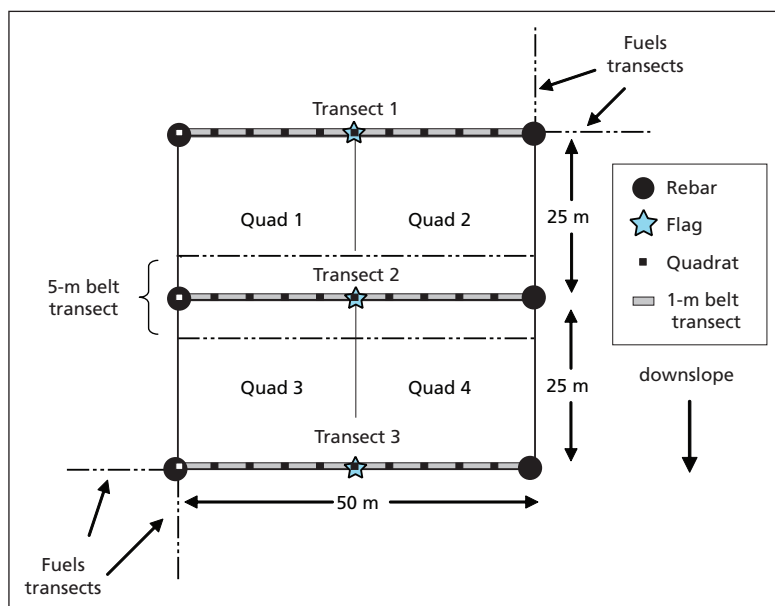


Figure 2-4. Plot layout for upland monitoring of forests and woodlands.

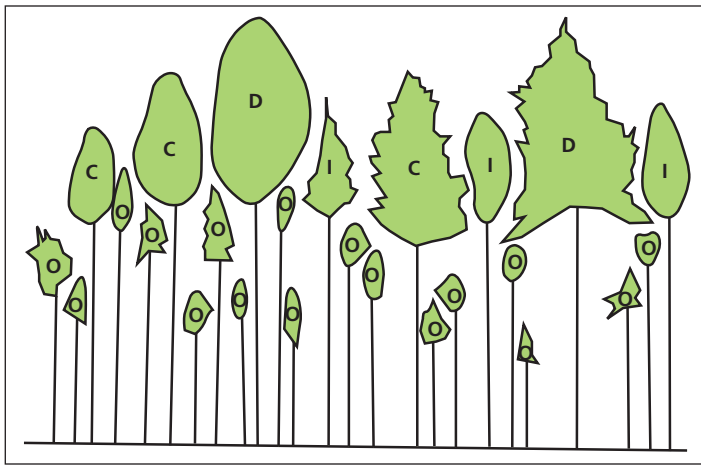


Figure 2-5. The relative positions of trees using four classes for crown classification. D =Dominant, C = Codominant, I = Intermediate, and O = Overtopped/Suppressed.

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. Diameter of trees is typically measured at breast height (dbh), except for woodland species that typically have multi-stem growth forms (e.g., pinyon pine and Utah juniper), which are measured at the root crown (drc). Before 2011, all trees were measured at breast height. 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 2-5):

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

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

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

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

Overstory canopy closure is recorded along each transect using a concave spherical densiometer in forest plots. 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, diameters of coarse woody fuels, and depth of litter and duff are recorded to derive fuel loading of each fuel class. 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. Soil stability is also recorded at woodland plots.

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

## 2.3 Database

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

## 3 Results

### 3.1 Monitored plots

In August 2011, eighteen plots were monitored as part of the long-term revisit design, including ten in PJ woodland and eight in mixed-conifer forest (see Figure 2-2). Six PJ and four mixed-conifer plots were established, and the remaining plots were revisited. Each plot was sampled using the suite of measures appropriate for that vegetation type.

### 3.2 Vegetation type summaries

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 these preliminary 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.

#### 3.2.1 Species richness

Eighty-three species were detected during monitoring: 44 species in PJ plots and 54 species in mixed-conifer plots. Species richness by life form is reported for each vegetation type in Table 3-1 (tables begin on page 8). Recorded species were compared to the NPSpecies database to determine first-time observations in Bryce Canyon NP. One new species, wild hollyhock (*Iliamna rivularis*), was detected in 2011. A voucher was created for this species.

Although Bryce Canyon NP does not have any populations of federally listed threatened or endangered plant species within its borders, at least 51 species of special concern exist within the park (Fertig and Topp 2009). One of these species, Markagunt aster (*Aster wasatchensis*), was detected at a mixed-conifer plot in 2011.

#### 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 (brca11\_species.xls).

#### 3.2.3 Shrub density

Density of shrub species is shown in Table 3-4 for all vegetation types. In PJ, alder-leaf mountain mahogany (*Cercocarpus montanus*) was found at all but one plot and had one of the highest densities. In mixed-conifer forests, Utah mountain-lilac (*Ceanothus martini*) had the highest density and was detected at three-quarters of the plots.

#### 3.2.4 Tree density

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

#### 3.2.5 Exotic species

Percent cover and frequency of detection of exotic plant species are shown in Table 3-7. When exotic species were detected, cover and frequency were summarized for all plots in the ecological site type.

Three perennial exotic plant species, orchard grass (*Dactylis glomerata*), Kentucky bluegrass (*Poa pratensis*), and common dandelion (*Taraxacum officinale*), were detected at mixed-conifer plots. All of these species had low cover and frequency. No exotic plant species were detected at PJ plots.

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 (brca11\_exotics.xls).

3.2.6 Surface features

Surface-feature cover is shown in Table 3-8. 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 3.2 and a range of 1.9–4.4. Soil stabil-

ity 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 loading of downed woody material, litter, and duff is reported in Table 3-9. Mixed-conifer plots were characterized by higher fuel loading than PJ plots.

| Table 3-1. Mean (range) number of plant species detected per monitoring plot by life form and vegetation type, Bryce Canyon National Park, 2011. |                            |              |               |                 |              |              |
|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|--------------|---------------|-----------------|--------------|--------------|
| Vegetation type                                                                                                                                  | Number of species detected |              |               |                 |              |              |
|                                                                                                                                                  | Total                      | Tree         | Shrub         | Perennial grass | Annual grass | Forb/Herb    |
| PJ                                                                                                                                               | 11.4<br>(6–17)             | 2.5<br>(2–4) | 6.3<br>(3–11) | 0.6<br>(0–3)    | 0            | 2.0<br>(0–4) |
| Mixed conifer                                                                                                                                    | 17.5<br>(9–25)             | 3.6<br>(2–4) | 5.9<br>(4–8)  | 3.6<br>(0–7)    | 0            | 4.3<br>(1–9) |

**Table 3-2. Mean (range) percent overstory canopy closure, and percent cover of vegetation by life form for each vegetation type, Bryce Canyon National Park, 2011.**

| Vegetation type | Overstory canopy closure | Total*              |                     | Tree                |                     | Shrub              |                    | Perennial grass |                 | Annual grass |       | Forb/Herb        |                  |
|-----------------|--------------------------|---------------------|---------------------|---------------------|---------------------|--------------------|--------------------|-----------------|-----------------|--------------|-------|------------------|------------------|
|                 |                          | Live                | Total               | Live                | Total               | Live               | Total              | Live            | Total           | Live         | Total | Live             | Total            |
| PJ              | na                       | 37.2<br>(25.3–53.7) | 43.2<br>(31.0–60.3) | 24.1<br>(14.3–39.3) | 25.7<br>(14.7–42.7) | 14.0<br>(1.3–30.7) | 18.4<br>(2.0–44.3) | 0.8<br>(0–5.7)  | 1.3<br>(0–8.3)  | 0            | 0     | 1.0<br>(0–2.3)   | 1.7<br>(0–5.0)   |
| Mixed conifer   | 32.8<br>(11.6–60.7)      | 19.3<br>(8.7–37.7)  | 23.0<br>(11.0–42.3) | 9.3<br>(0–23.7)     | 11.2<br>(0.7–25.0)  | 4.7<br>(1.7–8.3)   | 5.0<br>(1.7–8.7)   | 3.1<br>(0–6.7)  | 4.4<br>(0–10.3) | 0            | 0     | 3.3<br>(0.3–8.0) | 3.5<br>(0.3–9.0) |

\*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 National Park, 2011.**

| Scientific name                  | Common name                  | Life form   | Duration  | Nativeity | No. of plots with species present <sup>a</sup> | Percent cover <sup>b</sup> |                |
|----------------------------------|------------------------------|-------------|-----------|-----------|------------------------------------------------|----------------------------|----------------|
|                                  |                              |             |           |           |                                                | Live                       | Total          |
| PJ                               |                              |             |           |           |                                                |                            |                |
| <i>Arctostaphylos patula</i>     | greenleaf manzanita          | Shrub       | Perennial | Native    | 5                                              | 3.7 (0–12.3)               | 4.9 (0–18.3)   |
| <i>Cercocarpus montanus</i>      | alder-leaf mountain mahogany | Shrub       | Perennial | Native    | 9                                              | 1.7 (0–5.0)                | 2.4 (0–7.3)    |
| <i>Juniperus osteosperma</i>     | Utah juniper                 | Tree        | Perennial | Native    | 7                                              | 5.1 (0–13.3)               | 5.8 (0–15.0)   |
| <i>Pinus edulis</i>              | two-needle pinyon            | Tree        | Perennial | Native    | 7                                              | 9.0 (0–27.0)               | 9.8 (0–29.3)   |
| <i>Pinus ponderosa</i>           | ponderosa pine               | Tree        | Perennial | Native    | 5                                              | 7.8 (0–22.7)               | 8.0 (0–23.3)   |
| <i>Purshia tridentata</i>        | antelope bitterbrush         | Shrub       | Perennial | Native    | 5                                              | 1.5 (0–10.0)               | 1.9 (0–13.3)   |
| <i>Quercus gambelii</i>          | Gambel oak                   | Shrub       | Perennial | Native    | 7                                              | 4.6 (0–15.3)               | 5.2 (0–17.7)   |
| Mixed conifer                    |                              |             |           |           |                                                |                            |                |
| <i>Abies concolor</i>            | white fir                    | Tree        | Perennial | Native    | 8                                              | 7.9 (0–20.0)               | 9.3 (0.3–21.3) |
| <i>Arctostaphylos patula</i>     | greenleaf manzanita          | Shrub       | Perennial | Native    | 4                                              | 0.5 (0–2.3)                | 0.7 (0–2.3)    |
| <i>Mahonia repens</i>            | Oregon grape                 | Dwarf Shrub | Perennial | Native    | 7                                              | 1.7 (0–5.0)                | 1.7 (0–5.0)    |
| <i>Poa fendleriana</i>           | muttongrass                  | Graminoid   | Perennial | Native    | 7                                              | 1.0 (0–2.7)                | 1.7 (0–4.3)    |
| <i>Pseudotsuga menziesii</i>     | Douglas-fir                  | Tree        | Perennial | Native    | 6                                              | 1.1 (0–4.3)                | 1.6 (0–5.3)    |
| <i>Symphoricarpos oreophilus</i> | mountain snowberry           | Shrub       | Perennial | Native    | 7                                              | 1.5 (0–4.3)                | 1.6 (0–5.0)    |

<sup>a</sup> 10 PJ and 8 mixed-conifer plots were monitored in 2011.

<sup>b</sup> Cover at all canopy heights for PJ and understory cover for mixed conifer

**Table 3-4. Density of shrub species per hectare by vegetation type, Bryce Canyon National Park, 2011.**

| Scientific name                    | Common name                  | No. of plots with species present* | Density (number of shrubs/ha) |         |         |
|------------------------------------|------------------------------|------------------------------------|-------------------------------|---------|---------|
|                                    |                              |                                    | Mean                          | Minimum | Maximum |
| PJ                                 |                              |                                    |                               |         |         |
| <i>Arctostaphylos patula</i>       | greenleaf manzanita          | 3                                  | 960                           | 0       | 7,467   |
| <i>Artemisia nova</i>              | black sagebrush              | 1                                  | 67                            | 0       | 667     |
| <i>Ceanothus martinii</i>          | Utah mountain-lilac          | 4                                  | 313                           | 0       | 1,333   |
| <i>Cercocarpus ledifolius</i>      | curl-leaf mountain mahogany  | 3                                  | 293                           | 0       | 2,533   |
| <i>Cercocarpus montanus</i>        | alder-leaf mountain mahogany | 9                                  | 553                           | 0       | 1,533   |
| <i>Chrysothamnus nauseosus</i>     | rubber rabbitbrush           | 2                                  | 53                            | 0       | 333     |
| <i>Chrysothamnus viscidiflorus</i> | green rabbitbrush            | 1                                  | 13                            | 0       | 133     |
| <i>Ephedra viridis</i>             | Mormon tea                   | 3                                  | 60                            | 0       | 333     |
| <i>Mahonia fremontii</i>           | Fremont's mahonia            | 2                                  | 33                            | 0       | 267     |
| <i>Purshia mexicana</i>            | cliffrose                    | 1                                  | 40                            | 0       | 400     |
| <i>Purshia tridentata</i>          | antelope bitterbrush         | 6                                  | 367                           | 0       | 2,267   |
| <i>Rhus trilobata</i>              | skunkbush sumac              | 1                                  | 20                            | 0       | 200     |
| <i>Sambucus caerulea</i>           | blue elderberry              | 3                                  | 27                            | 0       | 133     |
| <i>Shepherdia rotundifolia</i>     | roundleaf buffaloberry       | 1                                  | 47                            | 0       | 467     |
| <i>Tetradymia canescens</i>        | spineless horsebrush         | 4                                  | 87                            | 0       | 400     |
| Mixed conifer                      |                              |                                    |                               |         |         |
| <i>Arctostaphylos patula</i>       | greenleaf manzanita          | 7                                  | 283                           | 0       | 667     |
| <i>Ceanothus martinii</i>          | Utah mountain-lilac          | 6                                  | 842                           | 0       | 4,000   |
| <i>Cercocarpus ledifolius</i>      | curl-leaf mountain mahogany  | 1                                  | 17                            | 0       | 133     |
| <i>Chrysothamnus depressus</i>     | dwarf rabbitbrush            | 2                                  | 58                            | 0       | 400     |
| <i>Chrysothamnus nauseosus</i>     | rubber rabbitbrush           | 1                                  | 8                             | 0       | 67      |
| <i>Chrysothamnus parryi</i>        | Parry's rabbitbrush          | 4                                  | 208                           | 0       | 1,133   |
| <i>Chrysothamnus vaseyi</i>        | Vasey's rabbitbrush          | 1                                  | 8                             | 0       | 67      |
| <i>Juniperus communis</i>          | common juniper               | 2                                  | 100                           | 0       | 733     |
| <i>Pachystima myrsinites</i>       | mountain-lover               | 1                                  | 167                           | 0       | 1,333   |
| <i>Purshia tridentata</i>          | antelope bitterbrush         | 1                                  | 8                             | 0       | 67      |
| <i>Ribes cereum</i>                | wax currant                  | 5                                  | 358                           | 0       | 1,467   |

\* 10 PJ and 8 mixed-conifer plots were monitored in 2011.

**Table 3-5. Mean (range) density of live seedlings, saplings, and overstory trees, and crown class of live overstory trees by vegetation type, Bryce Canyon National Park, 2011.**

| Scientific name              | Common name            | No. of<br>plots with<br>species<br>detected <sup>a</sup> | Density of trees by diameter <sup>b</sup> class (no. of trees/ha) |                |                |                  | Crown class <sup>c</sup> |               |               |                |            |
|------------------------------|------------------------|----------------------------------------------------------|-------------------------------------------------------------------|----------------|----------------|------------------|--------------------------|---------------|---------------|----------------|------------|
|                              |                        |                                                          | Seedling                                                          | Sapling        |                | Tree             | % D                      | % C           | % I           | % O            |            |
|                              |                        |                                                          | <2.5 cm                                                           | 2.5–5.0<br>cm  | 5.1–10.0<br>cm | 10.1–<br>15.0 cm |                          |               |               |                |            |
| PJ                           |                        |                                                          |                                                                   |                |                |                  |                          |               |               |                |            |
| <i>Abies concolor</i>        | white fir              | 1                                                        | 0                                                                 | 4<br>(0–40)    | 0              | 0                | 0                        | na            | na            | na             | na         |
| <i>Juniperus osteosperma</i> | Utah juniper           | 6                                                        | 80<br>(0–400)                                                     | 8<br>(0–80)    | 16<br>(0–80)   | 20<br>(0–80)     | 102<br>(0–320)           | na            | na            | na             | na         |
| <i>Juniperus scopulorum</i>  | Rocky Mountain juniper | 4                                                        | 60<br>(0–467)                                                     | 20<br>(0–120)  | 32<br>(0–120)  | 20<br>(0–80)     | 18<br>(0–128)            | na            | na            | na             | na         |
| <i>Pinus edulis</i>          | two-needle pinyon      | 7                                                        | 180<br>(0–533)                                                    | 12<br>(0–80)   | 40<br>(0–120)  | 76<br>(0–320)    | 74<br>(0–224)            | na            | na            | na             | na         |
| <i>Pinus ponderosa</i>       | ponderosa pine         | 5                                                        | 120<br>(0–600)                                                    | 12<br>(0–80)   | 28<br>(0–160)  | 8<br>(0–80)      | 54<br>(0–304)            | na            | na            | na             | na         |
| Mixed conifer                |                        |                                                          |                                                                   |                |                |                  |                          |               |               |                |            |
| <i>Abies concolor</i>        | while fir              | 8                                                        | 2292<br>(0–8,000)                                                 | 185<br>(0–600) | 135<br>(0–480) | 55<br>(0–360)    | 76<br>(0–304)            | 8<br>(0–33)   | 45<br>(0–83)  | 44<br>(17–100) | 0          |
| <i>Pinus flexilis</i>        | limber pine            | 1                                                        | 0                                                                 | 0              | 0              | 0                | 4<br>(0–32)              | 0             | 100           | 0              | 0          |
| <i>Pinus ponderosa</i>       | ponderosa pine         | 6                                                        | 25<br>(0–67)                                                      | 0              | 5<br>(0–40)    | 10<br>(0–40)     | 30<br>(0–192)            | 27<br>(0–100) | 33<br>(0–100) | 38<br>(0–100)  | 2<br>(0–8) |
| <i>Populus tremuloides</i>   | quaking aspen          | 5                                                        | 167<br>(0–667)                                                    | 0              | 0              | 5<br>(0–40)      | 2<br>(0–16)              | 0             | 0             | 100            | 0          |
| <i>Pseudotsuga menziesii</i> | Douglas-fir            | 8                                                        | 200<br>(0–600)                                                    | 17<br>(0–80)   | 40<br>(0–160)  | 17<br>(0–80)     | 28<br>(0–64)             | 7<br>(0–50)   | 49<br>(0–100) | 44<br>(0–100)  | 0          |

<sup>a</sup> 10 PJ and 8 mixed-conifer plots were monitored in 2011.

<sup>b</sup> Diameter was measured at root crown for Utah juniper and two-needle pinyon and at breast height for all other species.

<sup>c</sup> Crown class codes: D=Dominant, C=Codominant, I=Intermediate, O=Overtopped. Crown class is not recorded in PJ woodlands.

**Table 3-6. Mean (range) density, diameter, and crown health for all trees >15 cm diameter by vegetation type, Bryce Canyon National Park, 2011.**

| Scientific name              | Common name            | No. of plots with species detected <sup>a</sup> | Density (no. of trees/ha) | Diameter <sup>b</sup> (cm) | Crown health <sup>c</sup> |            |            |          |            |
|------------------------------|------------------------|-------------------------------------------------|---------------------------|----------------------------|---------------------------|------------|------------|----------|------------|
|                              |                        |                                                 |                           |                            | % 1                       | % 2        | % 3        | % 4      | % 5        |
| PJ                           |                        |                                                 |                           |                            |                           |            |            |          |            |
| <i>Juniperus osteosperma</i> | Utah juniper           | 6                                               | 118 (0–336)               | 28.6 (24.8–31.6)           | na                        | na         | na         | na       | 13 (0–28)  |
| <i>Juniperus scopulorum</i>  | Rocky Mountain juniper | 3                                               | 19 (0–128)                | 28.7 (20.7–36.5)           | na                        | na         | na         | na       | 11 (0–33)  |
| <i>Pinus edulis</i>          | two-needle pinyon      | 6                                               | 82 (0–240)                | 26.7 (22.8–33.7)           | na                        | na         | na         | na       | 11 (0–25)  |
| <i>Pinus ponderosa</i>       | ponderosa pine         | 5                                               | 59 (0–304)                | 40.1 (24.8–51.4)           | na                        | na         | na         | na       | 18 (0–67)  |
| Mixed conifer                |                        |                                                 |                           |                            |                           |            |            |          |            |
| <i>Abies concolor</i>        | white fir              | 8                                               | 152 (48–368)              | 27.0 (19.5–37.0)           | 21 (0–50)                 | 19 (0–83)  | 7 (0–50)   | 3 (0–17) | 50 (0–100) |
| <i>Juniperus scopulorum</i>  | Rocky mountain juniper | 1                                               | 8 (0–64)                  | 26.5                       | 0                         | 0          | 0          | 0        | 100        |
| <i>Pinus flexilis</i>        | limber pine            | 1                                               | 4 (0–32)                  | 24.1                       | 100                       | 0          | 0          | 0        | 0          |
| <i>Pinus ponderosa</i>       | ponderosa pine         | 6                                               | 50 (0–224)                | 37.2 (23.0–48.2)           | 10 (0–50)                 | 21 (0–100) | 15 (0–50)  | 1 (0–7)  | 52 (0–100) |
| <i>Populus tremuloides</i>   | Quaking aspen          | 1                                               | 4 (0–32)                  | 19.8                       | 0                         | 50         | 0          | 0        | 50         |
| <i>Pseudotsuga menziesii</i> | Douglas-fir            | 8                                               | 86 (16–160)               | 30.7 (26.6–37.5)           | 14 (0–50)                 | 8 (0–40)   | 20 (0–100) | 2 (0–14) | 56 (0–100) |

<sup>a</sup> 10 PJ and 8 mixed-conifer plots were monitored in 2011.<sup>b</sup> Diameter was measured at root crown for Utah juniper and two-needle pinyon and at breast height for all other species.<sup>c</sup> 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. Crown health is not recorded in PJ woodlands except to denote standing dead trees.

**Table 3-7. Mean (range) percent cover and frequency of exotic plant species detected by vegetation type in Bryce Canyon National Park, 2011.**

| Ecological site type | Scientific name             | Common name        | Life form | Duration  | No. of plots with exotic species detected* | Percent cover  |                | Frequency of detection (%) |
|----------------------|-----------------------------|--------------------|-----------|-----------|--------------------------------------------|----------------|----------------|----------------------------|
|                      |                             |                    |           |           |                                            | Live           | Total          |                            |
| PJ                   | -                           | -                  | -         | -         | -                                          | -              | -              | -                          |
| Mixed conifer        | <i>Dactylis glomerata</i>   | orchard grass      | Graminoid | Perennial | 1                                          | 0.1<br>(0-0.7) | 0.1<br>(0-0.7) | 0                          |
|                      | <i>Poa pratensis</i>        | Kentucky bluegrass | Graminoid | Perennial | 2                                          | 0              | 0              | 0.8<br>(0-3.3)             |
|                      | <i>Taraxacum officinale</i> | common dandelion   | Forb      | Perennial | 2                                          | 0              | 0              | 1.7<br>(0-10.0)            |

\* 10 PJ and 8 mixed-conifer plots were monitored in 2011.

**Table 3-8. Mean (range) percent cover of surface features by vegetation type, Bryce Canyon National Park, 2011.**

| Vegetation type | Crust, undifferentiated | Cyanobacteria | Lichen         | Moss            | Bare soil       | Litter              | Woody debris     | Small rock         | Large rock       | Bedrock         |
|-----------------|-------------------------|---------------|----------------|-----------------|-----------------|---------------------|------------------|--------------------|------------------|-----------------|
| PJ              | 11.2<br>(0-34.7)        | 0             | 0.1<br>(0-0.7) | 0.3<br>(0-0.7)  | 0.5<br>(0-1.7)  | 65.2<br>(45.3-85.0) | 1.5<br>(0-3.7)   | 17.0<br>(3.7-36.3) | 2.5<br>(0-6.3)   | 0.03<br>(0-0.3) |
| Mixed conifer   | 10.9<br>(0-38.7)        | 0             | 0.1<br>(0-0.3) | 0.04<br>(0-0.3) | 2.9<br>(0-15.0) | 69.4<br>(19.3-87.3) | 4.0<br>(2.0-9.0) | 7.9<br>(1.7-21.0)  | 2.5<br>(0.3-5.7) | 0               |

**Table 3-9. Mean (range) fuel loading of downed woody material (1-hr, 10-hr, 100-hr, and 1,000-hr fuels), litter, and duff by vegetation type, Bryce Canyon National Park, 2011.**

| Vegetation type | Fuel loading (tons/acre) |                   |                  |                |                    |                |                  |
|-----------------|--------------------------|-------------------|------------------|----------------|--------------------|----------------|------------------|
|                 | Total                    | 1-hr              | 10-hr            | 100-hr         | 1000-hr            |                | Litter           |
|                 |                          |                   |                  |                | Sound*             | Rotten*        |                  |
| PJ              | 13.5<br>(5.6–33.0)       | 0.2<br>(0.04–0.4) | 0.8<br>(0.1–2.1) | 0.6<br>(0–2.2) | 3.1<br>(0–13.6)    | 0.7<br>(0–5.6) | 4.8<br>(0.6–9.3) |
| Mixed conifer   | 23.9<br>(6.1–41.1)       | 0.3<br>(0–0.5)    | 0.9<br>(0–2.2)   | 1.8<br>(0–7.1) | 15.5<br>(4.0–29.3) | 0.6<br>(0–3.8) | 2.9<br>(0.2–5.6) |

\*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 year. One-half of plots monitored in 2011 were newly established, and it is important to remember that any differences between years could be due to the different suite of plots sampled, rather than any actual changes in ecological site types. This variation will be accounted for in status and trend analyses after plots have been revisited; it is too early to draw conclusions from these preliminary data.

One notable difference in the 2011 data compared to those from the previous year was the number of exotic plant species detected. Exotic species were much more likely to be detected at plots using the new frequency method than using cover derived from point-intercept sampling or density of exotic perennials in the 1-m belt. This difference is most likely because the new exotic frequency methods are better-suited to detecting exotic species in these ecological site types, and not due to an actual increase in exotic plant species in the park in 2011.

Another important difference in the 2011 data compared to those from the previous year was the amount of fuels reported. Again, this is likely due to a change in the way we summarized fuels, rather than an actual change in fuel loading in the areas monitored at Bryce Canyon NP. In the 2010 report (Witwicki 2012), fuel volumes were calculated using a general specific gravity from Brown (1974), and depth of litter and duff was summarized. In this report, fuel loading, which is the same as fuel volume, is reported for all fuel types, including litter and duff. The specific gravities of downed woody materials and bulk densities of litter and duff used in the 2011 calculations were derived from values for the dominant tree species in each vegetation type.

In 2012, we plan to monitor 18 plots according to the full operational monitoring design. One-half of the plots visited in 2011 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.



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