Bryce Canyon National Park
Survey Design and Site Selection Report

Defining the Upland Resources for Monitoring

Initial discussion with BRCA resource staff identified mixed conifer forests, Ponderosa pine forests, subalpine meadows, and Pinyon Juniper (PJ) woodlands as potential vegetation types for long-term monitoring. 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. Ponderosa pine forests occur at middle elevations and are interspersed with subalpine meadows above the rim in the northern half of the park. The spatial extent of meadows is limited, but these areas are of particular interest because they provide habitat for the threatened Utah prairie dog. 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.

After reviewing ideas for an upland design at BRCA, it was agreed that high elevation mixed conifer forests and PJ woodlands were the highest priority for NCPN monitoring. The goal of monitoring these vegetation types is to provide information on the natural variability of upland resources as well as early warning of system degradation. Ponderosa pine forests in the park are already heavily monitored through the fire management program at BRCA. The Utah prairie dog may have created some additional challenges for upland monitoring with concerns about placing rebar through burrows. BRCA resource staff agreed that meadows could be looked at more closely through a smaller research project.

Accessibility

An accessibility map was created for BRCA based on road and trail access using the NCPN Landscape Accessibility Model (Figure 1). Steep slopes ($\geq$ 50%) and areas isolated due to steep slopes (e.g. mesa tops) were considered inaccessible.

Delineating the Target Population

Defining Target Vegetation Communities

Inspection of the draft NCPN vegetation map for BRCA and field visits to the park determined the vegetation associations corresponding to the target communities for monitoring (Table 1). High elevation mixed conifer forests primarily consist of white fir vegetation map units. PJ woodlands include all vegetation map units with Pinyon Pine / Juniper spp. in the name.

Defining Target Soils and Ecological Sites

NCPN typically creates a sampling frame based on ecological sites and their associated soil map units. The National Resource Conservation Service (NRCS) mapped soils for BRCA within the Panguitch Soil Survey (1990). NRCS did not have permission to dig soil pits within the park for this soil survey, however, and 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 BRCA. Instead the sampling frame was stratified by elevation.

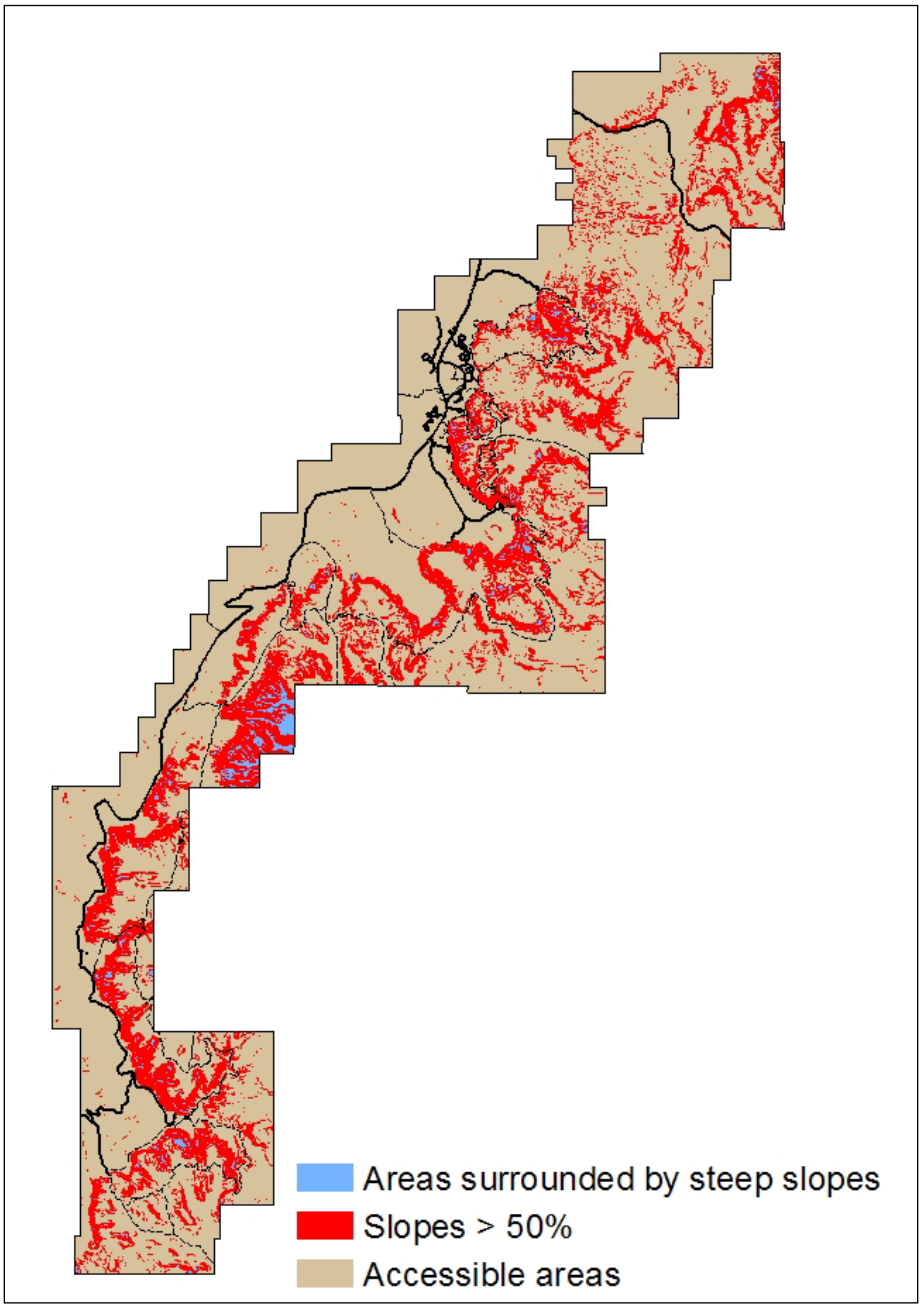

Figure 1. Accessible areas of Bryce Canyon National Park.

Table 1. Area (ha) of vegetation types in Bryce Canyon National Park. Shading designates priority map units for monitoring.

Map unit #	Map unit name	area (ha)	
		entire park	accessible
1	White Fir Forest Complex	1038.2	958.4
2	White Fir / Gambel Oak - (Bigtooth Maple) Forest	103.1	82.1
3	White Fir / Manzanita - Mixed Shrub Forest	1273.4	964.5
5	White Fir / Mixed Herbaceous Forest	175.1	167.6
6	Blue Spruce Forest Complex	83.0	66.3
7	Ponderosa Pine - (Douglas Fir) / Manzanita Woodland Complex	3302.8	2841.2
8	Ponderosa Pine / Mixed Mountain Shrub Woodland Complex	367.0	328.3
9	Ponderosa Pine / Mixed Herbaceous Woodland Complex	797.1	784.6
10	Ponderosa Pine / Gambel Oak Woodland	286.2	219.0
11	Ponderosa Pine / Pinyon Pine - Juniper spp. / Gambel Oak Forest	336.1	235.2
12	Ponderosa Pine / Pinyon Pine - Juniper spp. / Mixed Mountain Shrub Forest	624.4	485.8
13	Bristlecone Pine Woodland	695.2	474.4
14	Pinyon Pine - Juniper spp. / Saline Wildrye Woodland	170.2	89.2
15	Pinyon Pine - Juniper spp. / Sagebrush spp. Woodland Complex	26.5	25.9
16	Pinyon Pine - Juniper spp. / Mixed Mountain Shrub Woodland Complex	2135.1	1375.7
17	Pinyon Pine - Juniper spp. / Gambel Oak Woodland Complex	644.6	505.4
18	Pinyon Pine - Juniper spp. / Sparse Understory Woodland	69.9	64.0
23	Aspen Forest Complex	17.5	17.0
24	Narrowleaf Cottonwood Woodland Alliance	3.8	3.7
25	Curl-leaf Mountain-mahogany Woodland Complex	32.2	24.5
26	Gambel Oak Shrubland Complex	119.8	92.9
27	Mixed Mountain Shrubland Complex	254.5	161.9
28	Water Birch Shrubland	0.8	0.6
29	Willow spp. Temporarily Flooded Shrubland Complex	4.3	4.3
30	Black Sagebrush Shrubland Complex	276.8	276.4
31	Manzanita Shrubland	127.7	105.3
32	Rabbitbrush spp. Shrubland Complex	50.1	48.7
33	Bottomland Shrubland Complex	0.6	0.5
34	Big Sagebrush Shrubland Complex	75.3	72.6
37	Pygmy Sagebrush Dwarf-shrubland	6.5	6.5
40	Dry Meadow Mixed Herbaceous Vegetation Mosaic	110.1	101.2
41	Perennial Disturbed Grassland Complex	36.0	35.9
42	Sedge and Rush Wet Meadow Herbaceous Vegetation Mosaic	39.0	38.9
43	Roadside Restored Herbaceous Vegetation	43.6	42.8
45	Mixed Desert Shrubland Complex	114.3	74.4
46	Claron Formation	985.1	142.3
47	Barren Washes	81.2	78.1
48	Siltbush Shrubland	16.7	10.5
50	Transportation, Communications, and Utilities	74.5	73.9
51	Mixed Urban or Built-up Land	14.2	14.2
57	Reservoirs	1.2	1.2
60	Strip Mines, Quarries, and Gravel Pits	0.9	0.9
61	Seeps and Springs	0.2	0.1
	Total	14614.5	11097.3

Basis for Sampling Frame

The sampling frame was delineated by elevation in order to include areas dominated by high elevation mixed conifer forest and PJ woodland. The mixed conifer sampling frame included accessible areas above 2600 m, and the PJ sampling frame included accessible areas 2300 m and below (Figure 2). The total and accessible area for each part of the sampling frame is summarized in Table 2.

Before site selection, the sampling frame was buffered by 65 m to prevent plots from crossing roads, trails, the park boundary, and inaccessible areas (Figure 3).

Table 2. Area (ha) of the sampling frame by vegetation type for upland monitoring at Bryce Canyon National Park.

Dominant vegetation	Elevation	area (ha)		
		total in BRCA	sampling frame*	sampling frame buffered by 65 m**
Mixed conifer	above 2600 m	1659	1404	644
PJ	2300 m & below	5423	4042	951

* Includes only accessible area (<50% slope)

** Area where plot centroid can occur.

Monitoring Site Selection

Monitoring sites were selected using RRQRR (Reversed Randomized Quadrant Recursive Raster - Theobold et al. 2007). The sampling frame was converted to a 10-m grid to ensure complete coverage of the landscape. Sites were selected for the entire buffered sampling frame (Figure 3), producing the following shape files. All locations listed in these shape files have a selection probability of 1.

BRCA_smp_pts- ordered list of all possible monitoring points selected through RRQRR.
BRCA_sample_pts- ordered list of 250 initial monitoring points selected through RRQRR.

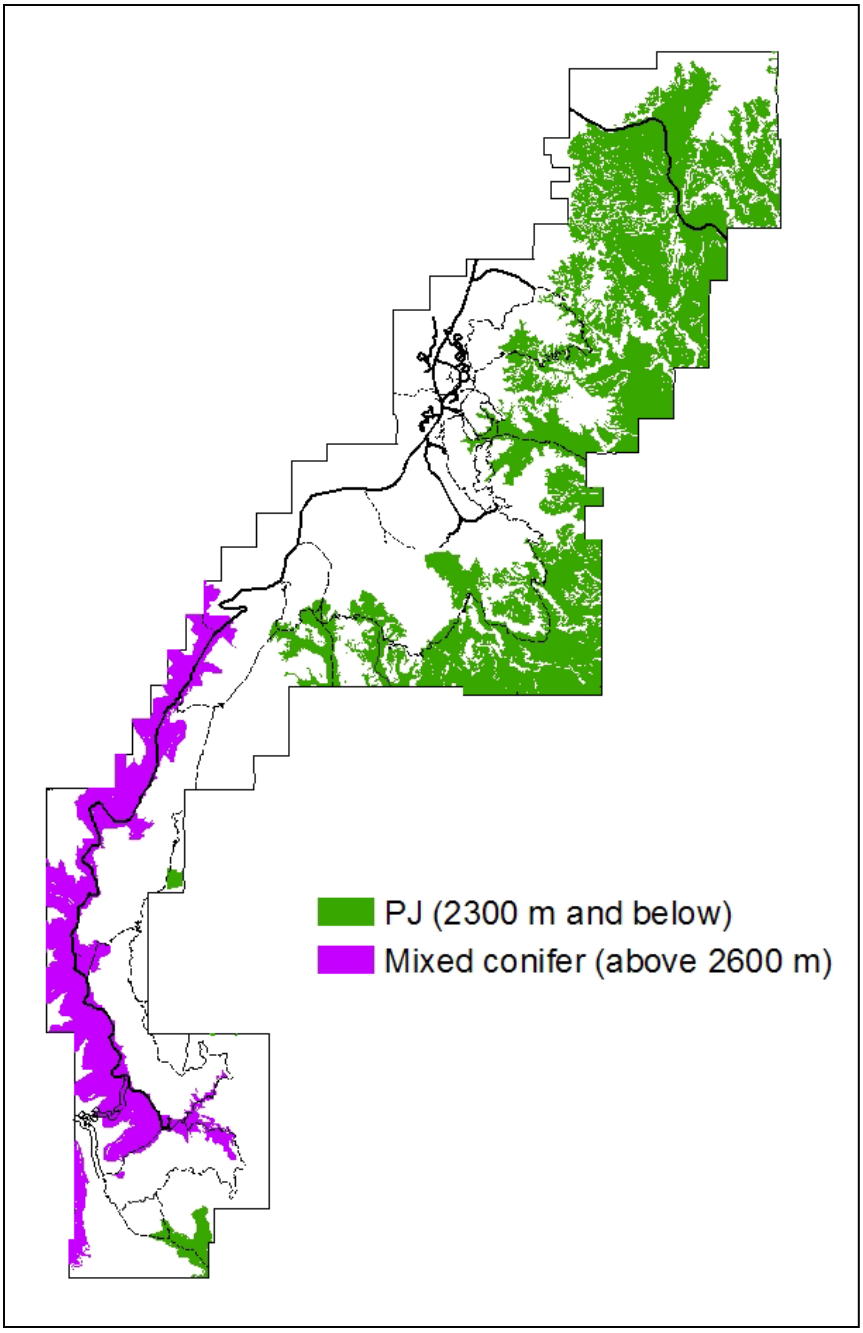

Figure 2. Sampling frame for Bryce Canyon National Park.

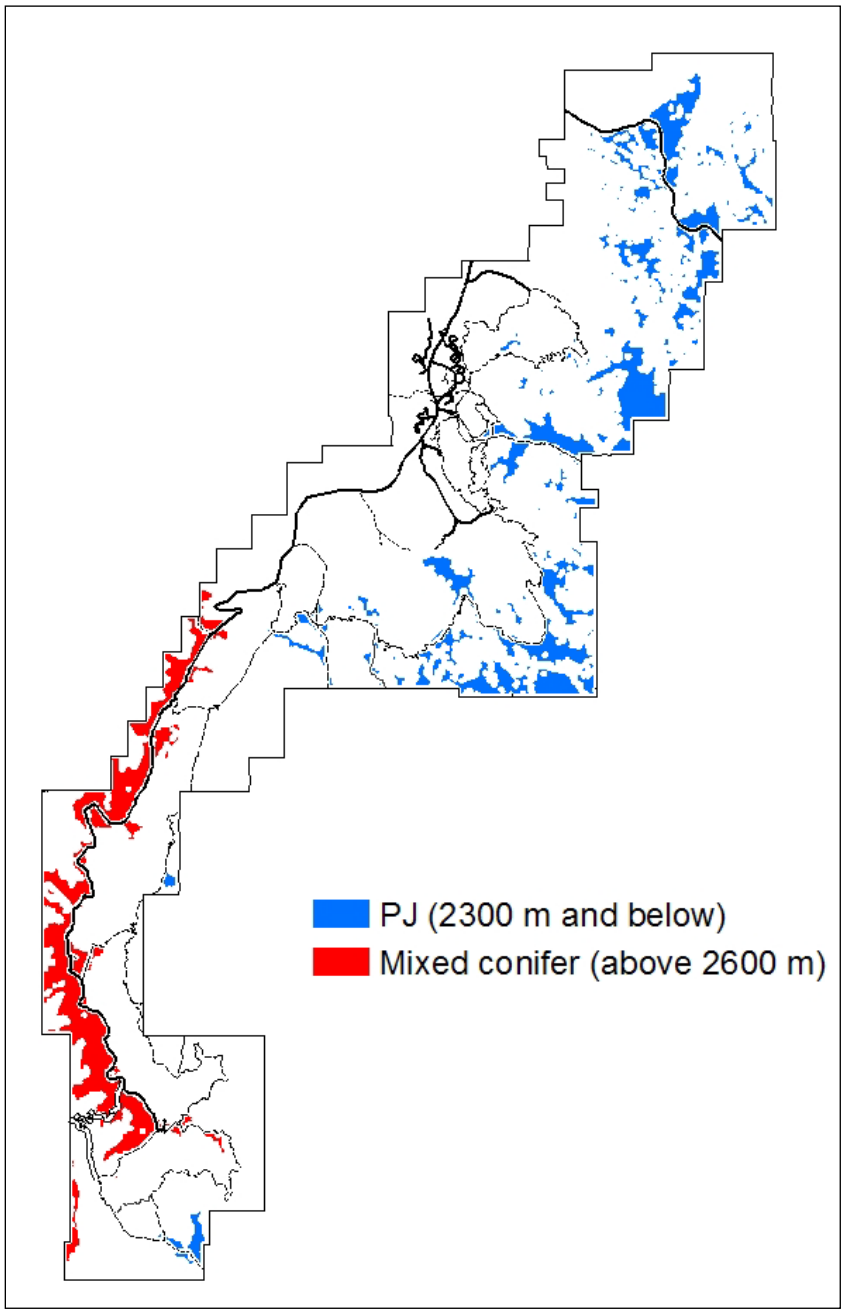

Figure 3. Sampling frame buffered by 65 m used for selecting plot centroids at Bryce Canyon National Park.

Tracking Monitoring Sites

BRCA_upland_master.shp, derived from BRCA_sample_pts.shp, contains the first 250 potential monitoring plots and any relevant tracking information (Table 3). The attributes include acceptance or rejections of plots, reasons for rejection, and date of plot establishment. It is used to schedule pre-monitoring evaluation of sites and for the eventual derivation of selection probabilities. In this file, the "order_" attribute was renamed "RQorder" for consistency among parks.

Table 3. Attributes of BRCA_upland_master.shp for tracking upland monitoring locations in Bryce Canyon National Park.

Field	Description
Veg_Type	Vegetation type for upland sampling methods (forest, woodland, oak)
EcoType	Predicted vegetation type based on sampling frame (Mixed conifer, PJ)
MasterStrat	Indicates groups for analyzing data
PlotID	The plot number, based on ascending order of the RQorder field, renumbered to give unique plot numbers for each point on the list.
panel	Panel that plot is associated with in the revisit design (1-5, panel=0 for rejected plots)
PanelYear	Year(s) that panel is sampled (1-5)
EvalStatus	Ultimate status of a plot (estab = established; NotEval = not visited; accept = visited and deemed to be acceptable as a monitoring site; reject = rejected)
S_Action	Status of plot determined in the field and recorded on GPS (accept or reject)
EvalReason	Describes why a site was accepted or rejected
Estab_Date	Month, day, and year of plot establishment
Soil_MU	Soil map unit from UT636 (Panguitch Soil Survey) associated with the monitoring plot
X	UTM E (NAD83, Zone 12)
Y	UTM N (NAD83, Zone 12)
Hike_km	Hiking distance to plot in kilometers
AreaDescr	General area of the park where the plot is located
Comments	Miscellaneous
RQorder	Sequence number produced by RRQRR that doesn't start at 1 or increment by 1 (=order_ in sample_pts shape files and =GRID_CODE in smpts shape files)
inc_prob	inclusion probability; 1 indicates equal probability of selection for all points from the sample_pts shape file

Survey Design

We decided that there was no need for pilot monitoring in BRCA because the number of monitoring plots is more limited by affordable effort than variability of vegetation. The affordable effort for BRCA is one pay period for a 6-person crew or approximately 18 monitoring plots per year.

Plots are sampled following a rotating-panel design (Figure 4) that samples 8 mixed conifer plots and 10 PJ plots each year. A total 20 mixed conifer plots and 25 PJ plots are sampled over 5 years. Plots are sampled 2 years in a row (in order to detect year-to-year differences due to temperature, precipitation, etc.) and rested for 3 years. Every 5 years, the sampling scheme repeats itself.

This design provides inference to all upland vegetation within the elevation zones sampled and allows us to investigate movement of species with climate change.

A. Mixed Conifer (Above 2600 m)

	Year									
panel	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

B. PJ (2300 m and below)

	Year									
panel	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

Figure 4. Number of mixed conifer (A) and PJ (B) plots sampled each year based on 5-year rotating panel revisit designs for long-term upland monitoring at Bryce Canyon National Park.

Response Design

The response design for BRCA is based on the NCPN upland monitoring protocol. Mixed conifer plots are sampled with forest methods, and PJ plots are sampled using woodland methods. Table 4 outlines specific measurements by vegetation type.

Table 4. Response design for vegetation monitored in Bryce Canyon National Park.

Method	Forest	Woodland
Transects	3 – 50 m transects	3 – 50 m transects
Plot establishment	Rebar at transect ends, plot side slopes, optional witness trees	Rebar at transect ends, plot side slopes, optional witness trees
Photos	Transect origin & end	Transect origin & end, BSCs
Point-intercept	0.5 m intervals (hits below monopod only)	0.5 m intervals
Soil stability		X
1-m belt (density of shrubs and seedlings, exotic frequency)	X	X
5-m belt (sapling density)	X	X
Tree census	Quadrat 1 only, record crown health & crown class	Quadrat 1 only
Spherical densiometer	X	
Fuels	X	X
Site Impact	X	X

Literature Cited

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.

USDA NRCS. 1990. Soil Survey of Panguitch Area, Utah, Parts of Garfield, Iron, Kane and Piute Counties. Richfield, UT.