

U.S. Department of the Interior

National Park Service

Inventory and Monitoring Program

**Integrated Upland Monitoring Protocol for the Park Units in the
Northern Colorado Plateau Network**

Prepared by:

Dana Witwicki (Ecologist)¹
Steven L. Garman (Ecologist)²
Helen Thomas (Data Manager)¹
Rebecca Weissinger (Ecologist)¹
Aneth Wight (GIS - Cartographer)¹
Mark E. Miller (Ecologist)³

¹ Northern Colorado Plateau Network Inventory and Monitoring Program
P.O. Box 848, Bldg. 11, Arches National Park
Moab, UT 84532

² Previously with the Northern Colorado Plateau Network Inventory and Monitoring
Program

³ U.S. Geological Survey, Southwest Biological Science Center
190 E. Center St., Kanab, UT 84741

Prepared for:

Northern Colorado Plateau Network Inventory and Monitoring Program
National Park Service, U.S. Department of the Interior

Version 1.01 (September 2009) - DRAFT

Revision History Log:

Prev. Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	9/09	DLW	Add point-intercept, forest & oak methods, procedures for after field sampling at a park, update ecoregion figure	Update for change to point-intercept, forest, woodland, and oak methods	1.01

This protocol consists of this Protocol Narrative and the following Standard Operating Procedures (SOPs):

- SOP 1: Preparations and Equipment Setup Prior to the Field Season
- SOP 2: Training Observers
- SOP 3: Using the Global Positioning System
- SOP 4: Crust-Friendly Field Procedures
- SOP 5: Site Characterization
- SOP 6: Plot Establishment and Revisit Set-Up
- SOP 7: Repeat Photographs
- SOP 8: Measuring Vegetation and Surface Cover Using a Point-Intercept Transect
- SOP 9: Measuring Basal and Canopy Gaps Using Line-Intercept Sampling
- SOP 10: Measuring Shrub, Tree Seedling, and Exotic Perennial Density in a 1-m Belt Transect
- SOP 11: Soil Aggregate Stability
- SOP 12: Site Impact Assessment
- SOP 13: Measuring Overstory Trees
- SOP 14: Measuring Fuels
- SOP 15: Sampling Gambel Oak/Mixed Montane Shrub Plots
- SOP 16: Unknown Plants
- SOP 17: After the Field Season
- SOP 18: Data Management
- SOP 19: Data Analysis and Reporting
- SOP 20: Revising the Protocol
- SOP 21: Survey Design and Site Selection

Acknowledgements

Funding for this project was provided by the NPS Northern Colorado Plateau Inventory and Monitoring Network (NCPN), the NPS Southern Colorado Plateau Inventory and Monitoring Network (SCPN), and the US Geologic Survey-Biological Resources Discipline. Also, several standard operating procedures were derived from other monitoring protocols, and sources are acknowledged in the relevant SOP.

Preface

The NCPN and SCPN developed this protocol in consort with Drs. Mark Miller and Jayne Belnap (USGS- BRD, Moab, UT). The intent of this collaboration was to develop standard methods for use across the range of upland systems of the 16 NCPN and 19 SCPN park units and to provide comparable data over a large region of the Colorado Plateau and adjacent physiographic provinces. Although standard methods were developed for integrated upland monitoring in desert ecosystems, each network employs somewhat different methods for monitoring. For this reason and to facilitate efficient tracking of park-specific enhancements and sampling designs, each network has generated a separate operational protocol. This protocol is thus specific to the NCPN.

Table of Contents

I	Background and Objectives	6
	Issues being Addressed and Rationale for Monitoring Upland Ecosystems.....	6
	Biogeographic Scope.....	7
	Historical Development of Upland Monitoring in Northern Colorado Plateau Network Parks	9
	Measurable Objectives	10
II	Sampling Design	11
	Response Design	11
	<i>Grasslands and Shrublands</i>	11
	<i>Forests and Woodlands</i>	12
	<i>Gambel Oak/Mixed Montane Shrubs</i>	13
	Target Population & Spatial Design.....	14
	Sampling Objectives.....	15
	Revisit Design	16
	Recommended Timing of Sampling.....	16
	Rationale for Selecting This Sampling Design.....	17
III	Field Methods	17
	Field Season Preparations, Field Schedule, and Equipment Setup	17
	Conducting Monitoring	18
	<i>Grasslands and Shrublands</i>	18
	<i>Forests and Woodlands</i>	20
	<i>Gambel Oak/Mixed Montane Shrubs</i>	20
	After Monitoring is Completed at a Park Unit	21
	End-of-Season Procedures.....	21
IV	Data Management	21
	Overview of Database Design	21
	Data Entry, Verification, and Editing	22
	Metadata Procedures	22
	Data Archiving Procedures.....	22
	Procedures for Revising the Protocol	23
V	Analysis and Reporting	23
	Annual Summaries and Reports	23
	Variance Assessment and Report	24
	Status and Trend Assessment and Report.....	24
VI	Personnel Requirements and Training	26
	Roles and Responsibilities.....	26
	Qualifications	26
	Training Procedures.....	26
	Annual Workload and Field Schedule	27
VII	References	27

List of Tables

Table 1. Park units of the NCPN.	7
Table 2. Summary of historic and ongoing vegetation monitoring in NCPN park units.	9
Table 3. Plot-level measures for grasslands/shrublands, woodlands, forests, and oak scrub.	25

List of Figures

Figure 1. Parks and ecoregions of the NCPN	8
Figure 2. Standard macroplot and transect layout for upland monitoring.	11
Figure 3. Additional measurements for forest and woodland monitoring plots	12
Figure 4. Plot layout for Gamble oak scrub/mixed montane shrub plots.....	13
Figure 5. Outline of field procedures for monitoring upland sites.....	19

I Background and Objectives

Issues being Addressed and Rationale for Monitoring Upland Ecosystems

Uplands represent the vast majority of land area in national parks of the Colorado Plateau. Plateau uplands include rock outcrops, badlands, shrublands, grasslands, woodlands, and forests, with local vegetation determined by soil type and depth, topography, climate, and disturbance history. Upland vegetation supplies most regional primary productivity, which translates to energy for other trophic levels. The condition of upland vegetation influences soil stability, which, in turn, determines potential above-ground production of native plant species and the propensity for invasion by non-native species. Vegetation also provides habitat for various organisms. The ability of uplands to retain soil and nutrients, absorb and release water, and buffer high-runoff precipitation events also influences riparian conditions.

Upland ecosystems of the Colorado Plateau are characterized by low resistance and resilience. Even moderate disturbances can affect vegetative composition and structure, and recovery to pre-disturbance conditions is relatively slow. Grazing, which has been a traditional land use throughout much of the plateau, has resulted in shifts in vegetation composition (Harris et al. 2003) and ecological states (Miller 2005). Increasing recreational use and unauthorized social trailing threatens the integrity of upland systems through soil disturbance and resulting increases in soil erosion by water and wind. Global climate change is expected to change levels and seasonality of dominant precipitation events, with unknown implications for plateau systems.

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

- 1) *Plant communities*: species and functional group composition and cover, vegetation structure.
- 2) *Biological soil crust*: cover of cyanobacteria, lichen, moss, and undifferentiated crust.
- 3) *Hydrologic function*: basal-gap size, cover and development of BSC, infiltration rate.
- 4) *Soil stability*: soil aggregate stability, cover of vegetation, litter, and BSC.
- 5) *Nutrient cycling*: not yet measured.

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

Biogeographic Scope

Park units in the NCPN occur in four states (Fig. 1), and range in size from 16 to over 136,000 hectares (Table 1). While the Colorado Plateau forms the core of the NCPN, portions of several other ecoregions are also included (Fig. 1). Although vegetation is predominantly desert shrubland, grassland, and pinyon-juniper woodland, some parks have significant high elevation forests. Because of this diversity, the Integrated Upland Protocol includes standard operating procedures (SOPs) for grasslands/shrublands, woodlands, forests, and oak scrub.

Table 1. Park units of the NCPN.

Park	Park Code	State	Area (ha)
Arches National Park	ARCH	UT	30,966
Black Canyon of the Gunnison National Park	BLCA	CO	12,239
Bryce Canyon National Park	BRCA	UT	14,502
Canyonlands National Park	CANY	UT	136,610
Capitol Reef National Park	CARE	UT	97,895
Cedar Breaks National Monument	CEBR	UT	2,491
Colorado National Monument	COLM	CO	8,310
Curecanti National Recreation Area	CURE	CO	17,433
Dinosaur National Monument	DINO	CO/UT	85,097
Fossil Butte National Monument	FOBU	WY	3,318
Golden Spike National Historic Site	GOSP	UT	1,107
Hovenweep National Monument	HOVE	UT/CO	318
Natural Bridges National Monument	NABR	UT	3,009
Pipe Spring National Monument	PISP	AZ	16
Timpanogos Cave National Monument	TICA	UT	101
Zion National Park	ZION	UT	59,900

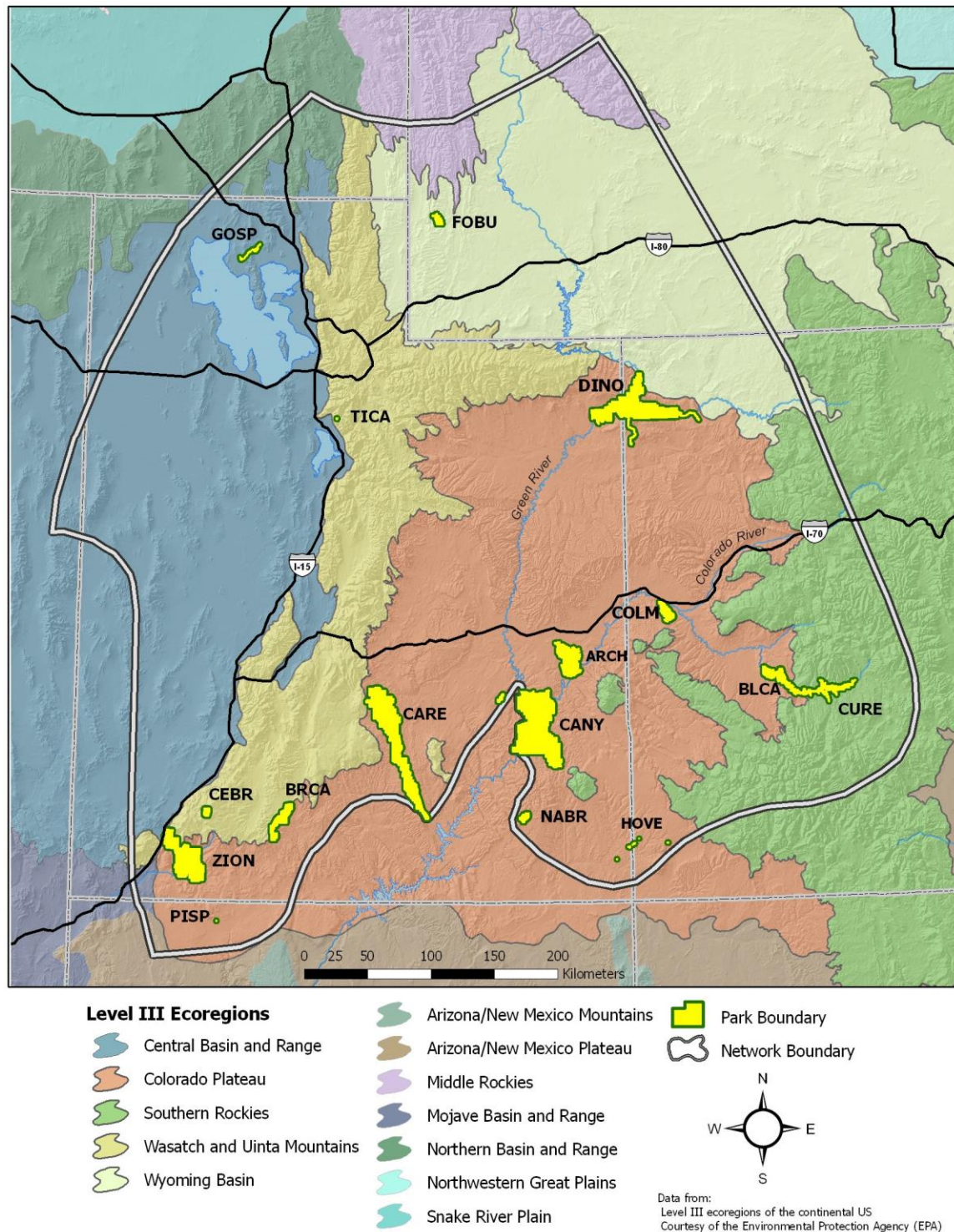


Figure 1. Parks and ecoregions of the NCPN.

Historical Development of Upland Monitoring in Northern Colorado Plateau Network Parks

Most NCPN parks have had some vegetation monitoring in their history, ranging from initial establishment of plots or photo points that have never been revisited to sites with over forty years of annually collected data. These efforts are summarized by type and duration in

Table 2. Three types of monitoring continue to occur: vegetation plots, photo points, and grazing trend studies. Plots are typically established to examine long-term trends in plant species cover and other attributes; some are specifically designed to monitor grazing. Photo points include the re-location of historic photographs (Webb et al. 2004) and the deliberate establishment of photo points for particular purposes. Grazing trend studies are conducted by land management agencies to monitor grazing on public grazing allotments including those on NPS lands. These typically consist of point-intercept (“step-point”) transects and photo plots.

Table 2. Summary of historic and ongoing vegetation monitoring in NCPN park units.

Park	Long-term vegetation plots	Photo plots (not grazing related)	Grazing trend plots	Other	Any ongoing?
ARCH	1 (1987)	3 (1990)		Fire effects	Y
BLCA	1 (1992)	3 (1990)			Y
BRCA	1 (1957)	3 (1990)		Fire effects	Y
CANY	1 (1987)	2 (1872)		Grazed/relict comparison; bunchgrass post-grazing	Y
CARE			1 (early 1960s)		Y
CEBR		3 (1990)			
COLM		3 (1990)			
CURE	1 (1992)	3 (1990)			Y
DINO			1 (1961)	Fire effects	Y
FOBU	2 (1977)	1 (1985)			Y
GOSP					
HOVE	1 (1999)				Y
NABR	1 (1987)			Grazed/relict comparison	Y
PISP					
TICA					
ZION	3 (1997)			Fire effects	Y

1 = More than three years of data (beginning year)

2 = Two to three years of data

3 = Plots established but not re-visited

Plant monitoring data, in the form of photographs, can be said to occur from as long ago as 1872. The historic photographic record for part of CANY is examined in detail by Webb et al. (2004). The most extensive vegetation plot monitoring in the NCPN currently occurs in the southeast Utah group of parks (SEUG). Plot-based vegetation monitoring began in SEUG parks as long ago as 1974, but the oldest studies lack permanently marked plots and available data. Various other vegetation monitoring efforts have occurred, primarily for targeted (sensitive or endangered) species. For a more detailed description of all NCPN vegetation monitoring efforts see Evenden et al. (2002, Volume 2, part III).

The stated monitoring objective of SEUG vegetation monitoring program is to “monitor condition and trend of the various vegetation types” [in each park]. All four SEUG parks have ongoing vegetation monitoring sites established over the past 22 years. The number of sites and length of data collection varies by park. Some ARCH, CANY, and NABR sites have been visited almost every year since 1985, while the first HOVE sites were not established until 1999.

Standard methods are used at the SEUG parks: sites were chosen to be representative of particular vegetation types and measurements are recorded in 50, 0.5 m x 0.5 m subplots (quadrats) on two more or less parallel transects per site. Measurements include nested frequency, ground cover (bare ground, litter, rock, lichen, moss, cyanobacteria, and *Collema* species), cover of each vascular plant species, and cover and development class of biological soil crust. Cover is estimated in 6 size classes. Sites are re-measured annually. There have been some methods changes over the duration of this program, most notably the introduction of permanent markers for each subplot beginning in 1997. This work is well documented in reports produced by Schelz (2002a-d).

Vegetation monitoring in Black Canyon of the Gunnison and Curecanti National Recreation Area has occurred since 1992. This monitoring consists of 0.5 x 0.5-m quadrats located every 5-m along five 100-m transects within each of 10 habitat types. Although monitoring has not occurred every year, this data set begins to allow evaluation of trends in measures of percent cover by species or lifeform. A review of this monitoring effort is provided in Garman (2007).

Measurable Objectives

For selected ecological sites in NCPN parks:

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

II Sampling Design

Sampling design for long-term monitoring incorporates efficient approaches to gathering data such that is credible and sufficient to achieve monitoring objectives. Requirements include specifying: what data are collected by what methods (response design); populations of interest and sampling locations (spatial design); and timing and frequency of measurements (revisit design).

Response Design

Grasslands and Shrublands

Measurements are based largely on rangeland assessment procedures (Herrick et al. 2004). The location of a sample unit (or site) is randomly selected using procedures described below. At each site, observations are recorded along three parallel, 50-m transects spaced 25 m apart (Fig. 2). End locations of transects are permanently marked with rebar. A point-intercept method is used to record percent cover of understory and ground-cover attributes at 0.5 m intervals along each transect. Density of shrubs, tree seedlings, and exotic perennials is recorded by species in a 1-m belt upslope of each transect. Canopy and basal-gap measures are acquired along each of the transects using a line-intercept method. Six surface-soil samples are taken along each of the transects to assess soil-aggregate stability. Soil-assay procedures are included in the integrated upland monitoring protocol, but have not been implemented due to costs and other factors. All measures recorded along transects are sub-samples scaled to the plot level. The plot-level measures are the primary values used in summaries and statistical analyses. Observations of disturbances on and around the site are also recorded.

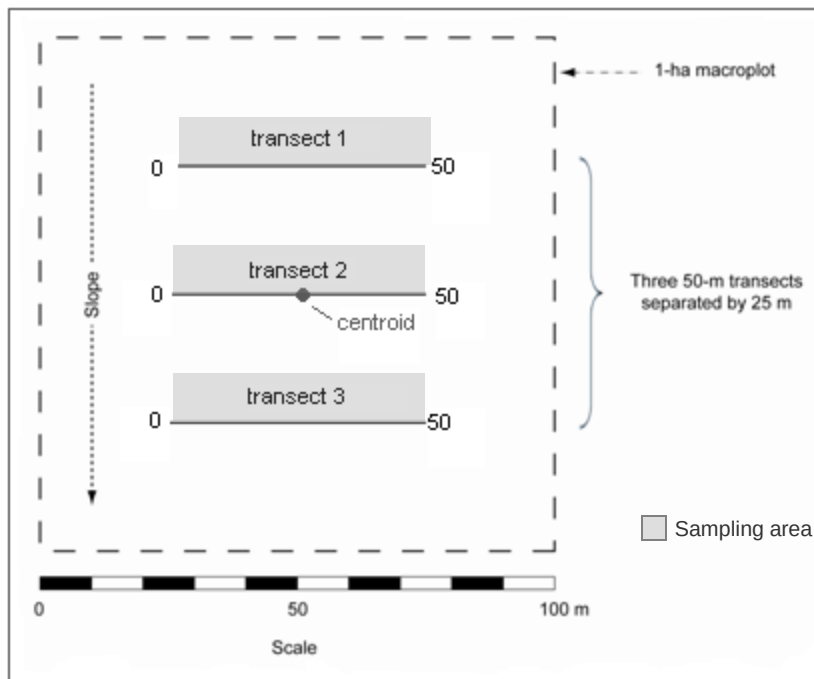


Figure 2. Standard macroplot and transect layout for upland monitoring.

Forests and Woodlands

Additional measurements are taken in forest and woodland systems in order to capture the dynamics of stand replacement or gap dynamics. Saplings are identified to species, and density is tallied in a 5-m belt transect centered on transect 2 (Fig. 3). Within Quadrant 1 (Fig. 3), species and dbh (diameter at breast height) are recorded for all mature trees. For forest plots, overstory cover is recorded along each transect using a concave spherical densiometer. Fuels are measured using Brown's planar method (Brown 1974) along four 15-m transects which extend beyond the plot on two corners (Fig. 3). Gaps are not recorded in forest or woodland systems, but soil stability measurements may be recorded for woodland ecological sites with potential erosion issues.

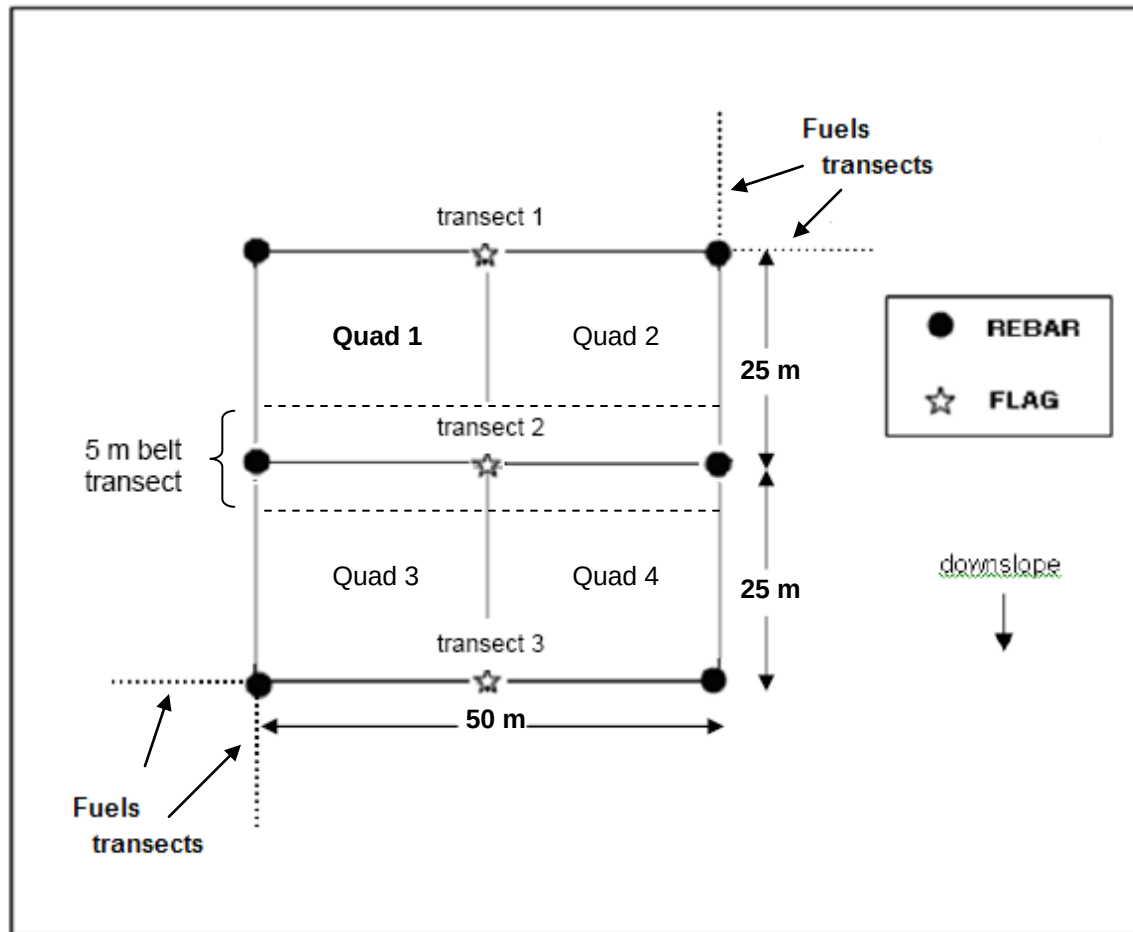


Figure 3. Additional measurements for forest and woodland monitoring plots, showing the 5-m belt transect for measuring saplings, Quad 1 for measuring overstory trees, and the fuel transects (not drawn to scale).

Gambel Oak/Mixed Montane Shrubs

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

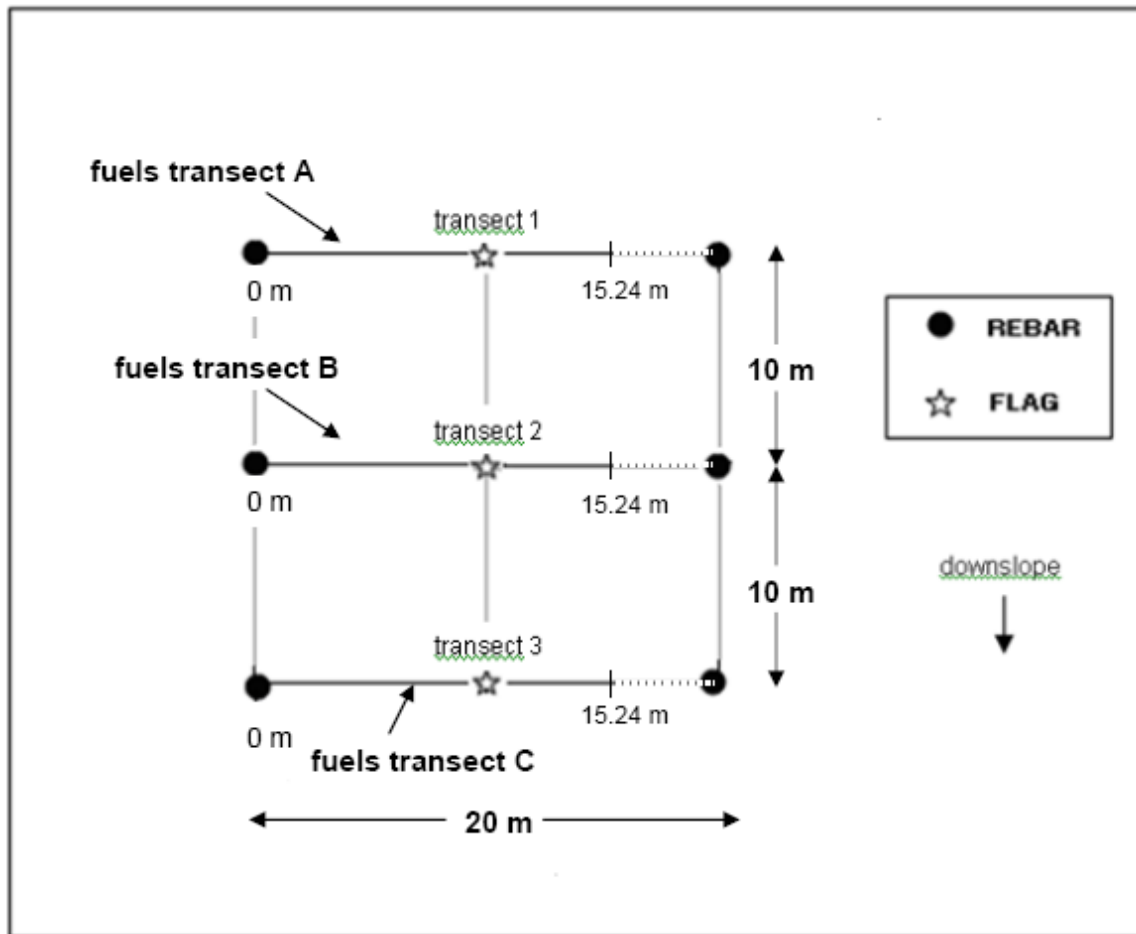


Figure 4. Plot layout for Gamble oak scrub/mixed montane shrub plots.

Target Population & Spatial Design

NCPN uses survey designs for upland monitoring. Survey designs have fewer assumptions and provide more reliable and legally defensible parameter estimates than other approaches, such as those designed to sample from infinite populations (Schreuder et al. 2004, Edwards 1998, Neusser et al. 1998, Cochran 1977). A central tenet of survey designs is the delineation of a finite target population, which defines the limit of statistical inference and serves as the basis for selecting samples. Additionally, every sample has a known probability of being selected. This probability equates to a weight that indicates the degree of influence of a sample's observations when making inference to the target population.

Guidelines for determining the target population and the spatial design of a monitoring effort are outlined in SOP #22. Methods will vary among NCPN park units according to park-specific needs and issues, and specifics are documented in a separate report for each park unit. There are eight basic procedures used to identify the target populations and the spatial design which are common to all park units:

- The upland issues of special long-term management concern or interest are identified through focused discussion between NCPN I&M staff and park staff. Examples include impact of grazing allotments, social-trailing effects in grasslands and shrublands, grassland-fire-herbivory interactions, general health/condition of dominant ecosystems, etc. Determining key issues is paramount given the limitation to effectively monitor all upland area within a park unit. The basic procedures for monitoring the integrated upland vital signs are constant among park units, but the emphasis of monitoring is allowed to vary to accommodate unique issues. Areas, habitats, or community types associated with the topical issues are identified and mapped as the target areas.
- Target areas are translated to ecological sites by cross-walking with National Resources Conservation Service (NRCS) ecological site descriptions (SRM 1989, 1995). This involves overlaying NRCS soil map units on the target areas and delineating ecological sites associated with target areas. The National Vegetation Classification System (NVCS) formation type of ecological sites is first used to match ecological sites with target areas. Ecological sites are further evaluated on the basis of vegetative and other attributes relative to target areas. This results in a list of possible ecological sites for monitoring consideration.
- The most dominant ecological sites associated with target upland areas are determined. Estimates of sample-size needs per ecological site are used to determine the maximum number of ecological sites which can be effectively monitored. This determines the target ecological sites for further consideration.

- Accessible area of a park unit is derived on the basis of slope using NCPN-created analytical software (Landscape Access Model [LAM], Garman unpublished). NRCS soil map units used in subsequent steps are clipped to the accessible area.
- Field evaluation of soil map units, ecological sites, and target upland areas is conducted to ensure appropriate selection of ecological sites.
- Ecological sites are not explicitly mapped by NRCS, but instead are listed as components of map units. Thus, multiple ecological sites can be contained within a soil map unit, with only some being target types. Also, ‘inclusions’ can occur within a soil map unit (e.g., rock outcropping). Explicit mapping of ecological sites is performed using various methods developed by the NCPN (Garman et al. in review). Methods range from spatial-pattern analyses using Feature Analyst (VSL 2002) to Classification and Regression Trees (Scull et al. 2005). The method of choice is highly dependent on the type and quality of relevant spatial data layers. The end product of this step is a map delineating the spatial extent of each target ecological site or groups of similar ecological site types.
- Ecological site maps serve as the sampling frame from which monitoring sites are selected. NCPN uses the GRTS (Generalized Random Tessellation Stratified) or RRQRR (Reversed Randomized Quadrat-Recursive Raster) method for site selection. These methods ensure a spatially-balanced design, and allow for site rejection and site additions over time (Stevens and Olsen 2004, Theobald et al. 2007).
- Sites are assigned a plot identification number (PlotID) and are visited in ascending order. There will always be selected sites that are inappropriate due to fine-scale anomalies presenting safety hazards, incorrect ecological site mapping, and other factors. When inappropriate sites are determined, they are rejected, and the next sequential site is considered. This process is continued until the target number of sites has been established. Oversampling of the initial GRTS or RRQRR site selection ensures a sufficient number of sites to accommodate site rejection.

Sampling Objectives

A sampling objective relates to the precision of a sampling effort. Specifically, it indicates the minimum detectable change per unit time over a time period, the acceptable level of error (Type I), and the probability to detect a change (Power). Determining the minimum detectable change level hinges on various factors, which for the most part are difficult to determine. Where monitoring is motivated to inform management of resource degradation, the minimum detectable change level must be sufficient to pick-up a rate of decline (or increase) that allows the detection of a management trigger or management assessment point. This assessment point is where management has sufficient time to begin to make decisions regarding a change in a resource. Decisions may include further investigation to fully evaluate reasons for observed changes, modification of monitoring

designs to better capture finer-scale trends, or immediate design and implementation of remediation measures. Early warning assessments points must be designated well above the point at which further decline will result in a substantive change in ecosystem or population conditions. Underlying this logic is the potential for systems to cross ecological thresholds which result in highly altered conditions that are effectively not amenable to restoration, or restoration to the native system becomes extremely costly. In practice, thresholds are poorly known and difficult to estimate. For the most part, management triggers tend to be based on a combination of hypothesized threshold levels, intuition, and a conservative perspective. Identifying threshold levels and factors that lead to crossing an ecological threshold are critical research needs, especially in arid and semi-arid ecosystems of the U.S. (e.g., Bestelmeyer 2006, Briske et al. 2006, Peters et al. 2006).

Sampling objectives of upland monitoring are determined by the specific issues being addressed and the level of understanding of thresholds and desired management triggers. Two key procedures are used to estimate sampling objectives. First, the current status of key indicators is determined from available field data, such as from vegetation mapping or remotely-sensed shrub or grass cover. Second, estimates of change are derived on the basis of current status and estimates of management triggers. The latter is supported by literature reviews, where possible. Where necessary, a default of 26-40% change over a 10-yr period (3-5% change/year) serves as an initial range. In the context of adaptive monitoring, this sampling objective will be modified as understanding of system dynamics increases. The inherent variability of vital signs in concert with the sampling objective determines the required number of sampling locations and the re-visit design.

Revisit Design

Establishment of monitoring sites typically occurs in two phases: pilot and full operational. For pilot monitoring, up to 10 permanent monitoring sites will be established per ecological site and revisited each year for three years. The pilot phase is designed to acquire measures of variance used to evaluate a survey designs ability to achieve the sampling objective. The three-year, 10-plot design is based on simulation experimentation that has shown the utility of variance estimates for evaluating survey designs. After potential survey designs have been evaluated using pilot data, a full operational monitoring design is developed for each ecological site in each park unit.

Survey designs will vary according to variance estimates and sampling objectives, however, complex survey designs with multiple panels and varying frequency of visitation will likely be used. Power analyses have shown the importance of distributing sampling plots over space. Designs will balance the need for observing inter-annual variability with maximizing replication (Woodward 2004).

Recommended Timing of Sampling

The overall monitoring period extends from mid-April to mid-October. The temporal window is tailored for specific park units and areas within parks on the basis of elevation

and phenology. Re-visits over time will be confined to within 1 month of the plot establishment date, where possible. Backcountry access issues due to weather and other factors, however, will dictate re-visit times.

Differences among years in precipitation patterns and temperature regimes will influence the growth period of all species, especially annuals. Confining re-measurement times to within 1 month of plot establishment time provides only a limited amount of control over variability. Trend and status estimates of woody vegetation are least likely affected by seasonality of re-measurement, especially over a long time frame. Trend and status variance associated with cover of herbaceous vegetation, and annuals in particular, are expected to be somewhat higher due to increased sensitivity to seasonal weather patterns.

Rationale for Selecting This Sampling Design

The proposed design attempts to efficiently monitor change in selected areas of specific parks within the network. It is directly linked to management needs by focusing on key resources. The GRTS and RRQRR methods of plot selection incorporate flexibility because they allow for future adjustment of plot numbers and selection probabilities. These methods produce a spatially-balanced sample which well-represents the area of interest, incorporates probabilistic sampling to meet statistical assumptions, and allows the flexibility to modify replication at a later time.

We based the methods of our response design on *The Monitoring Manual for Grassland, Shrubland and Savannah Ecosystems* (Herrick et al. 2004), a study comparing field sampling methods (Miller et al. 2007), and standard forest, woodland, and fuels procedures in the National Park Service's *Fire Monitoring Handbook* (USDI 2003, Brown 1974). After two years of testing, modifications were made to the original field procedures including the addition of point-intercept sampling of vegetation and surface cover (SOP #8) and shrub density in 1-m belts (SOP #10). The original protocol used 10-m² quadrats to measure shrub density and ocular cover of vegetation and surface features. This change was made to increase sampling efficiency and improve repeatability of cover measurements. The 1-m belt transects were added as an efficient way to perform density counts. Plots that were monitored using quadrat-based methods in 2006 and 2007 were monitored using both old and new methods in 2008 in order develop a conversion factor between the methods.

III Field Methods

Field Season Preparations, Field Schedule, and Equipment Setup

The project manager is responsible for ensuring that preparations are made for the ensuing field season (SOP #1). This requires the project manager or field coordinator to acquire lists of plots to be established or re-visited. The UTM coordinates of plots should be uploaded to GPS units. Sampling dates should be scheduled and logistics organized

prior to the start of the field season. Logistics include scheduling camping or park housing and acquiring back-country permits. Field work is typically conducted in eight-day hitches including a travel day on each end.

At least ten weeks prior to commencing field work, initiate a research permit request for each park to be visited. Additional contact should be made about two weeks before each visit to confirm logistics arrangements and to make sure the appropriate park staff know where we will be working. A sufficient number of data sheets, park-level species lists, ecological site descriptions (for plot establishment), maps, and directions to plots should be generated for the field season. Equipment listed in SOP #1 should be assembled or ordered to ensure availability by the beginning of the field season.

Prior to entering the field, crew members must review the entire protocol, especially the SOPs, and participate in a training session. The project manager must ensure that crew members understand all procedures and evaluate their understanding during the required training (SOP #2). Training involves GPS procedures for navigating to plots (SOP #3), plot layout and establishment (SOP #6), and all sampling procedures.

Conducting Monitoring

Plots must be established in the order provided. Revisits to established plots may occur in whatever order the project manager determines.

Details of taking measurements, with example field data sheets, are documented in the individual SOPs. Figure 5 outlines the procedures followed at a monitoring site on each visit. After navigating to the plot center, the site is characterized (SOP #5) to determine whether or not it meets criteria for establishing a permanent plot. Site characterization involves describing the soil and ecological site attributes of the one hectare area around the plot center. Soil texture, depth, landscape position, elevation, and dominant vegetation are components of site characterization. A specific suite of SOPs is then followed to establish a permanent plot and to record measures. The suite of SOP's used depends on whether the monitoring site is a grassland/shrubland, forest/woodland, or Gambel oak/mixed montane shrub system. When re-visiting any existing monitoring plot, a plot re-visit datasheet is used to record general observations of the plot (SOP #6). This form provides field crew with an opportunity to note qualitative information about site conditions which otherwise is not recorded in the site impact assessment (SOP #12).

Grasslands and Shrublands

Three permanent transects are established parallel to the slope contour by driving rebar stakes into the ground at the end points of each transect (SOP #6). Each rebar is tagged with the plot and transect number and transect origin or end notation. At the origin of each transect, a photograph is taken down the length of the transect toward the end point (SOP #7). Photos of biological soil crusts are also taken at a specified point along each transect.

To minimize impacts to vegetation and biological soil crusts, all measurements are taken on one transect before visiting the others, and crew members remain downslope of the transect while taking measurements. Starting at the origin of each transect, a 50-m tape is stretched over the length of the transect. At 0.5-m intervals, a leveled laser is pointed at the ground and all vegetation that contacts the laser is recorded to species (SOP #8). Ground cover attributes are also recorded at each point. Shrub, tree seedling (<2.5cm dbh), and exotic perennial density are then recorded by species in a 1-m belt upslope of the transect (SOP #10). Shrubs are additionally recorded by five height classes. While traversing each transect, soil samples are gathered to measure soil aggregate stability (SOP #11).

Gap measures are recorded while traversing the transect (SOP #9). Canopy gaps are measured by recording each segment (to the nearest cm) as canopy (shrub or other) or gap (must be at least 20 cm). Basal gaps are recorded similarly working from the 50-m end back to the origin and recording each segment (≥ 20 cm) that lacks any plant base.

While traversing each transect, on and off site disturbances are noted (SOP #12). These can include grazing, social trailing, and other significant disturbances with the potential to have an effect on soil and vegetation on the monitoring plot.

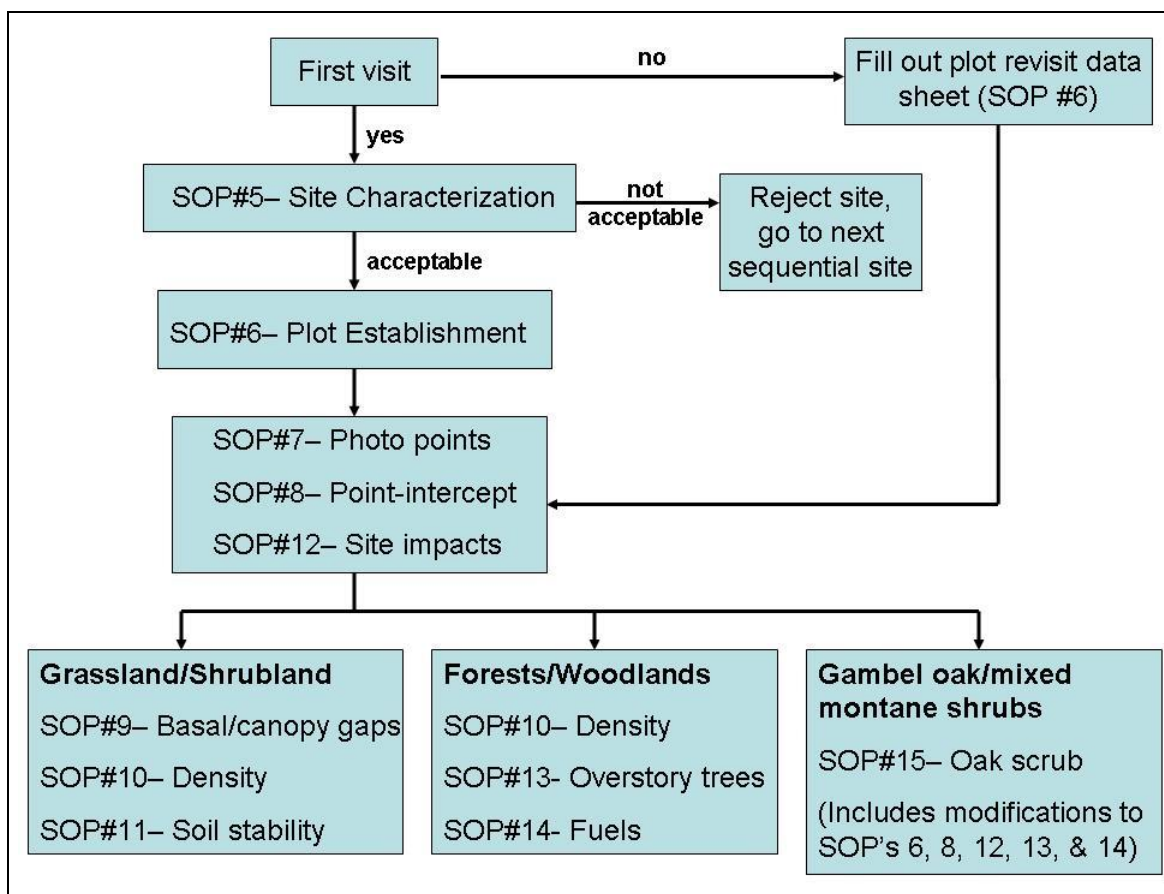


Figure 5. Outline of field procedures for monitoring upland sites.

Forests and Woodlands

Three permanent transects are established and monumented using the same methods as grasslands/shrublands (SOP #6). Additionally, trees may be tagged to assist in relocating transect ends. Photos are taken at the origin and end of each transect (SOP #7).

As before, all measures are taken on one transect at a time and trampling should be restricted to downslope of each transect. Using the same methods as for grasslands/shrublands, point-intercept cover of vegetation and surface features (SOP #8) and density of shrubs, tree seedlings, and exotic perennials (SOP #10) are recorded for each transect. The following additional information is also recorded. While recording point-intercept in forest plots, overstory cover is measured every 10 m along the transects (SOP #10). In a 5-m belt centered on transect 2, saplings (2.5-15 cm dbh) are identified to species and tallied by dbh class (SOP #13). After transect measures are completed, all trees (>15 cm dbh) in Quadrant 1 are identified to species, tagged with unique numbers, and measured for dbh (SOP #13). Crown class and health of trees are also recorded. Soil stability (SOP #11) may be recorded for woodland sites with potential for erosion.

Fuels are measured along four transects which originate at two corners and extend out from the plot (SOP #14). Depth of litter and duff, counts of fine woody fuels, and diameters of coarse woody fuels are recorded to derive characteristics of each fuel class. Since these measures are recorded outside of the area where other measures are obtained, they can be acquired without regard to the sequence of the other measures.

Using the same methods as for grasslands/shrublands, disturbances on and off the monitoring plot are recorded (SOP #12).

Gambel Oak/Mixed Montane Shrubs

Gambel oak/mixed montane shrub plots are established and recorded using modified procedures (SOP #15). Three 20-m transects are established and monumented, and photos are taken at the origin and end of each transect.

Like the other vegetation types, all measures are taken on one transect at a time and trampling is restricted to the downslope side of each transect. Along each transect, point-intercept is collected at 0.25-m intervals as you move down the transect, and shrubs are recorded by species using a line-intercept method as you move back towards the transect origin. Fuel measurements are recorded along the same 20-m transects because transect setup is particularly difficult in this system. Trees with dbh >15 cm and *Quercus gambelii* with dbh >10 cm are tagged with a unique number, and species and dbh are recorded.

Disturbances on and off the monitoring plot are recorded using the same methods as the other vegetation types, and additional conditions of the oak are recorded.

After Monitoring is Completed at a Park Unit

Once field sampling has been completed at each park unit, the project manager updates park staff on the progress of monitoring for the year. This update is either an informal meeting or an email detailing accomplishments for the season and projected timelines for reports. Any major concerns should be brought to the immediate attention of the Chief of Resources at this time.

End-of-Season Procedures

At the end of the field season, the project manager or field coordinator should ensure final completeness of all data sheets while field crew members are still available to clarify any ambiguities. After this, all paper data must be entered into the Integrated Upland Database and entries must be verified. The Data Management SOP (#18) provides explicit instructions for data entry and verification. In addition to traditional measurement data, the photos taken on each plot must be entered into the NCPN photo database.

While all crew members are still available, the project manager should complete a Protocol Review, which entails asking crew members specific questions regarding the clarity and efficiency of all procedures. Additionally, general feedback regarding procedures should be acquired. A Protocol Review form is completed by the project manager and stored with the protocol.

The equipment list should be updated with the number of equipment items that are functional and available for the next field season. This updated list should be compared to perceived needs of the next season, and supplies should be replenished as necessary.

IV Data Management

Goals of data management include accurately recording data in the field, assuring its quality, maintaining access in perpetuity, and thoroughly documenting data to ensure future usability. Effective long-term monitoring requires procedures for good data management. The NCPN has developed data management plans (Beer et al. 2005) that describe such procedures in general terms. The following outlines the application of those procedures to upland monitoring.

Overview of Database Design

Upland monitoring data are entered into a database designed to accommodate all data on the various field forms (SOP #18). The database conforms to Natural Resource Database Template standards established by the Inventory and Monitoring Program. The database accommodates data collected during plot establishment and re-measurement from all

parks in the network. The database provides numerous forms for plot measurements organized largely by SOP.

Field staff participating in monitoring uplands maintain this database and provide 1) an end-of-season copy of the verified and validated database and 2) electronic versions of any related images to the NCPN Data Manager.

Data Entry, Verification, and Editing

The project manager makes certain that persons performing data entry understand how to use the database and follow the protocols. Quality control routines are built into the database to the maximum extent possible so that validation of certain data fields will occur at the time of data entry.

Data will be recorded by field crews either on paper forms or directly into field laptops; spatial data for each site will be recorded on GPS units. For field measurements, one crew member will make the measurement while the other verifies it by repeating back and then recording the value.

The primary goal of data entry is to transcribe the data from paper records into the computer with 100% accuracy. Data verification occurs after data entry, when records in the database are compared to the original paper data sheets and errors corrected immediately. While some data validation routines are automated to detect logic or range errors, a project specialist is also responsible for reviewing the data for content or context errors.

Metadata Procedures

Each table, field, query, form, and report in the database is defined and documented (see SOP #18). In addition, information on data manipulations and the status of data verification and validation is recorded by the users in a data management log.

Data Archiving Procedures

Digital data are archived in their native database format at the end of each field season after all data have been entered, verified, and validated. A complete copy of the database in its native database format is also archived whenever the database version changes. These version archives are supplemented by a platform-independent copy of the database files in ASCII format, which is created using the Database Export utility developed and provided by NCPN (<http://science.nature.nps.gov/im/units/ncpn/Tools.cfm>). All archived files are designated as read-only.

All files, both active and archival, are required to be stored on a secure server or hard disk with regular backup routines that include an off-site storage rotation. CDs or DVDs are not considered acceptable for long-term archiving because of the potential for media failure.

Field forms and photographic prints or slides are irreplaceable resources that must be managed so that their quality and integrity are maintained long-term. Copies of these materials are used for project binders that are regularly used or referenced, while originals are accessioned into park archives for permanent storage and care.

Procedures for Revising the Protocol

Over time, revisions to the protocol narrative and to SOPs are to be expected. Careful documentation of changes to the protocol and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate treatment of the data during data summary and analysis. The Microsoft Access® database for each monitoring component contains a field that identifies which version of the protocol was being used when the data were collected.

Steps for changing the protocol narrative and SOPs are outlined in SOP #20. Each SOP contains a revision history log that is filled out each time a SOP is revised to explain reasons for changes and to assign a new version number to the revised SOP. The new version of the SOP and protocol narrative is archived in the NCPN protocol library under the appropriate folder.

V Analysis and Reporting

Three general types of analyses are performed: annual summaries of the most recent monitoring observations, variance estimation of the overall sampling design, and status and trend assessments (SOP #19).

Annual Summaries and Reports

Annual summaries report the number of monitoring plots visited and a summary of the field measurements recorded in a given field season. Data for the annual summary are plot-level measures derived from the numerous sub-samples collected on a plot. The possible plot-level measures for grassland/shrubland, woodland, forest, and oak scrub systems are listed in Table 3. A recommended approach for summarizing is to derive and report the average, minimum, and maximum value for each plot-level measure on the basis of ecological site. Of special interest is the cover of exotic and Threatened and Endangered (T&E) species. Although annual summaries are not intended to provide status and trend information, the magnitude of exotics and T&E species across the plots each year may be of immediate interest to park management. The annual report contains annual summaries as well as an overview of any necessary changes to protocol procedures, and proposed future monitoring efforts. An annual report is generated separately for each park unit with upland monitoring each year that the park is visited.

Variance Assessment and Report

The ability of a sampling design to satisfy the sampling objective must be evaluated over the course of monitoring. After 3 years of pilot monitoring at a park, variance is used to evaluate the statistical power of alternative revisit designs to satisfy the sampling objective. The optimal sampling design is selected, and full operational monitoring is implemented according to this design. Results of the variance assessment are summarized in a separate report for each park. The initial 3-year pilot monitoring may be skipped for some smaller parks where the number of plots are limited by the size of the park or ecosystem of interest within the park, or if an estimate of variance can be obtained from another park with a very similar ecosystem (e.g. CANY for ARCH). Sampling designs should then be evaluated at least every 5 years. Results of these variance assessments are presented in the status and trend report or as part of the annual report after 5 years of data collection.

Status and Trend Assessment and Report

The evaluation of status and trends of upland attributes is a detailed assessment and interpretation of the monitoring data. This assessment uses a mixed-effects ANOVA model to evaluate a trend being different from zero. Status estimation hinges on the outcome of the trend assessment since a significant trend line is used to derive the status. Otherwise, status is simply the average of all observations over time. Additionally, the use of other monitoring data is useful to aid in interpreting trends observed in upland monitoring data. These data may include climate, air quality, land use, and land condition. Comparison of trend results for these ancillary data with trend assessments of upland attributes may be sufficient to account for the observed trends. Moreover, monitoring data of other vital signs may be incorporated directly into the statistical analysis of upland data. The intended outcome of this assessment is the indication of whether a trend in a monitored attribute is occurring, the magnitude of the trend, and possible reasons for the trend evidenced by the temporal patterns of other vital signs. Where significant trends are detected, park management should be alerted. The detailed assessment should start after 5 years of data and continue possibly every year thereafter, at least every 5 years. The assessment periodicity after 5 years will depend on the occurrence of trends or the degree to which a resource attribute is believed to be changing. The detailed assessment is reported in the status and trend report, which includes methods, analyses, results, and discussion of the findings. A detailed assessment report is generated separately for each park unit with upland monitoring.

Table 3. Plot-level measures for grasslands/shrublands, woodlands, forests, and oak scrub.

Measure	Attribute or Context	Spatial scale(s) of observation	Grassland / Shrubland	Woodland	Forest	Oak scrub
Plant species richness	Number of species detected	point intercept for understory, 1-m belt transects for shrubs & tree seedlings, 5-m belt transect for saplings, ¼ plot for trees	x	x	x	x
Percent cover	Life form (trees, shrubs, annual and perennial grasses, forbs/herbs)	point-intercept along all three transects (150 m)	x	x	x	x
	Individual plant species	point-intercept along all three transects (150 m)	x	x	x	x
	Overstory canopy cover	15 point samples across plot			x	
	Surface features (undifferentiated crust, cyanobacteria, lichen, moss, bare soil, litter, woody debris, small and large rock, bedrock)	point-intercept along all three transects (150 m)	x	x	x	x
	Disturbance features (livestock and wildlife scat, ant mound, wildlife excavation, tracks from wildlife, livestock, humans, bicycles, or motor vehicles, other).	point-intercept along all three transects (150 m)	x	x	x	x
Density	Individual tree species and total tree density	Quadrant 1 for trees; one 5-m belt for saplings		x	x	
	Individual tree seedlings, shrubs, and exotic perennials by species; and total tree seedlings, shrubs, and exotic perennials combined by group	1-m belt transects upslope of all 3 transects	x	x	x	
Mean canopy gap size; distribution of canopy gap sizes	Line-intercept length of canopy gaps; percentage of transects with different gap size classes	Along all three transects (150 m)	x			
Mean basal gap size; distribution of basal gap sizes	Line-intercept length of gaps between plant bases; percentage of transects with different gap size classes	Along all three transects (150 m)	x			
Soil stability class (from all samples, protected areas, and unprotected areas)	Slake test stability class (1-6) Protected-area samples are collected under vegetation. Unprotected-area samples lack 'overstory' vegetation.	18 point samples across plot	x	x		
Fuel loading	woody fuel volumes; duff and litter depth	four ~15-m transects		x	x	x

VI Personnel Requirements and Training

Roles and Responsibilities

A high level of consistency is necessary for implementing the protocol. Therefore, the project manager is responsible for training the seasonal and permanent personnel assisting with the monitoring effort. The data management aspect of the monitoring effort is the shared responsibility of the project manager and the data manager. Typically, the project manager is responsible for data collection, data entry, data verification and validation, as well as data summary, analysis, and reporting. The data manager is responsible for data archiving, data security, dissemination, and database design. The data manager, in collaboration with the project manager, also develops data entry forms and other database features as part of quality assurance and automates report generation. The data manager is ultimately responsible for ensuring that adequate QA/QC procedures are built into the database management system and that appropriate data handling procedures are followed.

Qualifications

Field technicians need to have a high level of knowledge of plants of the Colorado Plateau and nearby regions and good botanical skills for identifying unknown species. This, along with attention to detail, is the single most important qualification. Many of the duties can be taught, but knowledge of the regional flora is acquired over several years of study. Additional qualifications are knowledge of basic soil science, experience taking vegetation monitoring measurements, familiarity with local environmental conditions and hazards (travel in remote backcountry, rough terrain, extreme heat, etc.), good physical fitness, familiarity with GPS units, and basic computer data entry. Observers should also have good organizational skills, memory retention, and the ability to work methodically and consistently under difficult conditions.

Training Procedures

Training procedures are detailed in SOP #2. All participants in upland monitoring are required to participate in training prior to the beginning of each field season. All crew members must review the Integrated Upland Protocol narrative and SOPs. Field crew leaders will provide training on navigation and recording data using a GPS, and field procedures for collecting monitoring data. Of special concern is the ability of crew members to correctly identify plant species. Herbarium specimens and comparative notes on difficult or uncommon species will be provided for field observers. Observers should be tested frequently on their ability to identify plant species, tailoring the testing for the more problematic species.

Annual Workload and Field Schedule

Field work will occur from about April 15 to October 15 each year, with field crews will typically working in teams of two for plot visits. Approximately three teams will work in the field each season, and each will need a dedicated vehicle and sampling equipment. An average field season might consist of ten hitches, each with two travel days and six field days. A rough estimate is that each 2-person crew will be able to visit 6-8 plots per hitch. This will vary with the park unit being monitored and the location of plots in a park unit relative to roads and trails.

VII References

- Beer, M., E. Nance, A. Wight, M. Powell, and R. DenBleyker. 2005. Northern Colorado Plateau Network, data management plan. National Park Service, Inventory and Monitoring program, Northern Colorado Plateau Network, Moab, UT.
- Bestelmeyer, B. T. 2006. Threshold concepts and their use in rangeland management and restoration: The good, the bad, and the insidious. *Restoration Ecology* 14: 325-329.
- Briske, D. D., S. D. Fuhlendorf, and F. E. Smeins. 2006. A unified framework for assessment and application of ecological thresholds. *Rangeland Ecology and Management* 59: 225-236.
- Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA Forest Service General Tech. Report INT-16, Intermountain Forest and Range Experiment Station, Ogden, UT.
- Cochran, W. G. 1977. Sampling techniques. John Wiley & Sons, N.Y. 428pp.
- Edwards, D. 1998. Issues and themes for natural resource trends and change detection. *Ecological Application* 8:323-325.
- Evenden, A., M. Miller, M. Beer, E. Nance, S. Daw, A. Wight, M. Estenson, and L. Cudlip. 2002. Northern Colorado Plateau Vital Signs Network and Prototype Cluster, Plan for Natural Resources Monitoring: Phase I Report, October 1, 2002. [Two volumes]. National Park Service, Northern Colorado Plateau Network, Moab, UT. 138 p. plus appendices.
- Garman, S. L. 2007. Review of Black Canyon of the Gunnison National Park/Curecanti National Recreation Area Vegetation and Bird Monitoring Programs. Northern Colorado Plateau Inventory and Monitoring Program, Biology Department, Mesa State College, Grand Junction, CO 81501.
- Garman, S. L., D. Witwicki, and A. Wight. *in review*. Mapping ecological sites for long-term monitoring in national parks. 9th Biennial Conference of Research on the Colorado Plateau, Flagstaff, AZ.

- 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*, v. 6, no. 4, p. 368–383.
- Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M. Burkett, and W.G. Whitford. 2004. *Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems*. Published as 2 volumes. Jornada Experimental Range, USDA 236 pp.
- 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., D. L. Witwicki, R. K. Mann, and N. J. Tancreto. 2007. Field evaluations of sampling methods for long-term monitoring of upland ecosystems on the Colorado Plateau. U.S. Geological Survey Open-File Report 2007-1243. <http://pubs.usgs.gov/of/2007/1243/>.
- Neusser, S. M., F. J. Breidt, and W. A. Fuller. 1998. Design and estimation for investigating the dynamics of natural resources. *Ecological Application* 8:234-245.
- O'Dell, T.E., S.L. Garman, A. Evenden, M. Beer, E. Nance, A. Wight, M. Powell, D. Perry, R. DenBleyker, *et al.* 2005. Northern Colorado Plateau Inventory and Monitoring Network, Vital Signs Monitoring Plan, National Park Service, Inventory and Monitoring Network, Moab, UT. 174 p. plus appendices.
- Peters, D. P. C., B. T. Bestelmeyer, J. E. Herrick, E. L. Fredrickson, H. C. Monger, and K. M. Havstad. 2006. Disentangling complex landscapes: New insights into arid and semiarid system dynamics. *BioScience* 56: 491-501.
- Schelz, C. 2002a. Vegetation long-term monitoring – Arches National Park 2002 Annual report. Southeast Utah Group, National Park Service, Moab, UT.
- Schelz, C. 2002b. Vegetation long-term monitoring – Canyonlands National Park 2002 Annual report. Southeast Utah Group, National Park Service, Moab, UT.
- Schelz, C. 2002c. Vegetation long-term monitoring – Hovenweep National Monument 2002 Annual report. Southeast Utah Group, National Park Service, Moab, UT.
- Schelz, C. 2002d. Vegetation long-term monitoring – Natural Bridges National Monument 2002 Annual report. Southeast Utah Group, National Park Service, Moab, UT.
- Schreuder, H. T., R. Ernst, and H. Ramirez-Maldonado. 2004. Statistical techniques for sampling and monitoring natural resources. USDA Forest Service, Rocky Mountain Research Stn., RMRS-GTR-126. 111pp.
- Scull, P., J. Franklin, and O. A. Chadwick. 2005. The application of classification tree analysis to soil type prediction in a desert landscape. *Ecological Modelling* 181:1-15.
- SRM (Society for Range Management). 1989. Glossary of terms used in range management. 3rd edition. Denver: Society for Range Management.
- . 1995. New concepts for assessment of rangeland condition. *Journal of Range Management* 48:271–282.

- Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99:262-278.
- 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.
- USDI National Park Service. 2003. *Fire Monitoring Handbook*. Boise (ID): Fire Management Program Center, National Interagency Fire Center, 274p.
- VSL (Visual Learning Systems). 2002. *User Manual, Feature Analyst Extension for ArcView 3.2*, Visual Learning Systems, Inc. Missoula, MT.
- Webb, R.H., Belnap, J., and Weisheit, J.S., 2004, *Cataract Canyon -- A human and environmental history of the rivers in Canyonlands*. Salt Lake City, University of Utah Press, 268 p.
- Woodward, A. 2004. *Temporal Sampling Frames: Summary of a Workshop*. USGS Forest & Rangeland Ecosystem Science Center Olympic Field Station, Park Avenue, Port Angeles, WA.