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

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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: Establishing and Marking Permanent Dryland Sample Sites
- SOP 7: Repeat Photography
- SOP 9: Measuring Basal and Canopy Gaps Using Line-Intercept Sampling
- SOP 11: Measuring soil aggregate stability
- SOP 12: Site Impact Assessment
- SOP 17: After the field season
- SOP 18: Data Management
- SOP 19: Data Analysis and Reporting
- SOP 20: Revising the Protocol
- SOP 21: Measuring Occurrence and Cover of Vegetation and Soil Surface Features, and Shrub Density Using 10-m² Quadrat-Based Sampling

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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. To date, standard methods for integrated upland monitoring in desert ecosystems have been developed. However, each network employs different methods for monitoring of forest and woodlands. 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.

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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 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 reduced standing biomass and shifts in ecological states (Noss et al. 1995). 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 upland-ecosystem characteristics, processes, vegetation and other biota, soil/site stability, hydrologic function, and biotic integrity as vital signs to be monitored. Indicators of soil stability include cover of vegetation, litter, and biological soil crust (BSC), and soil aggregate stability. Indicators of hydrologic function include basal-gap size, cover and development of BSC, and infiltration rate. Indicators of biotic integrity include species and functional-group composition and diversity, and vegetation structure. Additional upland vital signs include vegetation composition and structure, key communities, and BSC (O'Dell et al. 2005).

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 biogeographic provinces are also included (Fig. 1). Although vegetation is predominantly desert shrub land, 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 dryland systems and for forest & woodlands.

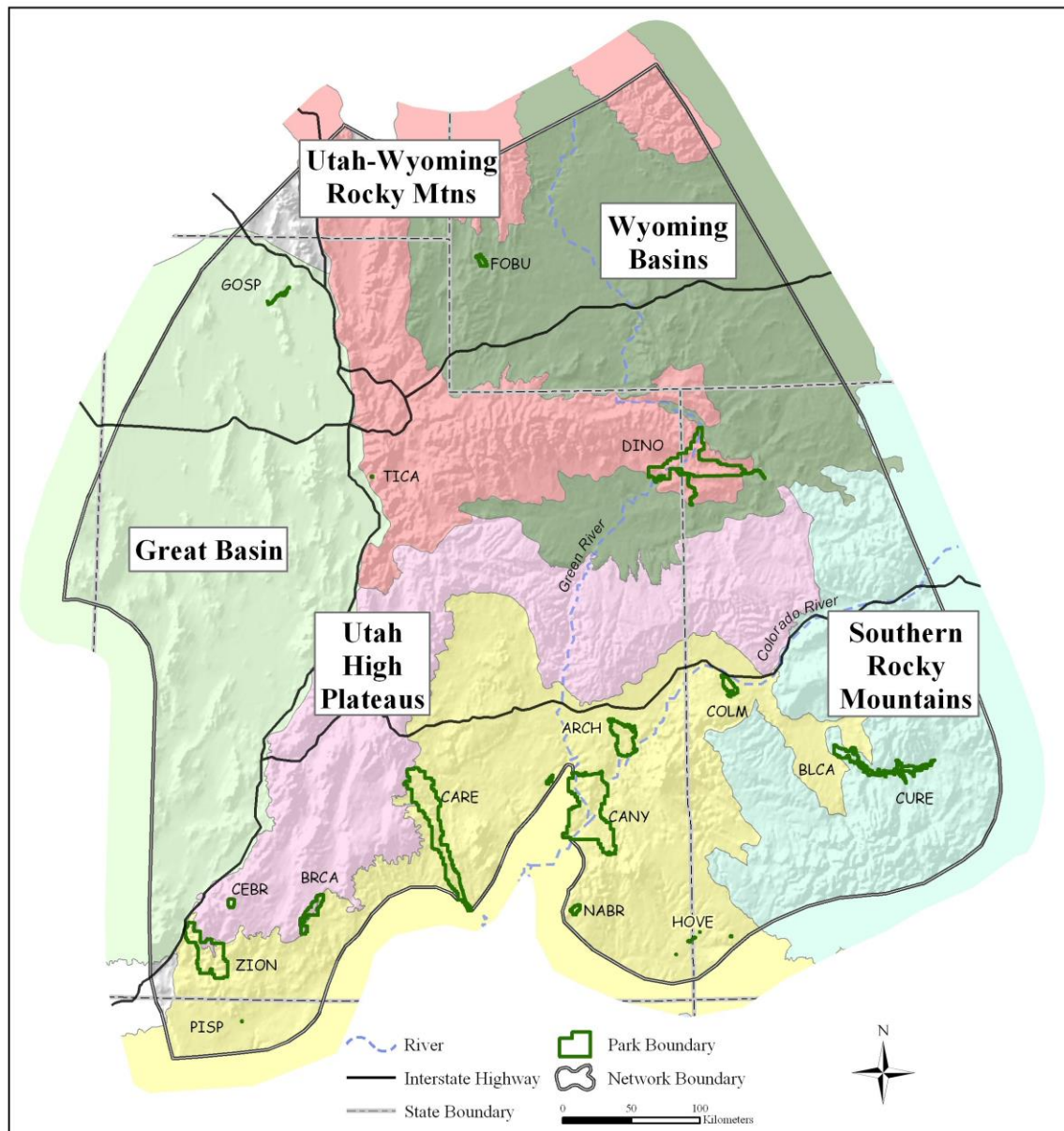


Figure 1. Parks and physiographic provinces of the NCPN.

Table 1. Park units of the NCPN.

Park	Park Code	State	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

Historical Development of Upland Monitoring in Northern Colorado Plateau Network Parks

Most NCPN parks have had some level of vegetation monitoring in their history. It ranges 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 in Table 2 as to type and duration. 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 plants 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; bunchgrasses 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 SEGU 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 x 0.5m 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*), cover of each vascular plant species and cover and development class of biological soil crust. Cover is estimated in 6 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); in live vegetation by life form; and in soil aggregate stability as an indicator of soil/site 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

Dryland Systems

Measurements are based largely on rangeland assessment procedures (Herrick et al. 2004), with modifications by Miller et al. (2007). The location of a sample unit (or site) is randomly selected using procedures described below. At each sample unit, observations are recorded along three parallel, 50-m transects, with an inter-transect spacing of 25 m (Fig. 2). Five 10-m² quadrats are located on the downhill side along each transect, with a 5-m spacing between quadrats (Fig. 3). End locations of transects, and corner locations of quadrats, are permanently marked with rebar and 8" nails, respectively. Within each 10-m² quadrat, three nested quadrats of 0.01, 0.1, and 1.0 m² in size are temporarily located (Fig. 4). Frequency of individual plant species and ground-cover attributes are recorded in the nested quadrats, and percent cover of species and features are recorded at the 1.0 or 10.0-m² scale. Canopy and basal-gap measures are acquired along each of the transects using line-intercept methods. Six surface-soil samples are taken along each of the transects, and combined 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 and in quadrats 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 sample unit are also recorded.

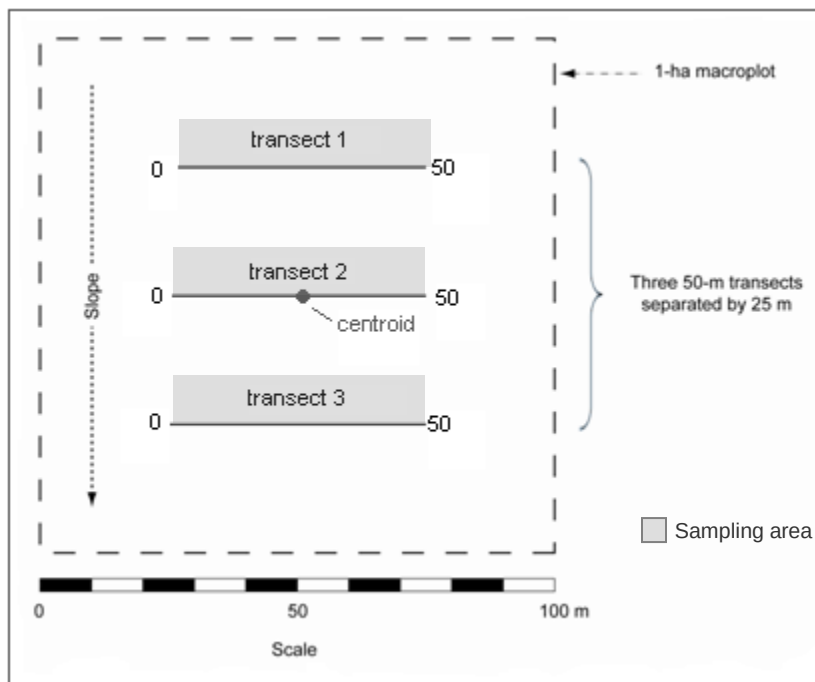


Figure 2. Standard macroplot and transect layout for terrestrial monitoring.

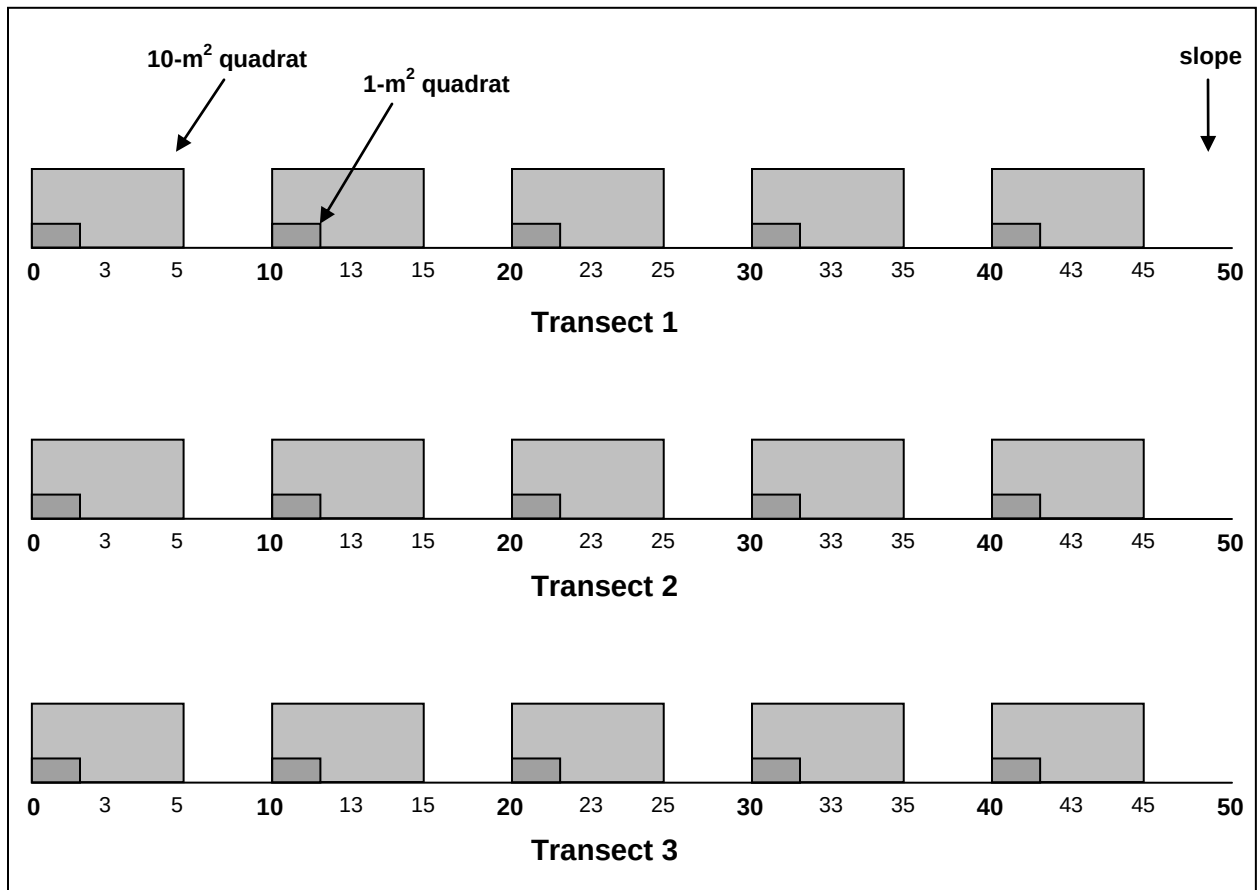


Figure 3. Quadrat placement along transects. Transects are not drawn to scale.

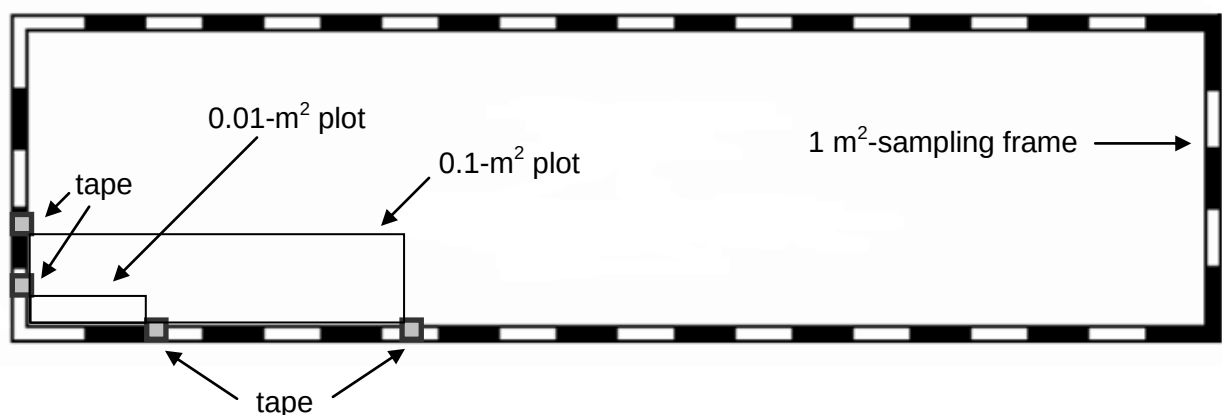


Figure 4. Alignment of nested frequency quadrats on the 1-m² sampling frame. Notice that the 0.01-m² and 0.1-m² quadrats are defined by the inside edge of the 1-m² sampling frame.

Forest and Woodland Systems

Procedures for these systems were adopted from the Shenandoah National Park long-term monitoring forest protocol (Smith and Torbert 1990), with modifications. A square, permanent plot is used to record tree, shrub, and understory/ground cover conditions. The size of the plot varies with community type being monitored. The impetus for this is to monitor an area large enough to capture the dynamics of stand replacement, or gap dynamics. An area at least 4-5 times the maximum canopy width of the dominant species is a minimum size for this purpose. The plot dimensions listed in Table 3 were based on field measures of canopy widths in forests and woodlands where these procedures will be employed.

Table 3. Plot dimensions for forest and woodland plots in the NCPN.

Forest, woodland community	Permanent plot dimensions
Aspen	30 x 30m
Cottonwood	50 x 50m
Pinyon-Juniper	20 x 20m

Measures are recorded at different spatial scales depending on the attribute. Within a plot, all trees ≥ 10 -cm dbh (diameter at breast height) are tagged with a unique number, and species and dbh is recorded. Shrubs and saplings (< 10 -cm dbh) are recorded in two 2-m belt transects established within the two halves of the plot (Fig. 5). The number of shrubs by species, and by height class is recorded. Saplings are identified to species and tallied by dbh class. Overstory cover is also recorded along the belt transect. A point-intercept method is used to record percent cover of the understory (< 2 -m) along three transects (Fig. 5). Downed-woody fuels are measured using Brown's planar method (Brown 1974) along four 15-m transects which extend beyond the plot on two corners (Fig. 5).

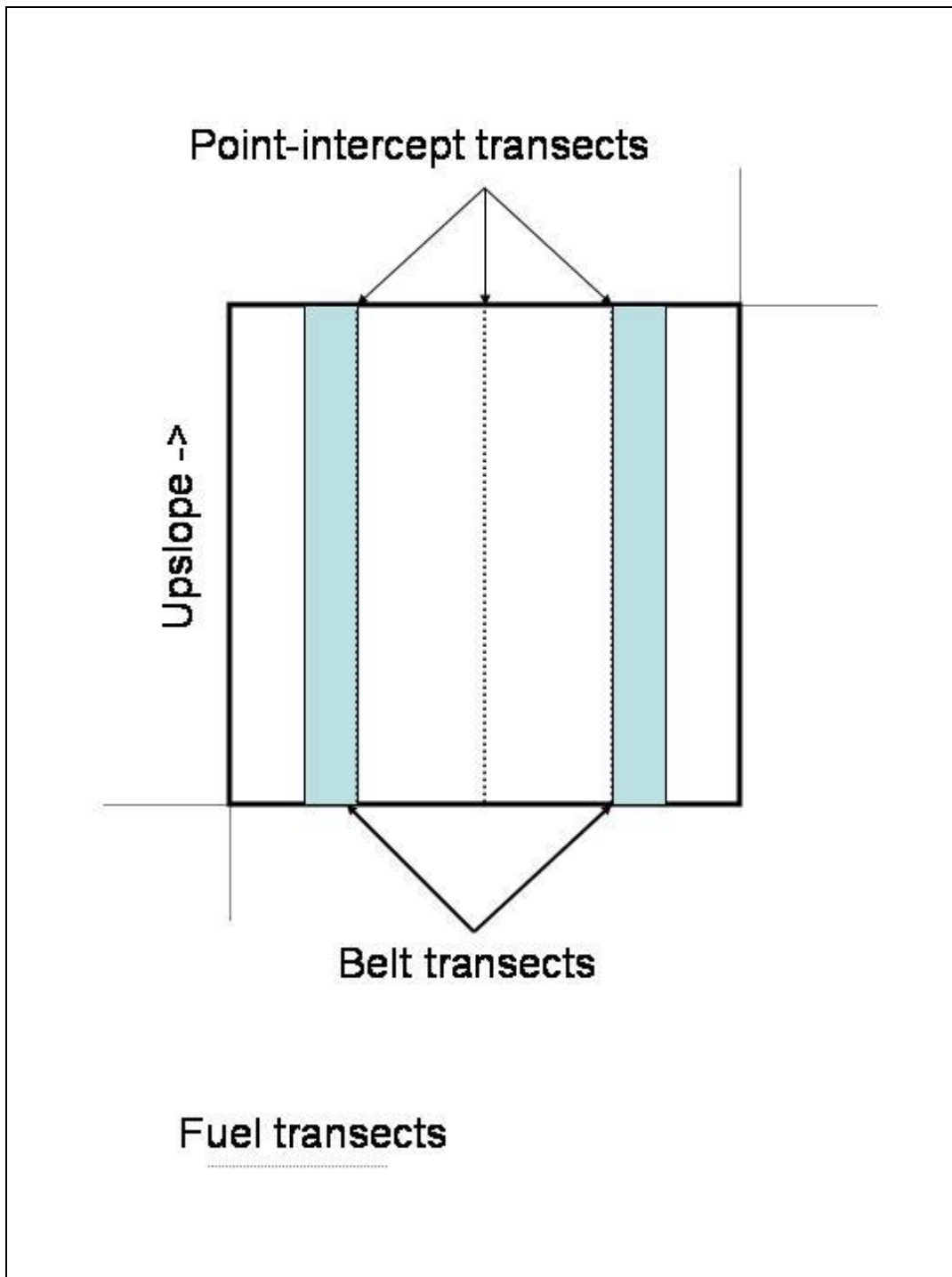


Figure 5. Forest and woodland monitoring plot, showing the belt transect for measuring shrubs and samplings, the point-intercept transects for measuring understory and ground cover, and the fuel transects for measuring downed woody debris (not drawn to scale).

Target Population & Spatial Design

The NCPN employs sampling and survey designs in the upland monitoring effort. 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, Nusser 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.

Methods for determining the target population and the spatial design of a monitoring effort will vary among NPCN park units according to park-specific needs and issues. However 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. These issues may 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 site type by cross-walking with NRCS Ecological site descriptions (SRM 1989, 1995). This involves overlaying NRCS map units on the target areas, and delineating ecological sites associated with target areas. The 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 unpubl.). NRCS map units used in subsequent steps are clipped to the accessible area.

- Field evaluation of 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 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.
- Ecological site maps serve as the sampling frame from which monitoring sites are selected. The NCPN generally will use the GRTS (Generalized Random Tessellation Stratified) method for site selection. GRTS ensures a spatially balanced design, and allows for site rejection and site additions over time (Stevens and Olsen 2004).
- Site accession is generated by GRTS, and is key to maintaining the spatial balance of sites. Sites are visited in accession order. There will always be selected sites that are inappropriate due to fine-scale anomalies presenting safety hazards, as well as 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. The over sampling in the initial GRTS 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, and 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 practices, 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 leading to ecological thresholds are topic research issues in especially the dryland systems of the U.S. (e.g., Bestelmeyer 2006, Briske et al. 2006, Peters et al. 2006).

The sampling objective of park monitoring is determined on the basis of 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 are determined from available field data, such as from vegetation mapping efforts, or remotely sensed estimates of shrub, 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 will occur in two phases. Up to 10 permanent monitoring sites will be established per ecological site and revisited each year for three years. This initial phase is designed to acquire measures of variance for use in evaluating a survey design sufficient 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.

Survey designs will vary according to variance estimates and sampling objectives. However, complex survey designs are likely, which will include multiple panels and varying frequency of visitation. 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 the end of September. 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 ± 1 mo. of plot establishment, 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 mo. of plot establishment time provides only a . 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 and frequency of herbaceous, and annuals in particular, is expected to be somewhat higher due to increase sensitivity to seasonal weather patterns.

Rationale for Selecting This Sampling Design

The proposed design attempts to efficiently monitor change in selected areas of target parks of the networks. It is directly linked to management needs by focusing on key resources. The unequal probability method of plot selection incorporates flexibility because it allows for future adjustment of plot numbers and selection probabilities. GRTS produces a spatially balanced sample which well-represents the area of interest, incorporates probabilistic sampling to meet statistical assumptions and allows flexibility to modify replication at a later time. Vegetation sampling in the intermountain west lags behind other regions, so no true standard exists. We base our methods for dryland systems on those of Herrick (2004), a study comparing methods in the field (Miller et al. 2007), and standard forest and woodland procedures.

III. Field methods

Field Season Preparations, Field Schedule, and Equipment Setup

The principle investigator [PI] (vegetation ecologist) is responsible for ensuring that preparations are made for the ensuing field season (SOP#1). This requires the PI or designee (i.e., field-crew leader) to acquire lists of plots to be established or re-visited. This list is acquired from the network ecologist or from the schedule posted each year in the Upland Monitoring directory maintained by NCPN Data Management. The UTM coordinates of plots should be uploaded to GPS units. When establishing plots, the accession number which guides visitation sequence is included with the coordinates. Sampling dates should be scheduled and logistics organized prior to the start of the field season. Logistics include scheduling park housing and acquisition of back-country permits. Field work is typically conducted in eight day tours with a travel day on each end. At least ten weeks prior to commencing field work, contact resource managers at each park to be visited and initiate a research permit request. Additional contact should be made about two weeks before each visit to confirm logistics arrangement with park staff. A sufficient number of data forms, park-level species lists, ecological site descriptions (for plot establishment), and maps and directions for plot access should be generated for the field season. Equipment listed in SOP#1 should be assembled or ordered to ensure their availability at the beginning of the field season.

Prior to entering the field, crew members must review the entire protocol, especially the SOPs, and participate in the training session. The PI or designee is required to ensure that crew members understand all procedures, and to evaluate this understanding during the required training (SOP#2). Training involves exercising GPS procedures for

navigating to plots (SOP#3) as well as plot layout and measurement procedures in locations outside of park units (i.e., USDI BLM lands). The off-park location of training is to minimize trampling effects on National Park lands.

Conducting Monitoring

The plots being established must be visited in the order provided. Revisits to established plots may occur in whatever order the PI or designee determines.

Details of taking measurements, with example field forms, are documented in the individual standard operating procedures (SOPs). Fig. 6 outlines the procedures at a monitoring site on the first 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.

Fig. 7 outlines the procedures if a site is accepted or if a re-visit to a monitoring site. For dryland systems, a specific suite of SOPs are followed to establish a permanent plot, and to record measures. A different collection of SOPs are used for forest and woodland monitoring. For both, when re-visiting an existing monitoring plot, a plot re-visit datasheet is used to record general observations of the plot (SOP #5). 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).

Dryland Systems

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 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 are also acquired along the diagonal of the plot at specified quadrats while recording frequency and cover measures.

To minimize impacts to vegetation, all measurements are taken on one transect before the others are visited and workers remain downslope from the transect while taking measurements. Starting at the origin of each transect, a 50m tape is stretched over the length of a transect. A 10m² quadrat is located every 5 meters (SOP #21). All corners of the quadrat are permanently marked with large nails. Frequency, cover, and density of all living plant species, ground features and soil crust are measured in rectangular subplots. The 10 m² plot contains a 1m² quadrat which is sub-divided into 0.01 m² and 0.1 m² rectangles for a nested frequency determination of species occurrence. Foliar cover by species is estimated in 1% increments in all 10m² subplots (since each species is measured separately, the sum of cover can be greater than 100%). Additionally cover by lifeforms is estimated. Cover for each lifeform cannot exceed 100% as it is the direct

aerial projection of cover in the plot. While traversing each transect, soil samples are gathered for the soil aggregate stability measure (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 20cm). Basal gaps are recorded similarly working from the 50m end back to the origin and recording each segment ($\geq 20\text{cm}$) 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 disturbance with the potential to have an effect on soil and vegetation on the monitoring plot.

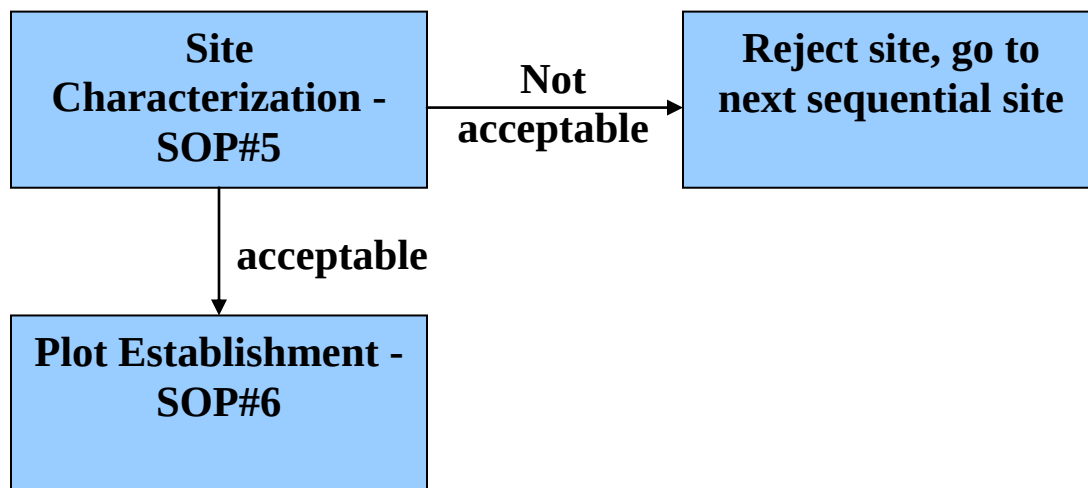


Figure 6. Outline of the initial field procedures when visiting a potential monitoring plot for the first time. If a plot is acceptable, plot establishment occurs, then procedures outlined in Figure 7 are performed.

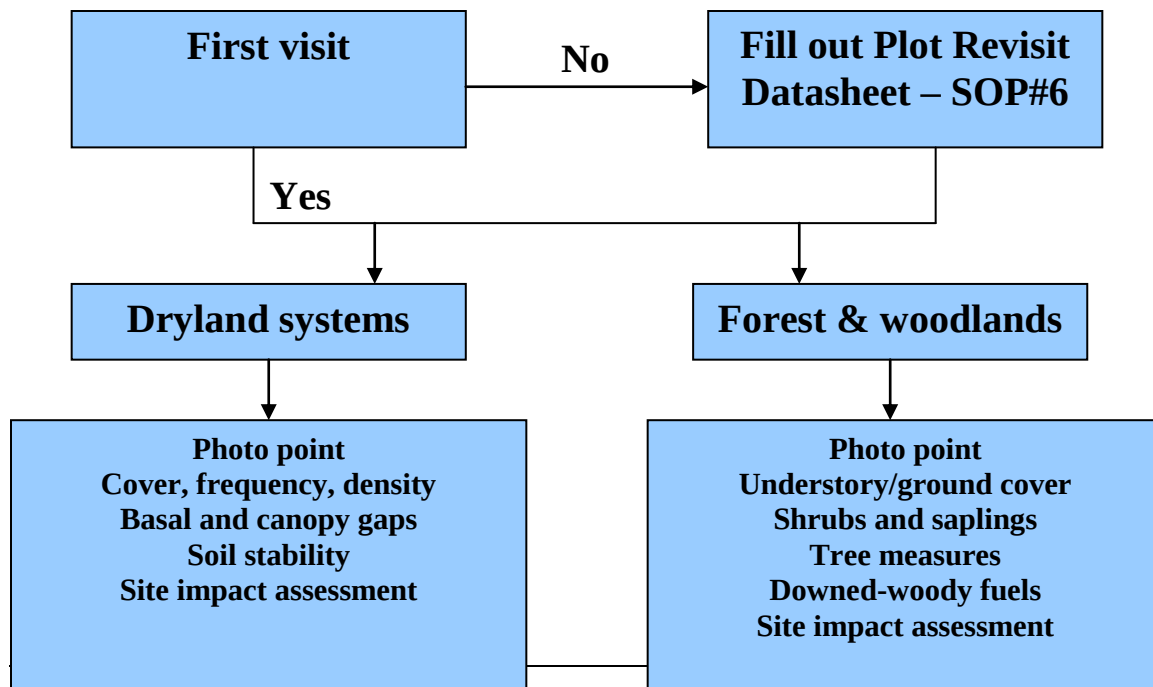


Figure 7. Outline of field procedures for monitoring upland sites.

Forests and Woodlands

A square permanent plot is established, the size of which varies with the community type being monitored. Each corner and several mid-points along the edge of the plot are permanently monumented with rebar. Three transects within the plot are established, which are oriented parallel to the slope. Two of these transects form the edges of 2-m belt transects, and all three are used for point-intercept measures of understory and ground cover. Photos of the plot are acquired after monuments are established.

Measures are acquired following a sequence that minimizes the influence of trampling on measures. Point-intercept measures are recorded first along the three transects. At every 1-m interval, a pin rod is dropped and all vegetation coming in contact with the end of the rod is recorded to species. Ground cover attributes are also recorded where the rod contacts the surface of the ground. Shrub and sapling density is then recorded in two 2-m wide belt transects. Shrubs are identified to species and recorded by five height classes. Saplings (<10-cm dbh) are identified to species, and are tallied by dbh (diameter at breast height) classes. Overstory cover is measured along the belt transects using a densiometer. After transect measures are acquired, all trees (≥ 10 -cm dbh) within the plot are identified to species, tagged with unique numbers, and measured for dbh. Crown class and health of trees are also recorded.

Downed woody fuel is measured along four 15-m transects which originate at two corners and extend out from the plot. Fine-woody and coarse woody fuels are recorded to derive volume measures of woody fuels. 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.

Similar to the Dryland monitoring, disturbances on and off the monitoring plot are recorded. This can occur while acquiring measures of other attributes, but prior to leaving the plot, a final evaluation of nearby disturbances off the plot should be performed.

End-of-Season Procedures

At the end of the field season, the PI or field crew leader should ensure final completeness of all data sheets while field crew members are still available to clarify any ambiguities. After this, all 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 PI 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 PI 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.

III 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 and 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 noted 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 plot establishment and re-measurement from all parks in the network. The database provides numerous tables for biophysical features of a plot, and for measures organized largely by the field-based SOPs.

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

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Data Entry, Verification, and Editing

The project leader 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.

Most data will be recorded by field crews on paper forms; spatial data for each site will be recorded on GPS dataloggers. For field measurements one crew member will make the measurement while the other verifies it by repeating back and then records 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 immediately after data entry, when data printouts are compared against the original field forms 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 table.

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://www.nature.nps.gov/im/units/ncpn/data>). 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.

IV Analysis and reporting

Three general types of analyses are performed: annual summaries of the most recent monitoring observations, status and trend assessments, and variance estimation of the overall sampling design (SOP#19). The more detailed assessments of status and trends and of variance should begin at least 5-yrs after initial implementation and possibly every year thereafter depending on the number of plots visited each year. At a minimum, these in-depth assessments should be performed at 5-yr intervals.

Annual Summaries and Reports

Annual summaries are intended to provide an accounting of the number of monitoring plots visited in a year, and a summary of the field measures. Data for the annual summary are plot-level measures derived from the numerous sub-samples collected on a plot. The possible plot-level measures are listed in Table 4 for dryland systems, and table 5 for forest & woodland systems. A recommended approach to summarizing is to derive and report the average, minimum, and maximum value for each plot-level measures on the basis of ecological site type, and noting the number plots per site type (e.g., Table 6). Of special interest is to report on the cover and frequency of exotic, and Threatened and Endangered (T&E) species. Although annual summaries are not intended to provide status and trend information, the frequency and magnitude of exotics and T&E species across the plots of an annual monitoring event may be of immediate interest to park management.

The annual report contains the 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.

Table 4. Dryland system plot-level measures.

Measure	Attribute or Context	Spatial scale(s) of observation
Percent frequency	Individual plant species	0.01, 0.1, 1.0, 10m ²
	Surface features (undifferentiated crust, cyanobacteria, lichen, moss)	0.01, 0.1, 1.0m ²
	Disturbance features (livestock and wildlife scat; ant mound, bicycle; human, livestock, wildlife track; motor vehicle; wildlife excavation; other).	0.01, 0.1, 1.0, 10m ²
Percent cover	Individual plant species	10m ²
	Surface features	1m ²
	Disturbance features (see above), and bare soil, litter, woody debris, small and large rock, bedrock, biological crust, and undifferentiated crust	10m ²
	LifeForm (shrubs; annual, perennial grasses; forbs/herbs)	10m ²
Density	Individual shrub species, and all shrub species combined	10m ²
Length of canopies (shrubs and non-shrub vegetation) and of canopy gaps; percent canopy and percent canopy gaps; mean canopy length and mean gap size; frequency distribution of canopy lengths and of gap size	Line-intercept length of canopies of shrubs and of non-shrub vegetation, and of canopy gaps	Along all three transects (150 m)
Length of basal areas (all vegetation combined) and of basal-area gaps; percent basal area and percent basal-area gaps; mean basal-area length and mean basal-area gap size; frequency distribution of basal-area lengths and of basal-area gap sizes	Line-intercept length of basal area of all vegetation combined (excluding annual grasses) and of basal-area gaps	Along all three transects (150 m)
Soil stability class (from protected and unprotected combined, from protected areas,	Slake test stability class (1-6) Protected-area samples are those collected under vegetation.	18 point samples across plot

from unprotected areas)	Unprotected-area samples are those lacking ‘overstory’ vegetation	
Plant species Richness (no. of species)	Lifeform, all species combined	all 10m ² quadrats on a plot
Plant species Diversity & Evenness	All species combined	all 10m ² quadrats on a plot

Table 5. Forest and woodland plot-level measures.

Measure	Attribute or Context	Spatial scale(s) of observation
Percent cover	Individual plant species	Point intercept
	Surface features (undifferentiated crust, cyanobacteria, lichen, moss)	Point intercept
	Disturbance features (livestock and wildlife scat; ant mound, bicycle; human, livestock, wildlife track; motor vehicle; wildlife excavation; other).	Point intercept
	LifeForm (shrubs; annual, perennial grasses; forbs/herbs)	Point intercept
	Overstory cover	Locations along belt transect
Density	Individual tree and shrub species, and all trees and shrub species combined	Plot scale for trees, two 2-m belt transects for shrub species
Fuel loading	fine and coarse woody debris volumes	four 15-m transects
Plant species Richness (no. of species)	Lifeform, all species combined	plot scale for trees, 2-m belt transect for shrubs and saplings, point intercept for understory
Plant species Diversity & Evenness	All species combined	plot scale for trees, 2-m belt transect for shrubs and saplings, point intercept for understory

Table 6. Mean (range) percent canopy and basal measures, by ecological site type; Capitol Reef National Park, 2007.

Ecological site (no. of plots)	Canopy			Basal	
	Gap	Non-shrub vegetation	Shrub	Gap	Basal area
SDSL215 (11)	64.4 (54.2-76.6)	31.9 (13.7-44.1)	3.6 (1.0-9.8)	80.8 (68.6-88.8)	19.2 (11.1-31.4)
SDASL201 (7)	69.4 (51.3-86.5)	21.0 (12.8-38.2)	9.5 (0.8-30.1)	86.8 (80.8-93.2)	13.2 (6.8-19.2)
SDS212 (1)	68.6 (68.6-68.6)	26.9 (26.9-26.9)	4.5 (4.5-4.5)	81.8 (81.8-81.8)	18.2 (18.2-18.2)

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 for a trend being different from zero. The status estimation hinges on the outcome of the trend assessment in that 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 the 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 with five-yr of data, and possibly every year thereafter or 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.

Variance Assessment and Report

The ability of the extant sampling design to satisfy the sampling objective must be evaluated over the course of monitoring. This aids in ensuring that the sampling design is achieving the sampling objective, and determines the need to adjust the design. This effort parallels the assessment of status and trends. That is, at least 5-yr of data are required before a credible and meaningful assessment can be performed. Further assessments may be every year thereafter, depending on the sampling intensity, but at least every 5-yr. Results of the variance assessment are reported in the status and trend report, or as part of the annual report after 5-yr of data collection.

V Personnel requirements and training

Roles and Responsibilities

The project manager is the lead ecologist for implementing the vegetation community monitoring protocol, and is supervised by the program coordinator for the NCPN Program. Because of the need for a high level of consistency in implementing the protocol, the project manager will be responsible for training the seasonal and permanent personnel assisting with the monitoring efforts. 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.

Additional Roles for Project Staff

Vegetation Ecologist – hires seasonal staff, applies for park research permits, coordinates with quantitative ecologist to determine plot selection, conducts end of season review procedures, conducts or arranges training, reviews procedures in field, resolves questions about methods and procedures.

Field lead/Vegetation Program Assistant – ensures that required equipment is available and maintained prior to field season, contact parks regarding logistics of site visits, prepares site packets, schedules field activities, collects and enters data.

Field staff – performs all field procedures, collects and enters data, provides feedback on methods during and after season.

Quantitative Ecologist – lead for plot selection, works with project manager to analyze data and prepare reports.

Data manager – reviews data quality assurance and quality control procedures, performs data archiving, modifies database if necessary, prepares metadata.

All involved staff participate in end of season project review procedures.

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 must be acquired over a period of several years of study. Additional qualifications are knowledge of basic soils science, experience in taking plot based ecological measurements, familiarity with local environmental conditions and hazards (travel in remote back country, rough terrain, extreme heat, etc.), familiarity with GPS data loggers, and basic computer data entry. Observers should also have good organizational skills, memory retention, and an 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. The PI will provide training on navigation and recording using a GPS, and field procedures for collecting monitoring information. Of special concern is the ability of crew members to correctly identify plant species and to accurately estimate percent cover. 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. Time should also be invested in training personnel on cover estimation. Estimating cover is best taught at the start of the season in the field with all crew members present and then reviewed periodically throughout the summer to reduce within-year observer differences in cover estimation. Prior to the field season, observers should practice estimating cover of different vegetation guilds and ground cover categories using practice plots. Differences in cover estimation between observers will strongly affect survey results.

VI Operational requirements

There will be teams of two for field site visits. A minimum of two teams will go to the field each season. Each will need a dedicated vehicle, and equipment.

Annual Workload and Field Schedule

Field work will occur from about April 15 to September 30 each year. Prior to field work the PI will make necessary preparations during March and April. An average field season might consist of eight tours each with two travel days and six field days. A rough estimate is that each 2-person crew will be able to visit 5-6 plots per tour. This will vary with the park unit being monitored, and the location of plots in a park unit relative to roads and trails.

Facility and Equipment Needs

The nature of vegetation monitoring does not require much in the way of facilities beyond offices space and herbarium storage. Equipment is detail in SOP #1.

Startup Costs and Budget Considerations

Approximately ten days, including travel, are required to complete the sampling for each tour. Personnel expenses for field work are based on two crews of two people, one field project lead and three seasonal biological science technicians. Field costs will vary from year to year depending on the skill level and size of the crew (Table 7). Not included are

data management, program coordination, analysis and reporting and administrative costs that are shared among multiple monitoring projects. Startup costs include the purchase of equipment and supplies listed in SOP # 1 as well as maintenance and or replacement of equipment shared among multiple projects (e.g. GPS units, cameras, vehicles).

Table 7. Estimated startup costs and annual budget for NCPN vegetation community monitoring.

Category	Cost
Field work (salary)	44,300
Travel	8,000
Startup Equipment Costs	3,000
Annual Equipment/supplies	3,000
TOTAL	\$58,300

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.

The steps for changing the protocol narrative and SOPs are outlined in SOP #20, “Revising the Protocol.” 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.

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