National Park Service
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Vegetation Composition Structure and Soils: Alpine
Version 1.0

ON THE COVER
Looking towards the 3rd GLORIA summit at Great Sand Dunes National Park and Preserve, 2008
Photograph by: Phyllis Pineda Bovin, Great Sand Dunes National Park and Preserve

Vegetation Composition Structure and Soils: Alpine

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Natural Resource Report NPS/XXXX/NRXX—20XX/XXX

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1 Executive Summary

The Rocky Mountain Inventory & Monitoring Network (ROMN) includes a wide range of environments, ranging from mountain peaks to deciduous forests to Western grasslands. The six units of the Network include Glacier National Park, Grant-Kohrs Ranch National Historic Site, Little Bighorn Battlefield National Monument, Florissant Fossil Beds National Monument, Great Sand Dunes National Park and Preserve, and Rocky Mountain National Park. Here, we present a protocol to inventory and monitor alpine vegetation within the three mountainous units of the Network (Glacier, Great Sand Dunes, and Rocky Mountain).

The objectives of the Vegetation Composition, Structure, and Soil: Alpine (AlpineVCSS) monitoring protocol are to understand the status and trends in five parameters at four sentinel alpine peaks at a range of elevations. Specifically, for these sentinel sites, our objectives are to:

(1) Determine the status and trend in **vegetation composition and structure**.
(2) Determine status and trend in the **cover of invasive and exotic plant species**.
(3) Determine the status and trend in **soil temperature and snow cover** period.
(4) Determine the status and trend in **soil condition** based on a suite of physical and chemical properties that include: soil carbon and nitrogen content, pH, texture, evidence of erosion, extent of bare soils, and compaction.
(5) Determine the status and trend of **natural and human disturbance** based on a qualitative survey of the surrounding area and measures of herbivore presence.

A sixth "optional" objective is to determine status in vegetation structure, species composition, natural and anthropogenic disturbance and soil condition in alpine tundra within the parks. The ROMN would consider adding this objective should increased network funding allow us to characterize the status of vegetation and soils throughout alpine communities in the parks, not just at four select sentinel sites in each park.

To meet the AlpineVCSS objectives we follow methods from the Global Observation Research Initiative in Alpine Environments (GLORIA), an international monitoring network established in 2001 to assess and predict biodiversity changes in alpine communities in response to climate change. The methodology is extended by cooperators, such as the ROMN, to create a long-term monitoring network at the global scale. We use the GLORIA sampling design, which is a sentinel site approach, where vegetation is monitored on four summits in a park that vary in elevation. Species diversity, ground cover, browsing and trampling pressure, and soil temperatures are measured in an array of plots on the summit set in all cardinal directions. In addition to the components of the GLORIA protocol, the AlpineVCSS extends the monitoring to include measures of soil condition and chemistry, natural and human disturbance, phenology, and photographic documentation of treeline. The sentinel sites will be monitored annually or every 5 years, as funding allows. We have also developed optional methods for spatially-balanced probabilistic survey designs of alpine vegetation that can be implemented in the future. Ultimately, we aim for the ROMN AlpineVCSS protocol to provide a robust method for measuring status and trend in alpine vegetation and soils in the parks and to provide data that can be used in collaboration with other networks and programs to monitor climate change and its effects on alpine communities across the globe.

2 Background and Objectives

2.1 The National Park Service Inventory and Monitoring Program

The purpose of the National Park Service (NPS) Inventory & Monitoring (I&M) Program is to develop and provide scientifically credible information on the current status and long-term trends in the composition, structure, and function of park ecosystems. As part of the NPS's effort to "improve park management through greater reliance on scientific knowledge," a primary role of the I&M Program is to collect, organize, and make available natural resource data and to contribute to the NPS institutional knowledge by facilitating the transformation of data into information through analysis, synthesis, and modeling of specific key "vital signs." The I&M Program defines the term "vital sign" as "a subset of physical, chemical, and biological elements and processes of park ecosystems that is selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values" (Fancy et al. 2009).

The five goals of the I&M Program are to:

(1) Inventory the natural resources and park ecosystems under NPS stewardship to determine their nature and status.
(2) Monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with altered environments.
(3) Establish natural resource inventory and monitoring as a standard practice throughout the NPS system that transcends traditional program, activity, and funding boundaries.
(4) Integrate natural resource inventory and monitoring information into NPS planning, management, and decision making.
(5) Share NPS accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives.

These goals are accomplished through park-wide inventories and a long-term monitoring program. In establishing a service-wide natural resources inventory and monitoring program, the NPS created networks of parks that are linked by geography and shared natural resource characteristics. Working within networks improves the efficiency of inventory and monitoring because parks are able to share budgets, staffing, and other resources to plan and implement an integrated program.

The Rocky Mountain I&M Network (ROMN) is comprised of six NPS units: Glacier National Park (GLAC), Grant-Kohrs Ranch National Historic Site (GRKO), and Little Bighorn Battlefield National Monument (LIBI), in Montana; and Florissant Fossil Beds National Monument (FLFO), Great Sand Dunes National Park and Preserve (GRSA), and Rocky Mountain National Park (ROMO), in Colorado (Figure 1). The ROMN recognized 12 high priority vital signs for focused monitoring (Britten et al. 2007). The vital signs include: Wet and Dry Deposition, Weather and Climate, Water Chemistry, Surface Water Dynamics, Freshwater Communities, Invasive/Exotic Aquatic Biota, Groundwater Dynamics, Wetland Communities

Invasive/Exotic Plants, Vegetation Composition, Structure, and Soils, Focal Species: Beaver, Elk, Grizzly Bear, and GRSA Endemic Insects; and Landscape Dynamics.

The Vegetation Composition Structure and Soils: Alpine Protocol (AlpineVCSS) presented here directly addresses the monitoring of three vital signs: Invasive/Exotic Plants, Weather and Climate, and Vegetation Composition, Structure, and Soils. Three other high priority vital signs are indirectly linked to vegetation condition including: Landscape Dynamics, Wet and Dry Deposition, and Focal Species – Elk.

Figure 1. Map of Rocky Mountain Inventory & Monitoring Network park units

2.2 Alpine Vegetation and Rationale for Monitoring

The alpine is defined as the vegetation communities that exist above tree line, which comprise approximately 3% of the global surface (Korner 2002). It is an environment characterized by extreme natural conditions including high winds, low temperatures, scouring and burial by snow and ice, low nutrient availability, high incident solar radiation, thin atmosphere, and a short growing season (Bowman 2001). Alpine is present on all continents, but the elevational limit of trees and the transition to alpine tundra varies with latitude, such that the elevational boundaries of the alpine increase with proximity to the equator

(Gurevitch et al. 2002). The vegetation community is small in stature and dominated by perennial herbaceous species with species composition varying strongly across environmental gradients of water availability (Walker et al. 2001). While the alpine is typically dominated by grasses, sedges, and forbs, nonvascular plants and woody shrubs are also common. Compared to other grassland types, the alpine tundra shows high local diversity (Gough et al. 2000). Species that persist in the alpine have adapted to the extreme environment, but growth and reproduction are strongly limited by environmental conditions and nutrient availability. As a result, changes in weather and climate patterns, natural disturbance, nutrient budgets (due to atmospheric nitrogen (N) deposition), and human use may strongly influence the persistence of alpine communities.

The alpine environment is represented in three of the ROMN parks: GLAC, ROMO and GRSA at 28%, 20%, and 3% land cover, respectively (Figure 2). The ROMN selected alpine ecosystems as an important monitoring target in these parks for a number of reasons. **First**, the tundra is typified by spectacular wildflower displays that draw park visitors. **Second**, the alpine supports numerous animals of management concern including bighorn sheep (*Ovis canadensis*), mountain goats (*Oreamnos americanus*), white-tailed ptarmagins (*Lagopus leucura*), and pikas (*Ochotona princeps*). Recent evidence suggests that climate changes have contributed to the extinction of pika populations (Grayson 2005), but how future changes will affect these and other alpine species remains unknown. The first step to understanding changes in fauna lies with understanding the patterns of biodiversity loss and gain in alpine vegetation. **Third**, much of the water resources in the West are derived from snowmelt, and the quality and quantity of this water is influenced by ecosystem processes in the alpine tundra (Williams and Caine 2001). **Fourth**, because the alpine is particularly sensitive to climate change and atmospheric deposition and is globally distributed, it may provide an important indicator for change (Seastedt et al. 2004). Long-term records provide evidence for ongoing warming in high mountain environments (Price and Barry 1997). The extent of glacier loss, warming temperatures, and changes in snowpack have been well documented (e.g. Hall and Fagre 2003) but concurrent changes in vegetation composition and patterns are not well understood due to a paucity of long-term monitoring. Climate changes may affect biodiversity and species richness, by contributing to the extinction of some species while simultaneously increasing the elevation and latitudinal limitations of other species. A survey of summit sites in the Alps of Switzerland showed that vascular plants have been establishing at higher altitudes than recorded earlier (Grabherr et al. 1994). Thus, it is assumed that an upward and northward migration of plants, induced by recent climate warming, is an already ongoing process. In recent decades, the deposition of atmospheric N has increased in the Rocky Mountains due to the increasing growth of metropolitan areas and agriculture (Fenn et al. 2003). Alpine regions in the Rocky Mountains have a low capacity to sequester this excess N because of short growing seasons, shallow soils, and steep slopes that encourage rapid run-off (Fenn et al. 2003). There is evidence that N deposition has altered alpine lake chemistry and biota (Baron et al. 1994) and it can alter the structure of alpine communities (Bowman 2000). **Finally**, due to extreme conditions and remote access, the alpine tundra has had less direct exposure to invasive species, pests and pathogens, and fire than many ecosystems. It therefore becomes possible to examine changes in the status or trend of alpine vegetation caused by changes in climate and atmospheric N deposition without the confounding affects of other stressors.

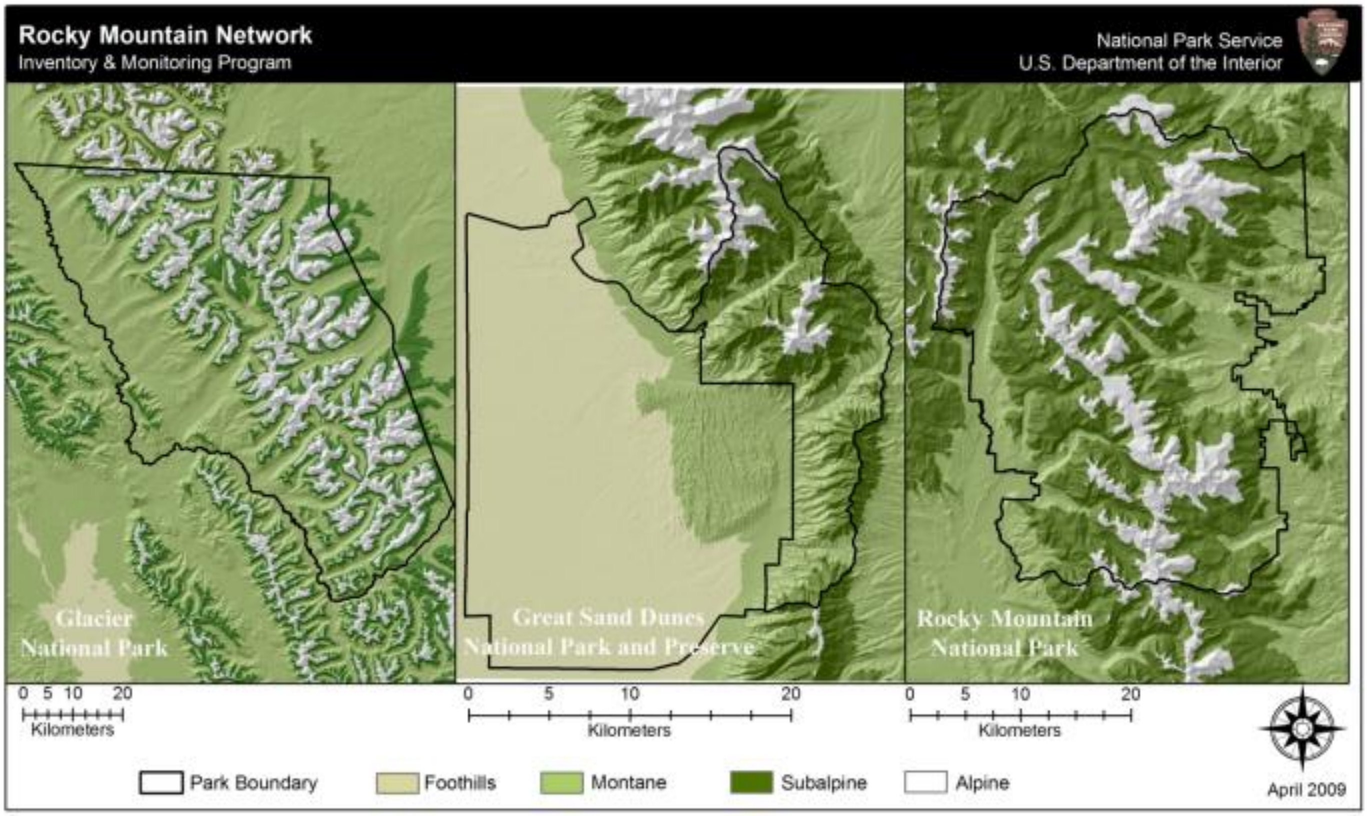

Figure 2. Map of ecoregions in Glacier, Great Sand Dunes, and Rocky Mountain National Parks. Boundaries of ecoregions were determined by elevation with best estimates based on ecological literature, maps, and park definitions. Alpine is defined as areas above 3500m in ROMO and GRSA and 1980m in GLAC.

History of Protocol Development

Prior research and monitoring of alpine vegetation

Vegetation maps, experimental work, and surveys have been conducted in the alpine of GRSA, GLAC, and ROMO (see Appendix 1 for a bibliography of published work and investigator annual reports relating to alpine vegetation in the three parks). Vegetation maps were recently completed for ROMO (Salas et al. 2005), GRSA (Salas et al. 2009), and GLAC (USGS-NPS 2007). The maps include detailed descriptions of vegetation alliances throughout the park, including an assortment of alpine communities.

Alpine ecology has historically been of great interest in ROMO. Studies have examined community composition and effects of trampling (Willard et al. 2007) and changes in diversity at the alpine ecotone (Stohlgren et al. 2000). More recently, work has been done to describe patterns and effects of elk herbivory on willows (see Steltzer, Appendix 1) and the effects of N deposition on alpine communities (see Bowman, Appendix 1). Baron and colleagues have conducted ecological research and monitoring in the Loch Vale watershed in ROMO since 1982 (e.g., Baron et al. 2000). They have measured meteorological and hydrological parameters and N cycling in vegetation and soils to determine the watershed-scale response to atmospheric deposition and climate variability. The majority of the work, however, has focused on forested and subalpine areas and to date, there has not been long-term monitoring of alpine tundra in other areas.

Compared with ROMO, there has been less emphasis on alpine vegetation research in GLAC and even less in GRSA. While the flora of GLAC has been well described and there has been work on the loss of rare alpine wetland plants (Lesica and McCune 2004), much of the work has focused on modeling efforts exploring the expansion of treeline (Klasner and Fagre 2002, Malanson et al. 2007). One exception is a dissertation (Damm 2001), which provides a baseline of vegetation above treeline in GLAC. GRSA recently expanded to include alpine regions of the Sangre de Cristo Range. Previously, this was part of the San Isabel National Forest and historically there was extensive domestic sheep grazing in the area. While the vegetation has been described and mapped (Salas et al. 2009), there are few other references to vegetation work in the area.

In summary, relatively few studies have explicitly *monitored* alpine vegetation in ROMO, GRSA, and GLAC. The ROMN AlpineVCSS protocol should help address this shortcoming by providing standardized methods for long-term of monitoring of alpine vegetation in these three parks.

Protocol development

The ROMN adopted an alpine monitoring protocol from the Global Observation Research Initiative in Alpine Environments (GLORIA), an international monitoring network established in 2001 to assess and predict biodiversity and temperature changes in alpine communities in response to broad drivers such as climate (Pauli et al. 2004). The goals of the GLORIA program include providing a global baseline for vegetation monitoring in alpine environments and assessing the risks of biodiversity loss and ecosystem instability from climate change. GLORIA collects monitoring data by using an array of plots to measure vegetation across sets of four neighboring peaks (Grabherr et al. 2000). The peaks vary in elevation from treeline to the limits of vascular plants; vegetation composition and structure, and soil temperatures are monitored within plots on these peaks. This methodology is extended by cooperators, such as the ROMN, to create a long-term monitoring network at the global scale. To enable ROMN parks to understand changes in alpine vegetation and climate in a global and regional context, we will follow the published GLORIA protocol (Pauli et al. 2004); hereafter referred to as the GLORIA Field Manual. Recent additions to the standard operating procedures (SOP) have been developed and implemented by the GLORIA network to facilitate the use of the temperature dataloggers and to better describe tundra in areas with a low density of vegetation (GLORIA Field Manual Amendments).

Following these methods, a GLORIA multi-summit site was established in 2003 and 2004 in GLAC by Daniel Fagre of the United States Geological Service (USGS). The University of Colorado Mountain Research Station established a site outside of ROMO in 2007 that will complement a ROMO site within the park placed on the opposite side of the continental divide. Initiating GLORIA monitoring in ROMO and GRSA and continuing monitoring in GLAC will provide an invaluable transect of alpine monitoring from the Southern to Northern Rockies. In addition, our methods will be comparable to other NPS I&M Networks (including the North Coast and Cascades and Greater Yellowstone) that are considering GLORIA sites.

During the process of establishing sites in ROMO and GRSA, we found it necessary to make minor modifications to the published field methods, primarily to reduce the cost of dataloggers and the use of permanent markers. These modifications are found in *SOP AlpineVCSS* Adapting GLORIA to National Parks. In addition to the minor modifications to the GLORIA field methods, we have expanded the protocol to include a suite of extended methods that will be implemented when funding is available. The extended methods were developed to allow us to gain a better understanding of local and regional changes in soil chemistry and ecosystem process driven by atmospheric N deposition, to better relate alpine work to the other ROMN vegetation monitoring efforts (e.g., grassland, shrubland, and woodlands and wetlands), and to increase our ability to determine the status of alpine tundra across the park. In brief, the extended methods include a modest array of soil parameters, descriptions of anthropogenic and natural disturbances at all sites, phenology, documentation on the extent of treeline, and an *optional* probability-based survey design. These methods are described below in Section 3-Section 4 and the corresponding *AlpineVCSS* SOPs.

2.4 Measurable Objectives

The goals for conducting ecological monitoring of alpine vegetation, within GLAC, GRSA, and ROMO are two-fold: to recognize and document long-term status and trends in vegetation structure and composition and to supply short-term feedback for managers to assess strategies to maintain and restore these communities. *Status* is defined as some statistic (e.g., a mean or a proportion) of a vital sign or measure over all monitoring sites in a park (from one to many) within a single or well bounded temporal window (Britten et al. 2007). *Trend* is a non-cyclic, directional change in a response measure that can be with or without pattern and, if it exists, always has a linear component (Urquhart et al. 1998). ROMN aims to determine the correlation between trends in vegetation and soil conditions and potential drivers of these changes, particularly climate and atmospheric N deposition. Specifically, for GLAC, GRSA, and ROMO the core objectives of the AlpineVCSS protocol are to:

(1) Determine the status and trend in **vegetation composition and structure** of four sentinel alpine peak communities at a range of elevations.

(2) Determine status and trend in **cover of invasive exotic plant species** at four sentinel alpine peak communities at a range of elevations.

(3) Determine the status and trend in **soil temperature and snow cover** period of four sentinel alpine peak communities at a range of elevations.

(4) Determine the status and trend in **soil condition** based on a suite of physical and chemical properties that include: surface stability, soil carbon (C) and nitrogen (N) content, pH, texture, evidence of erosion, extent of bare (non-vegetated) soils, and compaction at four sentinel alpine peak communities.

(5) Determine the status and trend in **natural and human disturbance** at four sentinel alpine peak communities at a range of elevations based on a qualitative index of disturbance and the presence of feces, trampling, and browsing damage.

A sixth "optional" objective is to determine status in vegetation structure, species composition, natural and anthropogenic disturbance and soil condition in alpine vegetation within the parks. The ROMN would consider adding this objective should increased network funding allow us to characterize the status of vegetation and soils throughout alpine communities in the parks, not just at four select sentinel sites in each park.

These objectives are the foundation upon which all assessments, interpretation, and additional measures are built. A secondary and future goal of the alpine monitoring program is to develop quantitative methods to assess ecosystem integrity and condition in the alpine tundra through the development of bioassessment models that will incorporate empirically-defined reference condition distributions and thresholds to identify both temporal and spatial departures from these distributions within a park. Reference conditions are distributions of key response variables that serve as criteria or thresholds by which we can compare all future data (Stoddard et al. 2006). For example, N critical loads have been established for alpine vegetation and it is estimated that deposition of greater than 4-10 kg N ha^{-1} yr^{-1} may cause changes at the species and community level (Bowman et al. 2006). If we then consider 4 kg N ha^{-1} yr^{-1} a threshold for N deposition, we can describe the status of a given site by comparing measured N deposition to this value. Unfortunately, with the exception of N critical loads, few empirical and modeled reference conditions have been identified for the alpine. For instance, there is not a defined range of vascular plant diversity that can be considered as a reference for alpine communities. Developing robust reference condition distributions and thresholds for the alpine will take time and in the interim we will rely on survey data, other monitoring programs, and related research. Once reference conditions are established, we can determine the relative context of trends in vegetation and soil condition based on a comparison of park or site estimates to reference conditions. While still in the future, this remains a long-term goal because reference conditions and thresholds are the primary mechanisms for interpreting data and connecting monitoring data to the management objectives of a park.

3 Sampling Design

3.1 Sentinel Site Design and Criteria for Sampling

To meet the core objectives outlined above, we followed the sample design prescribed in the GLORIA Field Manual. The design consists of establishing four sentinel sites in the alpine on peaks representing an elevation gradient within a target region (e.g. the Sangre de Cristo Mountains, CO). The sites are established on the top of the peaks (summits) and should vary from just above treeline to the highest life zones of vegetation. Within one region, all four summits should share qualitatively similar geology, climate, disturbance, and land-use history (For more details see the GLORIA Field Manual, pages 9-15). Vegetation differences among the summits within a region should be driven primarily by elevation. The design consists of only four sentinel sites (summits) per region (in our case, only four sites within a park) but these are sampled intensively through time. Target regions and summits have been selected in GLAC, GRSA, and ROMO using the GLORIA criteria (Table 1).

Table 1. Location, elevation, date of establishment of GLORIA sentinel sites within GLAC, GRSA, and ROMO

GLORIA Summit code	Summit name	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)	Vegetation zone *estimated from photographs	Year established	Year of initial species composition
GRSA (GLORIA target region: GSD)							
SIX	Unnamed	37.861501	-105.492034	4000	alpine/nival ecotone	2008	2009
PAD	Unnamed	37.87965	-105.478217	3870	upper alpine	2008	2009
MUD	Unnamed	37.887517	-105.47665	3700	lower alpine	2008	2009
HUK	Unnamed	37.89615	-105.473733	3550	lower alpine/subalpine ecotone	2008	2009
ROMO (GLORIA target region: RMN)							
GLA	Ida	40.380617	-105.770072	3862	upper alpine	2008	2009
PIK	Unnamed	40.392956	-105.790538	3715	lower/upper alpine	2008	2009
VQS	Unnamed	40.406275	-105.799238	3623	lower alpine	2008	2009
JSM	Jackstraw	40.394304	-105.813083	3520	lower alpine/subalpine ecotone	2008	2009
GLAC (GLORIA target region: GNP)							
SWD	Seward	48.870238	-113.679656	2717	upper alpine/nival*	2004	2004
PKN	Pitamakin	48.519130	-113.446469	2493	upper alpine*	2004	2004
BSN	Bison	48.465154	-113.311013	2387	lower/upper alpine*	2003	2003
DGL	Dancing Lady	48.424477	-113.312034	2245	lower/upper alpine*	2003	2003

The primary constraint with GLORIA monitoring is the inability to infer results easily from sentinel sites to other non-sampled locations. Since sites are chosen based on models or judgment, there is element of unknown site-selection bias. It is therefore necessary to clearly specify that results apply to only the single sites (see Britten et al. 2007 for further discussion of the pros and cons of sentinel designs). However, there are numerous advantages to following the GLORIA sentinel sampling design for monitoring alpine vegetation. Mainly, the reduced cost associated with accessing remote sites allows for visiting sites more often and monitoring a greater number of parameters within a site. We will therefore have increased power to detect trends in vegetation, temperature, exotics, soil condition, and herbivory at these sentinel sites. Moreover, by following an established protocol we join a global network where all cooperators are using similar methods, and thus we increase our ability to place changes within the parks in the context of regional and global patterns.

Timing of sampling

The GLORIA Field Manual recommends visiting summits and recording vegetation composition every 5 years at a time of peak phenology. To better understand annual variation and provide information to park management in the short-term, ROMN will sample one peak annually in ROMO and if possible, GRSA, for the first 5 years and thereafter every 5 years (*SOP AlpineVCSS* Adapting GLORIA to National Parks). Visiting sites annually will allow for determining the amount of variance among years in key parameters, this in turn will provide data needed to perform power analyses. When these data are available, we will conduct power analyses to better estimate the intensity and length of sampling needed to detect a change in a resource. Specifically, we will estimate the length of time required to detect a change of 2%, a value defined from our other vegetation protocol (Manier et al. 2009) and one that we feel may be on interest to land managers.

3.2 *Optional* Alpine Probability-Based Sample Design and Criteria for Sampling

While our initial monitoring efforts will focus only on the sentinel sites, if and when time and budgets allow, we hope to increase our ability to make park-wide inferences by adding a survey design component to our monitoring approach. Probability-based surveys provide unbiased estimation of both status and, with repeated visits, trend across a resource (Larsen et al. 1995). When implemented successfully probability-based survey designs allow for unbiased inference from sampled sites to un-sampled elements of the resource of interest (Hansen et al. 1983). The goal of the optional probability-based design for the AlpineVCSS is to determine the *status* of alpine vegetation and soils in GRSA, GLAC, and ROMO in a given year.

As with all ROMN survey designs (Britten et al. 2007), the alpine survey uses a Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2003, 2004). The methods for the development of the survey design and site selection are described in *SOP AlpineVCSS* GRTS design. In brief, a probability-based survey design consists of implementing the following steps prior to field sampling: defining a resource or target population and any subpopulations of interest, creating a sample frame within the target population, selecting sites to visit within the sample frame, and determining when to sample. We define the target population as alpine vegetation in a park, the subpopulation as ecotypes, such as fellfield, and the sample frame as accessible alpine vegetation of those ecotypes within a park. We will visit 40 randomly located sites representing fellfield, dry meadow, and moist meadow tundra within a park and sample vegetation at peak phenology (June-August). In addition to describing each of these steps in more detail, we provide an example using alpine areas in GRSA in the SOP *AlpineVCSS* GRTS design.

4 Field Methods

There are four components to conducting field work for the AlpineVCSS monitoring protocol: (1) following ROMN I&M protocols for managing a field season, safety, and NPS compliance; (2) completing the GLORIA protocol and field methods; (3) extended monitoring at GLORIA sentinel sites; and (4) field methods for the optional probability-based survey design. Below, we briefly outline the resources and methods for each of these components.

All field sampling will be performed according to a set of SOPs. The purpose of detailed SOPs is to ensure that over time (and as personnel change) methods remain consistent to reduce bias and variance introduced by the observers (Oakley et al. 2003). The rationale for our approach and the field methods are summarized here, but methodological details are provided in each individual SOP.

4.1 ROMN Standard Operating Procedures

Managing a Field Season, Permits, Safety, and Data Requirements

ROMN standard administrative and equipment operating procedures cover all methods to ensure safety, resource protection, and compliance of a field crew working in ROMO, GLAC, and GRSA. In particular, permits (*SOP Admin* Permitting) and adequate safety training (*SOP Admin* Safety Preparation and Training) are required prior to research activities. End of season procedures including maintenance and storage of equipment and data are found in *SOP Admin* End of Season. Guidance for hiring and training a field crew, finding housing and park logistics, communications, and use of vehicles can also be found (*SOP Admin* Seasonal Hiring, *SOP Admin* Training, *SOP Admin* Park Logistics, *SOP Equipment* Communications, and *SOP Equipment* Vehicles, respectively). These administration and equipment operating procedures are maintained and updated by the ROMN staff and are available upon request or for NPS employees from the ROMN sharepoint site (http://imnetsharepoint/ROMN/Protocols/).

4.2 GLORIA Field Manual

Here, we briefly describe the field methods developed by the GLORIA network; detailed field methods are given in the GLORIA Field Manual and associated methods (GLORIA Field Manual amendments). The GLORIA Field Manual, associated data forms, and additional information can also be found at http://www.gloria.ac.at/.

Establishing and locating sites

Four summits per park (sentinel sites) are indentified using the GLORIA criteria as described above in section 3.1 and are referred to as a target region. Sentinel site locations (Table 1) are then uploaded to Global Positioning System (GPS) units and field crews navigate to these locations by GPS (*SOP Equipment* Using a GPS unit) and traditional orienteering skills using large area topographic maps (e.g., Trails Illustrated), site descriptions and a compass. Detailed directions and travel times for accessing the sentinel sites in ROMO and GRSA can be found in Appendix 2.

Plot layout

The plot layout at each summit consists of four types of sampling units: summit area sections, and three types of plots within these sections including: 100 m^2 plots (10 x 10 m), 9 m^2 quadrat clusters (3 x 3m), and 1 m^2 quadrats (1 x 1 m) nested in the quadrat cluster (Figure 3). Each peak is divided into 8 summit area sections, 4 lower and 4 upper, which divide the area of the peak among cardinal directions from 0 to 5 m and from 5 to 10 m below the highest point (e.g. north upper, north lower, east upper, etc.). The summit area sections are not permanently marked and are used to describe the cover types on the peak (rock, vegetation, etc) and to provide robust estimates of plant diversity on the peak. Four 100 m^2 plots were added to the GLORIA methods in 2009 and are used to better estimate plant diversity and cover on peaks with low vegetation cover. They are placed 5 m below the highest point in each cardinal direction and as with the summit area sections, are not permanently marked, and are read using line-intercept methods. There are also 4-9 m^2 quadrat clusters, one placed in each cardinal direction at 5 m below the highest point.

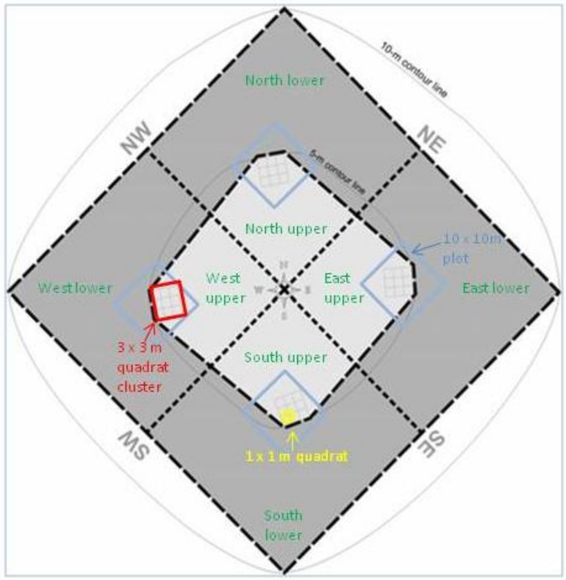

Figure 3. GLORIA summit and plot layout at sentinel sites (adapted from the GLORIA Field Manual). The highest point of the summit is in the center and all plots are located in reference to it.

Long-term markers are used to identify the corner points of each quadrat cluster and soil temperature is recorded from the center of each cluster. Finally, there are 16 1 m^2 quadrats on each peak where four are nested within each quadrat cluster. The 1 m^2 quadrats are used to record fine-scale changes in plant cover and frequency and grazing frequency. There are a few considerations and modifications of the GLORIA design for NPS units (e.g., minimal marking and selecting sites with reduced impacts to park or public visitors) that are outlined in *SOP AlpineVCSS* Adapting GLORIA to National Parks.

Vegetation

Vegetation is measured in four ways in the GLORIA field methods. The following data are collected from all summits: (1) ground cover and species abundance in summit area sections, (2) ground cover and species frequency in 100 m^2 plots (3) ground cover, species frequency and species cover in 16-1 m^2 plots per peak, and (4) grazing and trampling impact in the 1 m^2 plots. Vegetation data are recorded to the species-level for vascular plants and non-vascular plants are classified as either bryophytes or lichens. Where it is possible, lichen and bryophytes will be identified to species.

The first vegetation response variable in the GLORIA Field Manual is the absolute cover of herbaceous vegetation canopy and ground cover (e.g., litter, bare soil). Cover is the vegetation covering the ground surface as viewed from above and will be recorded by species. Advantages of using cover to measure vegetation and substrate include: cover is a direct measure of vegetation biomass, cover equalizes the contribution of abundant, small stature species and species that are larger in size, but fewer in number, and cover estimations do not require an account of each individual, so assessments are quick (Elzinga et al. 1998). Documenting the cover or extent of exposed surfaces (e.g., no vegetation cover) and characterizing the surface components also provides a means to assess the susceptibility of the surface to erosion.

Species frequency counts are done within the 1 m^2 plots where species presence is recorded in 100 10 x 10 cm grid cells. The aim of the frequency counts is to record fine-scale changes in vegetation patterns. In each grid cell, the presence of scat and evidence of browsing and trampling is also recorded. This is done to estimate the impact of herbivores on the vegetation.

Temperature

The GLORIA Field Manual recommends using buried dataloggers in the center of each 3 x 3 m quadrat cluster to measure soil temperature hourly at all peaks. Because composition and productivity of alpine vegetation may be driven by temperature and snow cover, it is critical to measure changes in temperature and snow cover over time. Soil temperature is measured rather than air temperature because buried loggers are less susceptible to damage and/or loss by animals and park visitors and avoid artificial extremes caused by high solar radiation. Soil temperature is used as a proxy for snow cover based on diurnal temperature range (temperatures remain near freezing and vary little with snow cover). We will download temperature loggers annually and replace them as needed to ensure a continuous temperature record.

Photographs

In addition to soil temperature and vegetation cover, the GLORIA methods include extensive photo documentation. This includes photographs of the highest point of the summit, location of the dataloggers, summit area sections, and all 1 m^2 plots. The methods are found in GLORIA Field Manual and the directions for use of digital cameras can be found in *SOP Equipment* Using a Digital Camera.

4.3 Extended Monitoring at GLORIA Sentinel Sites

The GLORIA Field Manual describes methods for documenting changes in vegetation and temperature at the sentinel sites. Below, we describe the methods and rationale for extending this monitoring to include measuring anthropogenic and natural disturbance, soil condition, plant phenology, distance to treeline, and N deposition.

Site context: measuring anthropogenic and natural disturbance

Observing and documenting land use and natural episodic events can provide insight into understanding status and trends in vegetation composition, structure, and soils. It is critical to document site-level disturbances especially when utilizing a small number of sentinel sites because in many cases, disturbance can act as a strong driver of change and cause direct alterations in community composition. For example, wildfire or logging may modify soils, alter the water balance, increase exposure sunlight, and introduce vectors for dispersal of new species (DeBano et al. 1998, Fleming and Baldwin 2008). Moreover, disturbances may be of particular interest to park staff because they may be able to reduce disturbances through changes in land management (e.g., reroute trails). In the alpine regions of GLAC, GRSA, and ROMO, current anthropogenic disturbances are often minimal and include trampling, heavily eroded hiking trails, and nearby roads. Historic disturbances such as logging and grazing may also be evident.

At all sites, a field crew will document potential anthropogenic stressors in and around the area in a semi-quantitative fashion. A site will be evaluated using a modified version of the 2008 Human Disturbance Index (HDI) developed by the Colorado Natural Heritage Program (Rocchio 2007) and the California Rapid Assessment Method for Wetlands (Collins et al. 2008). We use this HDI approach for evaluating site disturbance in all ROMN field protocols (e.g. streams, wetlands, grasslands) which allows for a greater understanding of park-level disturbance regimes. The index ranges from 0-100 % where the large values indicate increased disturbance. The site is surveyed and the HDI is calculated based on the severity or absence of disturbances within three general categories: buffer/landscape, hydrology, and physical disturbance. The buffer and landscape context includes measures of buffer width, adjacent land-use, degree of fragmentation within 1 km, and buffer condition. The HDI was modified for alpine vegetation to exclude many hydrological disturbances and metrics that are not relevant to upland vegetation; however, hydrological alterations relating to the presence of dikes, roads, and diversions are still recorded. Finally, physical disturbance includes metrics of soil disturbance from mechanical damage (e.g., 4WD vehicles) and onsite land use. The scores from each weighted category are combined to generate a HDI score following the equations presented in SOP *AlpineVCSS* Site Disturbance.

In addition to human disturbances, natural disturbances may have profound effects on the status and trends in alpine vegetation and soils. In protected areas, such as National Parks, natural disturbances, rather than human disturbances, are more likely to be the primary drivers of vegetation change. For the AlpineVCSS protocol, we will measure natural disturbance at sites in a semi-quantitative fashion. Each site will be surveyed for the presence and degree of impact from beaver, native ungulates, rodents, pests and pathogens, frost heave, fire, and landslides. For instance, the presence of wallows, hoof prints, standing dead shrubs, and large amounts of scat may indicate an area used heavily by elk. As with the HDI, each disturbance will be scored and a weighted mean of the scores is used to calculate the final Natural Disturbance Index (NDI). The *SOP AlpineVCSS* Site Disturbance provides detailed instructions and equations for determining the NDI.

Soil condition

Soil at each site will be characterized to assess the potential for erosion and compaction of top soils, the storage, cycling, and abundance of nutrients and water available to plants, and the potential for acidification of the soil from the deposition of pollutants. We are particularly interested in determining the status and trend in soil condition because of its direct link to vegetation condition, nutrient cycling, and water quality. Changes in soil condition may be caused by physical disturbance or anthropogenic deposition of nutrients. In the alpine tundra of the Rocky Mountains, atmospheric N deposition may be an important driver of change in vegetation via its effects on soil chemistry and nutrient availability (Fenn et al. 2003). To better characterize and inventory soils park-wide, we follow similar methods for monitoring soil in lower elevation grasslands, shrublands, and woodlands (Manier et al. 2009).

The first step in characterizing soils is to determine the area of the site covered by vegetation and bare soil. Bare ground, litter, scree (loose, rock debris), rock (bedrock, boulders, and unmovable outcrops), lichens and bryophytes on soils are measured in plots in concert with vegetation sampling (GLORIA Field Manual). To complement these measures and to better understand soil condition, an initial soil characterization at each site will be done and includes measures of the following: soil texture, bulk density, nutrients and mineral concentrations (e.g., phosphorus, aluminum, calcium), pH, carbon (C) and N content, % organic matter, cation exchange capacity, and soil aggregate stability (*SOP AlpineVCSS* Soil). Following the initial characterization, full soils characterization will be completed every 5 years. If costs allow, soil pH and total C and N will also be measured annually for the first 5 years. All soil tests will be based on soil cores taken in the field and sent to a cooperating laboratory.

The following is a more in-depth description of the soil characters we focus on and rationale for including them. *Soil texture* is a description of the percent sand, clay, and silt in a soil and is a critical component of soil monitoring (Elliott et al. 1999). Numerous soil properties are influenced by texture including: drainage, susceptibility to erosion, organic matter content, cation exchange capacity, and pH buffering capacity. For instance, soil with a high percentage of silt and clay particles has a greater erodibility than a sandy soil under the same conditions. We expect that texture will not change as rapidly as vegetation or other soil properties and will be measured at only the initial site visit. *Bulk density* is a measure of soil mass per volume and is an indicator of soil strength and structure. Soil compaction leads to an increase in bulk density and can affect porosity of soils and plant growth. Measuring bulk density is also necessary to convert soil nutrient concentrations to a volumetric measure (Elliott et al. 1999). The ability of soils to retain positively charged ions is referred to as *cation exchange capacity* (CEC). Essential plant nutrients, such as calcium (Ca2+), magnesium (Mg2+), and potassium (K+) are cations and CEC describes the ability of negatively-charged clays and organic matter in the soil to hold on to these cations. Mineral deficiencies are more likely to occur and soil pH tends to decrease faster in soils with low CEC (Robertson et al. 1999). *Soil organic matter* is the fraction of the soil that consists of plant or animal tissue in various stages of decomposition. Soil organic matter enhances aggregate stability, CEC, the soil's capacity to hold water, nutrient availability, and pH buffering capacity (Sollins et al. 1999). *Soil pH* measures the activity of hydrogen (H+) ions in soil solution. Many plant nutrients become less available to plants in acidic soils and atmospheric N deposition may lead to changes in soil pH (Robertson et al. 1999). Along with all the other soil parameters, we will estimate the concentration of plant *mineral nutrients* in the soil. Productivity is often linked to the availability and balance of plant nutrients. *Total N and C* content will also be measured and can be a useful indicator of ecosystem processes such as C sequestration, decomposition, and the potential for a site to leach nitrate (Sollins et al. 1999).

Phenology

In addition to monitoring soil condition and site disturbance, we will also monitor plant phenology at all summits. The timing of reoccurring events in an organism's life-cycle, or phenology, can be used as an indicator of climate change. In alpine systems, the growing season is short and the timing of leaf out and flowering is strongly influenced by the timing of snowmelt. To monitor phenology in our sentinel sites, we plan to record the presence of flowers for five indicator species at while conducting the summit area surveys (*SOP AlpineVCSS* Phenology). We will survey the summit area (the area encompassing 10 m below the highest point in each cardinal direction) for each indicator species and document whether they are found flowering. The indicator species were chosen based on lists published by the National Phenology Network (NPN 2009) and to include species that are highly visible, widespread, and typical of alpine environments. These include: *Dryas octopetala* (eightpetal mountain-avens), *Taraxacum officinale* (common dandelion), *Eritrichium nanum (*Alpine forget-me-not), *Silene acaulis* (moss campion), *Claytonia megarhiza* (alpine spring beauty). We will focus only on flowering, rather than all phenophases, because of the difficulty and the time required for identifying non-flowering plants in the alpine.

Treeline

Climate models predict that forests will expand upslope into alpine areas as temperatures continue to warm resulting in a change at the forest-alpine ecotone that will have large effects on C storage, nutrient cycling, wildlife habitat, and hydrodynamics (Field et al. 2007). In the past 46 years in GLAC, repeated aerial photographs suggest that there has not been a shift in treeline, but where krummholz and forest patches existed, these have increased in density and area (Klasner and Fagre 2002) Such changes in land cover and extent of forest cover will be monitored remotely via the Landscape Dynamics Protocol (Burke et al. in preparation). However, describing changes on the ground is an important component in documenting local landscape change. To document changes in treeline, we take a series of photographs of treeline from set locations at each sentinel site (*SOP AlpineVCSS* Treeline). These photographs will be repeated and compared when sites are revisited every 5 years.

N deposition

In high elevation systems with historically low nitrogen availability, the influx of N has caused changes in vegetation, soil, snow, and water chemistry (Fenn et al. 2003). The atmospheric deposition of nitrogen in the Rocky Mountains has increased in recent decades to greater than 6 kg ha^{-1} yr^{-1} (NADP 2009). As a result, it is critical to have an understanding of the current N loadings in the alpine environment. Annual N loadings may provide a covariate in trend analyses (as a driver for change) and spatial variation in N loadings may add to our understanding of different vegetation patterns within and across parks. The National Atmospheric Deposition Program (NADP) measures wet deposition of N (ammonium and nitrate), calcium, sulfate, potassium, and chloride at sites throughout the Rocky Mountains (Table 2). In addition, in collaboration with ROMN the USGS Rocky Mountain Snow Program samples snow at peak accumulation for nitrate, sulfate, and ammonium in GLAC, GRSA, and ROMO (Ingersoll et al. 2002, Ingersoll et al. 2009). While these data can provide a good understanding of current N loads in the region, there may be an interest in having a better understanding of site-level N deposition rates. This may be particularly relevant in areas of GRSA where NADP stations are distant from the park and/or at lower elevations. In *SOP AlpineVCSS* Nitrogen Deposition, we outline an inexpensive method to measure annual wet deposition in resin columns adapted from a protocol of the United States Forest Service (Fenn and Poth 2004). In brief, a resin collector is constructed using a standard rainfall collector, ion exchange resin is added, 8 collectors per site are placed in the field for 1 year, and ions are extracted from the collector and analyzed for nitrate and ammonium. Since this method should only be implemented as needed, it is considered an optional SOP.

Table 2. National Atmospheric Deposition Program stations relevant to GLAC, GRSA, and ROMO (from http://nadp.isws.illinois.edu/)

Park Unit	Relevant station codes	Locations	Elevation (m)	Dates of operation
GLAC	MT99	GLAC-St. Mary's ranger station	1391	1/25/1983 - 11/28/1989
	MT05	GLAC- Fire weather station	980	6/3/1980 - Present
GRSA	CO00	Alamosa	2298	4/22/1980 - Present
	CO91	Wolf creek pass	3292	5/26/1992 - Present
ROMO	CO19	ROMO- Beaver Meadows	2490	5/29/1980 - Present
	CO98	ROMO- Loch Vale	3159	8/16/1983 - Present

4.4 Field Methods for *Optional* Alpine Probability-Based Survey Design

The rationale and sampling design for a park-wide survey of alpine tundra is described above (Section 3.2) and in *SOP AlpineVCSS* GRTS design. Here, we briefly describe the field methods that will be conducted at each survey site. These methods are optional and will only be done if time and budgets allow for the intensive survey of alpine within a park. While we will measure species richness and composition, the field methods differ from the GLORIA Field Manual. We chose to change field methods for the survey because the GLORIA approach is labor intensive (e.g., 16-1 m^2 plots per peak) and designed for sparsely vegetated peaks. Instead, we modified field methods from the ROMN Wetlands Ecological Integrity (WEI) protocol (Schweiger et al. in preparation) by including only those procedures relevant to upland vegetation (e.g., groundwater wells are not installed). The WEI methods were chosen because they are more efficient (multiple sites can be done per day), they have been implemented in alpine wet meadows in ROMO, are better adapted for vegetation that includes woody components (e.g., willows) than the GLORIA Field Manual, and most metrics are consistent with those measured in the GLORIA Field Manual (e.g., species cover in 1 m^2 plots).

The probability-based design field method involves five steps that are outlined below and described in detail in the corresponding SOPs. These include: establishing and locating sites, determining the target status of a site, replacing or moving sites, laying out plots within a site, photographing the site, and measuring vegetation and soils within the plots.

Establishing and locating sites

The initial step in the AlpineVCSS survey is to determine where and when sampling will occur. Sites to sample are determined by the sampling design (*SOP AlpineVCSS* GRTS design) and the exact timing by the relevant index period for the park. When sites are selected, site dossiers are created to include maps of each site and relevant metadata (directions, estimated travel time, etc.). Site locations are uploaded to GPS units. Field crews navigate to these locations by GPS (*SOP Equipment* Using a GPS unit) and traditional orienteering skills using large area topographic maps (e.g., Trails Illustrated), site descriptions and a compass.

Once a field crew has navigated to a site, they must determine whether the site is appropriate for sampling and move or replace it if it is not suitable. There a few reasons for determining that a site is not appropriate including: safety, the presence of protected and sensitive resources (compliance) or the site is of the wrong target type. Safety and compliance issues are discussed in (*SOP AlpineVCSS* Site Suitability) and include issues like steep slopes and archeological artifacts. While the sample frame and GRTS sampling design were developed to include only areas of interest, they were based on GIS analyses and errors are inevitable based on incomplete ground truthing of data. For instance, the field crew may navigate to a site and find that rather than alpine fellfield it is sheer bedrock or an alpine wet meadow. In either case, the site is not in the appropriate target population and should be moved or replaced by the next site in the oversample list for the target type. To maintain the integrity of the survey design, strict rules regarding the moving of a survey site are followed. A site may only be shifted by a distance equal to the estimated GPS error (average of 4 m) plus the average positional accuracy in the base mapping methods (average of 9 m) used for the primary elements of the sample frame, plus (if needed) half of the longest axis of the field plot (7 m). This value is approximately 20 m. When sites are moved or replaced, it is critical that the fate of sites in the survey design be carefully recorded and tracked. The rules for moving and replacing sites are described in *SOP AlpineVCSS* Replacing Sites.

Plot layout

After determining that the site location meets the requirements of sampling, the field crews will lay out vegetation sampling plots using meter tapes and flagging. The AlpineVCSS plot design consists of a series of nested plots. The largest plot, the macroplot, measures 100 m^2 (10 x 10 m) and contains one subplot (16 m^2) and four microplots (1 m^2) (Figure 4). Details regarding layout are provided in the *SOP AlpineVCSS* Plots. These sites will not have long-tem markers (e.g., rebar); instead, plots will be marked temporarily while sampling with survey pins and meter tapes. The plot design was chosen to include a large area appropriate for estimates of plant species diversity and willow recruitment and smaller plots where cover estimates and browsing are measured with increased accuracy. Prior to sampling and before, after, or during the plot layout, it is critical that the site be adequately described to enable efficient location of sites in subsequent years and to provide a detailed overview of site environment (e.g., slope, aspect, etc.). A Sample Site Description Form should be used to clearly define (using UTM coordinates) and describe the location of the site (e.g., general topography, hydrology), and to describe the locations of the 4 corners of the macroplot and subplot (*SOP AlpineVCSS* Plots).

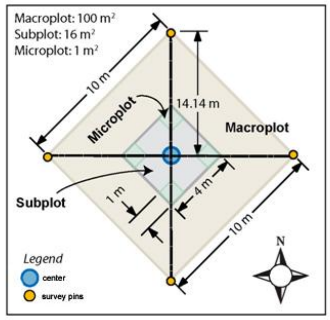

Figure 4. Plot layout for the optional AlpineVCSS survey design

Vegetation

As in the sentinel GLORIA sites, canopy cover and diversity of plant species is estimated in plots of varied size. In the microplots (1 m^2) and subplots (16 m^2) canopy cover is measured. To better estimate site-level diversity, species presence is recorded in the 100 m^2 macroplot. The detailed methods for measuring vegetation in the survey sites are described in *SOP AlpineVCSS* Vegetation.

Unlike the sentinel sites that are located on dry summits, woody plants may be present in other alpine areas. Willows (*Salix* spp.) are one the most commonly found woody plant in the alpine. Positive feedbacks between the presence of shrubs, temperature, snowpack, and nutrient availability have accelerated the encroachment of woody shrubs in many tundra systems (Sturm et al. 2001, Sturm et al. 2005). However, as a preferred browse species for elk, willow-dominated communities have been reduced or become impaired due to over browsing by expanding elk populations in ROMO (Peinetti et al. 2002, Baker et al. 2005, Gage and Cooper 2005). Consequently, the protocol includes methods for determining the presence and regeneration of willows and extent of herbivore damage. These methods include counting seedlings and sapling and recording dieback, browsing damage, and height of willows in the subplots. For details, see *SOP AlpineVCSS* Willows.

Photographs

The site will be photographed to aid in locating the site and to provide an invaluable tool for evaluating ecological change (Mast et al. 1997, Horsted and Grafe 2002). For example, processes such as tree or shrub invasion are readily apparent on photographs (Jakubos and Romme 1993). To aid in locating sites, the first set of photographs should be taken of a witness feature, such as a rock outcrop. The coordinates are recorded from a GPS and the distance and azimuth from the center of the plot to the location of witness features is determined by running a tape and using a compass. The second set of photographs involves collecting 8 photo points at fixed azimuths from the center of the macroplot (Figure 4). Finally, photographs of any noticeable disturbances, such as landslides, should be taken. A detailed discussion of photograph methods are presented in *SOP AlpineVCSS* Photographs and general instructions for the use of a digital camera can be found in *SOP Equipment* Using a Digital Camera.

4.5 Standard Operating Procedures (SOPs)

A full list of AlpineVCSS SOPs is included below (Table 3). Details of methods discussed in this narrative are included in these separate SOPS. The detailed procedures for the sentinel sites including site selection, measuring plant composition, photographs, and installation and use of dataloggers are provided in the GLORIA Field Manual.

5 Data Management and Analysis

5.1 Overview of Data Management and Procedures

The ROMN is the owner and long-term steward for all AlpineVCSS data and the management of these data follows the ROMN Data and Information Management Plan (NPS 2006b). Data management requirements for ROMN protocols include explicit procedures to enter, edit, document, store, and archive data (see *SOP DM* Data Quality Control, *SOP DM* Data Deliverable Standards and *SOP DM* Archiving Data). The GLORIA network maintains a database of soil temperatures, species composition, and photography for each target region in the network where the required format and details are found in the GLORIA Field Manual. The basic procedure for GLORIA data entry and database management requires the following steps to be completed after the field season:

(1) Create a list of all plant species within a target region that includes taxonomic authority conforms to international standards of nomenclature
(2) Email the list to the GLORIA network database managers
(3) Receive a final species list that conforms to international nomenclature where all synonyms are noted.
(4) Approve species list
(5) Receive a data entry database from the GLORIA network database managers that includes the approved species list
(6) Enter data into database, run all QA/QC analyses, and compile and copy finalized database to a CD to mail or email the GLORIA network.
(7) Enter all photographs into the GLORIA photographic database. Identify location, photographer, and date for all photographs. Send photographic database to GLORIA network.
(8) Upload temperature datalogger files to the GLORIA network via the website at: http://www.gloria.ac.at/
(9) Receive an editable and approved database back from GLORIA for data analysis and archive.
(10) Repeat procedure for each target region.

Since the GLORIA network does not maintain a database that fits all the needs of the NPS, nor does it include any of the additional field methods (e.g., soil chemistry), in addition to a copy of the GLORIA database, we will maintain a small database for extended alpine monitoring at the ROMN. We expect to complete the first draft of the AlpineVCSS database in 2009 and it will be built on the NRDT Phase III model (NPS 2007). We expect to revise the database structure with the inclusion of field data and refinement of the protocol over the next three years (2009-2012). As the database is developed and modified, the basic schematics and database structure will be included in future versions of this protocol.

Table 3. Standard Operating Procedures for AlpineVCSS protocol including published GLORIA Field Manual and associated methods, extended GLORIA methods, optional methods for a survey design, and shared ROMN SOPs.

SOP title	SOP description
GLORIA published methods	
GLORIA Field Manual	The GLORIA Field Manual: Multi-Summit Approach (Pauli et al. 2004)
GLORIA Field Manual amendments	The GLORIA Field Manual: Amendments
SOPS for extended GLORIA	
SOP AlpineVCSS Adapting GLORIA to National Parks	Considerations for adapting and establishing GLORIA in the NPS
SOP AlpineVCSS Site Disturbance	Site disturbance: Describing natural and anthropogenic disturbance to the site and surrounding area
SOP AlpineVCSS Soils	Soil condition at GLORIA sentinel sites
SOP AlpineVCSS Phenology	Phenology at GLORIA sentinel sites
SOP AlpineVCSS Treeline	Photographing the current and future location of treeline at GLORIA sties.
SOP AlpineVCSS N deposition	Deploying ion exchange resin collectors to measure N deposition (optional)
SOP AlpineVCSS Data Analysis	Guidelines for statistics and data summaries for GLORIA sentinel sites
SOPs for Survey Design (Optional)	
SOP AlpineVCSS GRTS design	Methods for developing a probability-based survey design of the alpine
SOP AlpineVCSS Site Suitability	Determining target status
SOP AlpineVCSS Replacing Sites	Moving and replacing sites
SOP AlpineVCSS Plots	Plot layout
SOP AlpineVCSS Photographs	Photographic documentation
SOP AlpineVCSS Vegetation	Vegetation composition in macro, sub, and microplot
SOP AlpineVCSS Willows	Measuring willow regeneration and herbivore damage
SOP AlpineVCSS Survey Data Analysis	Guidelines for statistics and data summaries for design-based analyses of optional survey sites
Shared ROMN SOPS	
SOP Admin Permitting	Permitting and compliance for monitoring in NPS units
SOP Admin Safety Preparation and Training	Safety requirements and training (e.g., wilderness first aid)
SOP Admin Training	Protocol and ROMN training for field crew
SOP Admin Park Logistics	Park logistics, housing, point of contacts
SOP Admin End of Season	End of season, equipment storage, data entry
SOP Equipment Using a Digital Camera	General guidelines for use of digital cameras
SOP Equipment Using a GPS unit	General guidelines for GPS use
SOP Equipment Communications	General guidelines for use of radios
SOP Equipment Vehicles	General guidelines and regulations for use of vehicles
SOP DM Data Quality Control (QC)	General data QA/QC procedures
SOP DM Data Deliverable Standards	Data deliverable standards
SOP DM Archiving Data	Procedures for archiving data

5.2 Recommendations for Routine Data Summaries and Statistical Analyses

To meet the objectives of the AlpineVCSS and to provide summary analyses for the scientific and management community, we expect to conduct a number of statistical analyses on all the data collected. While the details of the statistical methods may change, we outline below the raw data that will be collected at sentinel sites and the parameters that we will derive from the raw data (Table 5) and additional data that may be collected as part of the optional survey (Table 6). Below, we outline our general approach to statistical analyses but the approach and data are described in more detail in *SOP AlpineVCSS* Data Analysis and *SOP AlpineVCSS* Survey Data Analysis.

Status and trends and the GLORIA sentinel sites

To examine *status* at GLORIA sentinel sites, we will use descriptive statistics and linear mixed effect models or nonparametric equivalents to examine the difference in parameters among parks, summits, and summit aspects. Models will contain fixed factors (park, summit, aspect) and random factors (plot nested in aspect). Multivariate methods, such as analysis of similarity and ordinations, will use percent cover of all species to examine the differences in community structure among summits and aspects. We will explore the relationship between physical factors, such as elevation and soil chemistry, and vegetation structure using linear regression and tests of correlation. Where appropriate, these physical factors may be used as covariates in linear models. To determine which factors or drivers affect a given parameter, we will use model selection procedures and determine the best fit models using Akaike's Information Criteria (AIC) (Akaike 1973, Burnham and Anderson 2002). We are particularly interested in understanding how levels of grazing, temperatures, precipitation, and N deposition may alter community structure.

When two to three years of data are available, we may begin to examine and detect *change* at sentinel sites. To do this, we will use the same statistical methods described above but add year as a fixed factor. This will allow us to determine whether parameters, such as species richness, differ among years. After two to three years of data are available, we will conduct power analyses to determine the length of time and sampling effort required to detect a 2% change in vegetation. We will explore *trends* at GLORIA sentinel sites, when four or more years of data are available. To examine trends we will conduct repeated measures analyses where "plots" are the subject that is repeated over time.

Where it is possible, the data collected at ROMO, GRSA, and GLAC will be compared to other GLORIA sites. We are particularly interested in comparing the patterns of vegetation and temperature changes within the Rocky Mountains.

Table 4. AlpineVCSS protocol objectives and data collected relating to those objectives. Most raw data are collected in the field and the derived are calculated, but laboratory measures are indicated as lab.

Objective	Parameter	GLORIA, extended GLORIA, or optional	Raw/Derived	Units or index
Status and trend in vegetation structure and species composition at four alpine peaks	Cover of scree, rock, vascular plants, lichens, bryophytes, bare ground, litter	GLORIA	Raw	%
	Species cover (vascular plants)	GLORIA	Raw	%
	Species number	GLORIA	Derived	species
	Diversity Index	GLORIA	Derived	shannon-weiner index, H'
	Evenness,	GLORIA	Derived	Peilou index, J
	Mean Coefficient of Conservation	GLORIA	Derived	index C
	Floristic Quality Index	GLORIA	Derived	FQA index, based on C
	Species frequency counts	GLORIA	Derived	%
	Relative frequency of species	GLORIA	Derived	%
	Species presence/absence	GLORIA	Raw	categorical
	Relative frequency of graminoids and forbs	GLORIA	Derived	%
	Date of flowering	extended	Derived	Julian day
Status and trend in exotic invasive species at four alpine peaks	Identity of exotic species present	extended	Raw	categorical
	Number of exotic species present on summit	extended	Derived	species
	Percent cover of exotic species	extended	Raw	%
Status and trend in grazing at four alpine peaks	Scat presence/absence	GLORIA	Raw	categorical
	Browsing presence/absence	GLORIA	Raw	categorical
	Trampling presence/absence	GLORIA	Raw	categorical
	Browsing frequency	GLORIA	Derived	%
	Scat frequency	GLORIA	Derived	%
	Trampling frequency	GLORIA	Derived	%
Status and trend in soil temperature at four alpine peaks	Hourly temperature	GLORIA	Raw	°C
	Mean daily temperature	GLORIA	Derived	°C
	Minimum daily temperature	GLORIA	Derived	°C
	Maximum daily temperature	GLORIA	Derived	°C
	Mean annual temperature	GLORIA	Derived	°C
	Maximum annual temperature	GLORIA	Derived	°C
	Minimum annual temperature	GLORIA	Derived	°C
	Number of days above 100 °F in a given year	GLORIA	Derived	days
	First/last date of snow cover	GLORIA	Derived	Julian day
	Number of days of continuous snow cover	GLORIA	Derived	days
	First/last date of hard freeze	GLORIA	Derived	Julian day
	Accumulated growing degree days	GLORIA	Derived	growing degree days
	Diurnal temperature range	GLORIA	Derived	°C

Objective	Parameter	GLORIA, extended GLORIA, or optional	Raw/Derived	Units or index
Status and trend in soil condition at four alpine peaks	texture	extended	Derived (lab)	NA
	Sand silt and clay	extended	Raw (lab)	%
	bulk density	extended	Raw (lab)	g/m3
	pH	extended	Raw (lab)	pH
	cation exchange capacity	extended	Raw (lab)	$cmol_c$/Kg soil
	micro and macronutrients	extended	Raw (lab)	%
	organic matter	extended	Raw (lab)	%
	C:N	extended	Derived (lab)	ratio
	surface flow evidence	extended	Raw	ordinal
	rills and gullies	extended	Raw	ordinal
	pedestals and terracettes	extended	Raw	ordinal
	distance to road	extended	Derived	m
Status and trend in site characteristics and disturbance at four alpine peaks	human disturbance index	extended	Derived	%
	slope	extended	Raw	degrees
	elevation	extended	Raw	m
	nitrogen load (ammonium and nitrate)	extended	Raw (lab)	kg/ha
	beaver disturbance	extended	Raw	categorical
	native ungulate disturbance	extended	Raw	ordinal
	frost heave disturbance	extended	Raw	ordinal
	rodent disturbance	extended	Raw	ordinal
	pest & pathogens disturbance	extended	Raw	ordinal
	landslide disturbance	extended	Raw	ordinal
	fire disturbance	extended	Raw	ordinal
	natural disturbance index	extended	Derived	index; NDI

Design-based basic summaries

When optional alpine surveys are conducted to provide park-wide inference, we will use a design-based analysis which is a fundamentally different approach than the model-based approaches described above. In essence, parameters from different sites are determined and then weighted by the probability that that site was included in the sample design (inclusion probability) providing adjusted means and variance of the parameter that then represent the entire target population. From the GRTS AlpineVCSS survey designs we can generate more precise variance estimates using a proprietary technique developed by Stevens and Olsen (2003). Known as the local neighborhood variance, it is derived from smoothed or averaged contrasts among values in the local neighborhood of a sampled point. It provides estimates 20 to 60 percent smaller (i.e., more precise) than similar traditional survey-design variance estimators (Horvitz and Thompson 1952). In summary, the data collected at each survey site are combined and used to represent the status of the alpine within a park.

There is much overlap in the parameters that are collected at the optional survey sites and the sentinel sites (Table 5). The exceptions are as follows for the survey sites: species frequency will not be measured, temperatures will not be measured, and grazing/trampling measures will be replaced with those found in Table 6.

Table 5. Objectives of the optional alpine survey component of the AlpineVCSS protocol and related data

Objectives for Alpine Survey	Parameter	Raw/Derived	units
Status of grazing in alpine tundra	dieback	Raw	%
	live stems browsed	Raw	%
	dead stems	Raw	%
	willow height class	Raw	ordinal
	willow seedlings	Raw	willows
	willow saplings	Raw	willows
	mature willows	Raw	willows
	cover of mature willows	Raw	%

Reference conditions

A final example of analysis we use involves comparisons of the status or trend in AlpineVCSS response with a defined threshold or criteria in a reference condition(s). Empirical or modeled reference conditions for most AlpineVCSS parameters are typically not known and will take time to develop. Several approaches for defining reference conditions and thresholds within reference distributions have been identified in the literature (e.g., Carpenter and Turner 2000, Williams and Tonnessen 2000, Stoddard et al. 2006) Methods the ROMN are exploring for AlpineVCSS response measures include: 1) measuring vital signs at sites that are minimally or least disturbed in or around a park and using these values as thresholds (Hughes et al. 1990); 2) using ambient, measured distributions of a vital sign as developed through survey designs in a park (with thresholds placed within these distributions arbitrarily at the 5th or 25th percentile) where dose-response relationships suggest break points or where maximum species richness occurs (Stoddard et al. 2006); 3) interpretations of historical conditions; and 4) best professional judgment (i.e., applying future condition concepts from park General Management Plans). The ROMN will develop reference conditions through cooperative research projects and adventitiously from outside research. Reference conditions and thresholds are key parts of a mature monitoring effort as they are the primary mechanisms for interpreting data and connecting to management objectives for a given park.

Once reasonable numeric thresholds or criteria exist for a given response, linear models can be used to compare measured parameters at the sentinel sites to these thresholds. For population-scale, design-based results, non-parametric tests that incorporate design structures are available. Specifically, the Wald statistic and two Chi-squared statistics suggested by Rao and Scott (1981) can be used for testing differences (Kincaid et al. 2004).

6 Reporting

The goal of the AlpineVCSS protocol is to produce scientifically sound, consistent, and comparable monitoring information that can be used to support park management and decision making. The NPS hopes to "improve park management through greater reliance on scientific knowledge" (NPS 2006a); and the production of reports and effective communication of scientific results serves as the final link in transforming data into information.

The network is preparing a detailed Communication Plan, which will identify audiences, best formats and media, and delivery systems for all ROMN results including AlpineVCSS information. Our specific internal audiences include 1) ROMN park managers, 2) ROMN park resource professionals and other park staff, 3) the ROMN Technical Committee, and the Intermountain Region, and NPS-wide I&M and Resource Stewardship Programs. Our external audiences include: 4) the academic community, 5) other government agencies, 6) non-profit/non-governmental organizations and 7) the general public.

ROMN reporting plans are outlined in Chapter 7 of the VS Monitoring Plan (Britten et al. 2007). The plan guides the general goals and concepts for reporting and communicating all ROMN data and information including monitoring results. We anticipate providing quality assured ROMN data and information including (non-sensitive) data, reports including annual reports, synthesis reports, and other products (such as project summaries) via the Internet. In general, the ROMN is committed to regular reporting of AlpineVCSS information to internal and external audiences to maximize the usefulness of our data. We will report annually on the protocol and include simple summaries of annual accomplishments (e.g., annual monitoring tasks or objectives and number and types of sample events by park), data summaries and discussion of noteworthy observations and/or issues. Comprehensive syntheses and reports will be produced every 6-10 years.

6.1 Annual Reports

The routine preparation on a predictable and recurring basis of data summaries and basic interpretation can: 1) foster program support by establishing a client base, 2) motivate continued progress in program components, and 3) serve as the foundation for more comprehensive interpretive reports. Therefore, the ROMN will produce annual summaries of all monitoring activities and present these in the hierarchical web based format (they are also available in a summary form in a traditional report format). Annual reports provide a general accounting of yearly monitoring activities, issues and problems as they arise, and a status summary of measured indicators. All ROMN monitoring protocols are peer-reviewed and revised for improvements, and these will also be present in the hierarchical web delivery system.

We recommend that annual reports from the AlpineVCSS protocol include graphical and tabular summaries of statistically significant and biologically meaningful differences among summits and aspects, and the following at a minimum:

- Number and dates that sites were visited
- Bar graphs of species richness and floristic quality index (mean ± 1 standard error) by summit
- Bar graphs of percent cover of exotic invasive species, graminoids, and forbs by summit
- Scatterplot or line graph of daily mean, maximum, and minimum temperature at each summit.
- Table or text reporting number of days with soil temperatures above 100 °F, first and last days of continuous snow cover, and first and last date of hard freeze.

Also on an annual basis, the ROMN will provide non-sensitive and non-proprietary monitoring data and information to the NPS Washington Support Office (WASO) data and information management and delivery systems. We will provide this information as bundled snapshot summaries for a particular field season, including one year's worth of data along with supporting protocols, reports, and any other documentation. These annual reports and the associated databases will be available to NPS, the Department of the Interior, and other land managers, Congress, and the Executive Branch.

6.2 Comprehensive Synthesis and Analysis

Detailed status and trend analyses and syntheses will be conducted at 6-10 year cycles (depending on the final realization of sampling). Comprehensive synthesis reports will also use the hierarchical web based format outlined in the ROMN Vital Signs Monitoring Plan (Britten et al. 2007). They will be available in a traditional report format made available in hardcopy and digitally from ROMN websites (i.e., via a portable document format). The comprehensive reports will include park- and network-level assessments. Park-level assessments will emphasize detecting and interpreting trends in individual vital sign measures, and in interactions among drivers/stressors and responses measured at similar scales and across multiple scales. For the AlpineVCSS protocol, we recommend that the 6-10 year syntheses include complete analyses of trend and site status with particular attention to changes in species richness, presence of exotic species, loss of rare species, changes in dominant life forms, and changes in growing degree days and diurnal temperature range. Changes in vegetation structure over time or differences among sites should be examined in relation to two primary stressors – N deposition and climate. Climate effects can be inferred from soil temperature parameters and modeled data from PRISM data (2009). When measured, N deposition is best estimated from ion-exchange resin collectors or it can be inferred from nearby NADP sites, Rocky Mountain Snow Program sites, or soil C:N and CEC.

Where applicable, these comprehensive reports will be submitted for publication in peer-reviewed scientific journals. Where evidence of resource degradation exists, mitigation measures will be recommended. Network-level assessments will compare status (e.g., number of species, areal extent of patch types per time unit) and trends of vital-sign measures among ROMN parks with qualitative summaries and quantitative (where possible) methods. Comparisons with regional NPS networks and other GLORIA sites also will be considered.

6.3 Protocol Publication and Review

The primary component of the AlpineVCSS protocol is the sentinel site selection and field methods and these have been replicated from the GLORIA Field Manual (Pauli et al. 2004) which has been published, implemented globally, and made available via the internet (http://www.gloria.ac.at/). The AlpineVCSS protocol, which also includes the GLORIA Field Manual, will be made available through the ROMN internet site and NPS Vital Signs Monitoring Protocol Database (http://science.nature.nps.gov/im/monitor/VitalSigns/BrowseProtocol.aspx).

Methodological details of the ROMN AlpineVCSS protocol will be re-evaluated after 1-2 seasons of data collection and at the completion of a monitoring "cycle" (every 6-10 years). The purpose of the review is to evaluate the AlpineVCSS procedures and determine where procedures fall short of stated objectives. These reviews may include suggested modifications to field methods, data analysis, and reporting based on either scientific considerations or budgetary constraints. An official programmatic review of the AlpineVCSS vegetation approach to vital signs, including the objectives, designs, methods, and results as well as the ability of the network to sustain these protocols, will be conducted after at least two parks complete sample and resample events (~2-5 years). If changes to the protocol are made, these will be included as a new revision and made available in the manner described above.

7 Administration and Operations for AlpineVCSS Monitoring

7.1 Introduction

The administration and operations required for the AlpineVCSS protocol fall under the auspices of the Annual Administrative Report and Work Plan (AARWP) process for the ROMN and all NPS I&M Networks. Each year, the ROMN Program Manager will assign an AlpineVCSS protocol "lead" responsible for all aspects of the annual work planning, field monitoring, data management and reporting cycle. This will be a ROMN Ecologist/Crew Leader (see Staffing Options in the ROMN Vital Signs Monitoring Plan, Britten et al. 2007).

7.2 Annual Work Planning

Annual work planning will include: determining annual sampling goals and objectives, budgeting, field season planning and preparation (permits, communication and planning with park staff, hiring field crew(s), arranging and conducting training, arranging housing, procuring equipment, arranging field crew transportation, etc.), and data management preparation. The Ecologist/Crew Leader will develop annual work plans and solutions in coordination with the Program Manager and Data Manager and ensure that AlpineVCSS plans integrate with the annual AARWP and ROMN Data and Information Management Plan.

We anticipate visiting one GLORIA sentinel site annually for the first five years at ROMO and GRSA and all four sentinel sites will be visited every five years. GLORIA sites were established in GLAC in 2003-04 by the USGS and will be sampled every five years. The number of days required per sample event varies with access and weather, but we will plan for 2-3 days per event.

7.3 Budget

An estimated annual budget for AlpineVCSS work will be developed by the ROMN Ecologist/Crew Leader and included in the annual AARWP. As a planning tool for AlpineVCSS monitoring and overall ROMN planning and budgeting, costs based on preliminary work in 2008-2009 in ROMO and GRSA are presented in Table 7. GLORIA sites were established in GLAC in 2003-04 by the USGS and monitoring costs are covered through their programs; however, annual planning will include communication with USGS and GLAC staff to coordinate sampling GLORIA sites in the park.

The equipment cost to outfit one field crew is approximately $2000 with the primary expense being temperature dataloggers. The ROMN purchased AlpineVCSS field equipment for 2 crews in 2008. We anticipate replacement equipment costs to keep 2 AlpineVCSS crews operating to be $1000/yr.

Table 6. Average annual costs for AlpineVCSS monitoring in GRSA and ROMO 2008-2009. ROMN Ecologist/Crew Leader salary and travel is not accounted for here but in the general ROMN personnel and travel budget.

Item	Cost
Crew members	$1,500
Vehicle lease	$2,500
Gas for vehicle	$1,000
Travel for 2 crew members	$2,500
Equipment	$2,000
Total	$9,500

7.4 Compliance and Permitting

Compliance

Compliance is being handled on a park-by-park scale. The ROMN utilizes the Intermountain Region Environmental Screening Process for each protocol and park.

The general process is for the ROMN to designate an Interdisciplinary Team (IDT) of experts familiar with the park and protocol and potentially impacted park resources. The IDT usually consists of the Ecologist/Crew Leader, a park resource management specialist(s) with expertise in natural and cultural resources of the park, the park Compliance Officer (or designee), and other Subject Matter Experts (depending on specific resources that might be impacted (e.g., a wildlife biologist if there is a Threatened or Endangered animal potentially impacted). Considerations include National Historic Preservation Act, ethnographic resources, Endangered Species Act, Wilderness Act, Clean Water Act.

The role of the IDT is to work through the environmental screening process to document potential impacts of ROMN monitoring activities, recommend mitigating measures and alternatives, and recommend the appropriate level of compliance to the park superintendent. To date ROMN IDTs have recommended categorical exclusions for ROMN monitoring protocols and superintendents have concurred. Compliance for the AlpineVCSS monitoring in ROMO and GRSA has been completed. Critical documents for this process include the protocols (this document), specifically the site layout and site marking, and the monitoring design (including the map of all proposed sampling locations with alternates and replacement locations).

Permitting

ROMN policy is that NPS research permits will be acquired for each protocol and each park each field season. This is to ensure that ROMN monitoring activities are documented within the official NPS Research Permitting and Reporting System (RPRS web site). *SOP Admin* Permitting details the steps and timing for obtaining a permit and reporting annual results for all monitoring activities.

7.5 Field Monitoring

The Ecologist/Crew Leader will serve as the field monitoring Crew Leader during the field season. This includes supervising crews to accomplish annual sampling and other project goals. The Ecologist/Crew Leader will consider the safety of field crews as paramount and will never compromise safety to meet project goals. He/she will ensure that safety, training, communication, and pre and post season procedures are followed as laid out in *SOP Admin* Safety Preparation and Training, *SOP Admin* End of Season, *SOP Admin* Logistics, and *SOP Equipment* Communications.

The Ecologist/Crew Leader will also serve as the liaison with park staff and others (e.g., other cooperators) ensuring that they are aware of field monitoring plans and operations and that these are carried out in accordance with park policies and preferences.

Field crews

The ROMN monitoring program is evolving and the network continues to consider the costs: benefits of hiring options for field crews. Options include using volunteers, Student Conservation Association (SCA) interns, other interns, students hired through a university cooperative agreement, employees hired under the Student Temporary Employment Program (STEP) or Student Career Employment Program (SCEP) authorities, employees hired by the ROMN under seasonal or term employment hiring authorities, and employees hired and managed by a ROMN park.

In 2008-2009, the ROMN utilized volunteers, ROMN park employees, and ROMN staff to conduct AlpineVCSS monitoring. In addition, specialists were hired temporarily through a Professional Services Agreement to assist in the identification of non-vascular plants. The procedures for hiring and managing crew members under these options are documented in the network’s general field season *SOP Admin* Hiring.

Competent, well-qualified, and detail-oriented observers are essential for the collection of credible, high-quality vegetation data. Crew members must be skilled in accurately estimating species cover and identifying plant species. They should also have good organizational skills, and the ability to work methodically and consistently. Alpine areas are rugged, high elevation, and remote. Thus, crew members must also be physically fit, able to carry a 40 lb. pack and have tolerance for working outdoors in a range of conditions and be able to travel on foot to remote sites and camp in remote areas.

Training is essential for developing skilled field observers. The Ecologist/Crew Leader will be responsible for ensuring that field crews have adequate training for their work. This will include training in AlpineVCSS field and data management methods, safety, and communication (*SOP Admin* Training). For instance, all crew members should read and become familiar with the monitoring protocol and the flora of individual parks. Crew members will be trained in cover estimation at the start of the field season, and throughout the field season observers' cover estimates will be compared to ensure consistency. Observer bias in the estimation of cover and the misidentification of species can affect the ability to detect trends in vegetation over time.

8 Revising the Protocol

8.1 Protocol Evaluation

Methodological details of the ROMN AlpineVCSS protocol are re-evaluated after 1-2 seasons of data collection. An official programmatic review of the AlpineVCSS vegetation approach to vital signs, including the objectives, designs, methods, and results as well as the ability of the network to sustain these protocols, will be conducted after at least two parks complete sample and resample events (~2-5 years). Subsequent reviews should be conducted at least every 10 years, and more frequently as desired by ROMN staff, WASO I&M, the ROMN Board of Directors and ROMN Technical Committee. Changes will be documented in the change history (below) and the newest version will be made available through the ROMN internet site and the NPS Vital Signs Monitoring Protocol Database (http://science.nature.nps.gov/im/monitor/VitalSigns/BrowseProtocol.aspx).

8.2 Peer-Review Process

The AlpineVCSS protocol is adapted from GLORIA Field Manual (Pauli et al. 2004; http://www.gloria.ac.at/?a=20). It includes additional design elements and measures to meet additional ROMN monitoring objectives. The ROMN protocol was developed and written with scientific and technical input and review by many partners including ROMN park resource managers, biologists and ecologists. The protocol benefitted from input and advice from other parks, networks and partners who have adapted GLORIA field methods (see Acknowledgements). The protocol benefitted from an informal review by Tara Carolin, Gretchen Baker, and Regina Rochefort. We incorporated their input into the final protocol.

8.3 Change History

Previous version	Date	Author	Change description	Reason

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Appendix 1. Bibliography and Investigator Annual Reports of Research Completed in ROMO, GRSA, and GLAC Pertaining to Alpine Vegetation

The following bibliography was compiled in May 2009 via searching Web of Science and NatureBib for articles that included the park names (Glacier, Great Sand Dunes, or Rocky Mountain), alpine or tundra, and plant or vegetation. The investigator annual reports were found in May 2009 via the NPS research and reporting system (https://science.nature.nps.gov/research/ac/ResearchIndex).

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Recent Investigator Annual Reports from GLAC and ROMO Pertaining to Alpine Vegetation (none available for GRSA) May 2009

Glacier National Park

Year	Principal Investigator	Research Topic
2007	Bowman	Critical loads and N deposition in alpine vegetation.
2007	Sawyer	Patterned ground in an alpine tundra environment. Studied rock circle patterns due to frost heave.
2005	Resler	Plant interactions at tree-line
2006	Franklin	Herb chronology and dating recent glacial fluctuations
2004	Murray	Pygmy poppy genetic study
2004	Malanson	Invasibility of tundra in Northern Rockies. Remote sensing and modeling of feedback and shifts in treeline.
2004	Hartley	Long-term natural recovery of alpine vegetation from human trampling. Logan Pass. 40 year study of recovery.
2003	Gielstra	Conifer invasion in subalpine meadows
2003	Fagre	Invasibility in tundra. Model and field data on tree establishment in the tundra.
2002	Lesica	Monitoring effects of global warming using rare plants in wet alpine tundra.
1994	Damm	Inventory of alpine vegetation.

Rocky Mountain National Park

Year	Principal Investigator	Research Topic
2007	Bowman	Critical loads and N deposition in alpine vegetation.
2007	Benedict	Paleoenvironmental significance of spruce trees melting from an ice patch above timberline in the Mummy Range.
2007	Leukering	Monitoring birds with a tundra site at Sundance Mountain.
2007	Steltzer	Elk impacts on alpine willow communities.
2005	Hufford	Phylogeography of *Synthyris* across the Rockies.
2005	Malanson	Response of western mountain treeline to climatic variability and change.
2005	Wagner	Life history and ecophysiology of some arctic-alpine annual plant species.
2004	Liptzin	Effects of N decomposition and nutrient cycling at an ecotone.
2001	Rhode	Human trampling disturbance along alpine tundra social trails.
2000	Weigant	Vascular plant diversity at fellfields in RMNP.
1998	Rochelle	Pedogenic effects of krummholz migration
1997	Redente	Soil N availability affects on alpine tundra recovery.
1994	Baker	Potential response of forest tundra ecotone to global climate change.
1993	Willard	Recovery of alpine from trampling
1992	Aitken	Nival nests of pocket gophers.
1992	Stohlgren	Potential effects of global change on vegetation in the Colorado Rockies.

Appendix 2. Directions and Details of Site Access for GLORIA Work in GRSA and ROMO

Notes on accessing GLORIA sites: GRSA

Summit Code	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)	Trailhead	Approximate travel time
SIX	37.861501	-105.492034	4000	Medano Lake	3 hours to campground; ~2 hours to peak
PAD	37.87965	-105.478217	3870	Hudson Ditch	3 hours
MUD	37.887517	-105.47665	3700	Hudson Ditch	3 hours
HUK	37.89615	-105.473733	3550	Hudson Ditch	3 hours

Access to the summits requires ~3 hours of hiking and all field work should be completed prior to ~ 1 pm to avoid afternoon storms. We recommend the following access plans:

(1) Summit 1: The highest peak, N of Mt. Herard, is most easily accessed via the Medano Lake Area. Access will require backpacking into the Medano Lake campsite. The trail is approximately 4 miles uphill. A 4WD high clearance vehicle is required for access to the trailhead. From the campsite, the peak can be accessed in about 2 hours following a trail to just past Medano Lake and then scampering up the steep SE face of the summit.

(2) Summits 2, 3, 4: The lower summits can be accessed from 3 areas: walking along a ridge from Music Pass, up and over two ridges from Medano Lake, or via the Hudson Ditch. All access routes require ~3 hours of hiking, while the hike from Hudson Ditch requires a greater increase in elevation, it provides the best and safest access because much of the hike is below treeline. The Hudson Ditch trailhead can be accessed from Medano Pass with a 4WD high clearance vehicle. There is a primitive campsite at the trailhead that could be used. From Hudson Ditch, access sites by bushwhacking and following game trails along Hudson Creek, after passing Muddy Hill (~2miles), head N and straight up hill to a saddle below Padilla Peak. The saddle can be used as a backpacking camp. All summits can be accessed easily from this point and from one another.

Notes on accessing GLORIA sites: ROMO

Summit Code	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)	Trailhead	Approximate travel time
GLA	40.380617	-105.770072	3862	Milner Pass/ Ute Trail	2.5- 3 hours
PIK	40.392956	-105.790538	3715	Milner Pass/ Ute Trail	2 hours
VQS	40.406275	-105.799238	3623	Milner Pass/ Ute Trail	1.5 hours
JSM	40.394304	-105.813083	3520	Timber Lake	3 hours

All field work should be completed prior to ~ 2 pm to avoid afternoon storms. Access to all sites is possible on day hikes from the trailhead. However, campsites in the area of Jackstraw Mountain provide more efficient access for JSM and GLA. From the Milner Pass/Ute trail head, hike towards Mt. Ida and once in the alpine, leave the trail and navigate to the sites. VQS has a vision quest site (e.g., a small stone structure) on the peak. Both VQS and PIK are not true peaks, but rather are ‘peaklets’- small bumps ~20 m above the existing tundra.

SOP AlpineVCSS Adapting GLORIA to National Parks

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

The National Park Service has played a large role in the protection and preservation of high elevation mountain ecosystems due to their natural splendor, unique assemblages of flora and fauna, and their critical function as a source of water for much of the United States. Despite protection, alpine systems are increasingly threatened by climate change and atmospheric pollution. The Global Observation Research Initiative in Alpine Environments (GLORIA) is an international effort to monitor alterations in biodiversity and vegetation patterns in the world's high mountain ecosystems caused by climate change. There is immense potential in fostering the partnership between GLORIA and NPS. However, there are challenges and unique opportunities when implementing research and monitoring in NPS units that may or may not be relevant to other areas. Below we outline tips on how our program (ROMN) implemented GLORIA effectively and modified the GLORIA Field Manual (Pauli et al. 2004) to meet NPS regulations.

2.1.1 Site Locations

The GLORIA methodology requires that summits that are selected should be within one climate region, of a similar geomorphology, bedrock material, and habitat situation. Moreover, the selected summits should be “pristine” or exhibit “low to moderate impact from land use.” Many appropriate sites within National Parks fall within the category of “no present land use and the influence of historic land use is negligible.” Still there are sites that are heavily visited by hikers and/or rock climbers or heavily used by wildlife. To pick the best summits:

- Avoid large numbers of visitors by choosing unnamed summits and summits without marked trails.
- Consult park personnel and management to find the most popular areas with visitors and avoid these.

- Consult park personnel and management to avoid known favorite spots of bighorn sheep, mountain goats, and elk. In addition to the potential damage to plots, repeated visitation may cause stress to the animal populations.
- Where possible, avoid wilderness areas where access is very limited and markings are discouraged.
- Locate plots on “peaklets” or small rises off the shoulder or ridge to a larger peak.
- Find the best locations using topographic maps, hiking, and consulting with park personnel.

2.1.2 Long-term marking

The GLORIA methodology recommends short aluminum tubes to be used as plot markers on all corners of the 3 x 3 m quadrat clusters (4 quadrats per summit; 16 markers per summit). The highest summit point should be marked with a small cross cut into solid rock or metal stakes. After discussion with park personnel, we found the following option best fit the needs to establish long-term plots while limiting visible markers and unmarked rebar in the tundra.

- Mark the highest summit point with a rebar and an aluminum rebar cap marked:
  “NPS ROMN I&M Veg (plot) 2008 DO NOT DISTURB”
- Mark only the lower left (looking towards the summit) corner of the 3 x 3m quadrat clusters with a labeled rebar (as above). This should lie 5 m in elevation below the summit (Figure 1).
- Mark the remaining 3 corners of the 3 x 3m quadrat cluster with nails. The nails have labeled collars that lie flush with the soil surface marked “NPS ROMN I&M”

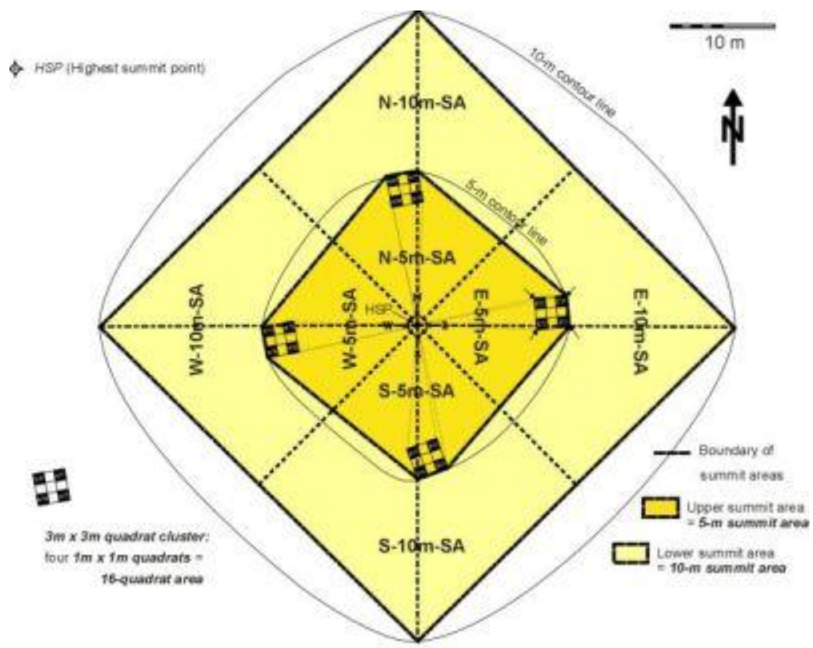

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Figure 1. GLORIA plot layout

2.1.3 Dataloggers

The GLORIA protocol recommends using StowAway Tidbit temperature loggers buried in the center of all the 3 x 3 m quadrat clusters (4 per peak; 16 per park). Due to considerations of short-term (cost) and long-term (battery replacement), we choose to use Hobo Onset UA-001-64 temperature alarm pendant 64K dataloggers. In 2008, the cost of the 32 loggers for 2 parks (16 each for ROMO and GRSA), the base station, and software was $1593. Previous work at Niwot Ridge LTER suggests that these dataloggers typically last 1-2 years in inclement conditions. Batteries can be replaced to prolong the life of the logger.

2.1.4 Sampling

The GLORIA protocol recommends visiting summits and recording vegetation composition every 5 years at a time of peak phenology. To better understand annual variation in vegetation and provide information to park management in the short-term, the most accessible sites should be sampled annually for the first 5 years and thereafter every 5 years. The full GLORIA protocol is time intensive and not all metrics are necessary at an annual timescale, but at a minimum revisits should include cover in 100 m^2 and 1 m^2 plots. With additional time, summit area sections can be read and finally frequency of species in the 1 m^2 plots. Such an increased sampling effort will increase our power to detect trends in vegetation and soil condition.

3 Literature Cited

Pauli, H., M. Gottfried, D. Hohenwallner, K. Reiter, R. Casale, and G. Grabherr, editors. 2004. The GLORIA field manual: multi-summit approach. European Communities, Belgium.

SOP AlpineVCSS Site Disturbance: Describing Natural and Anthropogenic Disturbance to the Site and Surrounding Area

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

Observing and documenting land use and natural episodic events can provide insight into understanding status and trends in vegetation composition, structure, and soils. It is critical to document site-level disturbances because in many cases, disturbance can act as a strong driver of change and cause direct alterations in community composition. Moreover, disturbances may be of particular interest to park staff because they may be able to reduce disturbances through changes in land management (e.g., reroute trails). In the alpine regions of GLAC, GRSA, and ROMO, current anthropogenic disturbances are often minimal and include atmospheric pollution, trampling, heavily eroded hiking trails, and nearby roads. Historic disturbances such as logging and grazing may also be evident. In addition to human disturbances, natural disturbances may have profound effects on the status and trends in alpine vegetation and soils. In protected areas, such as National Parks, natural disturbances, rather than human disturbances, are likely to be the primary drivers of change. This SOP provides detailed instructions outlining how to complete both natural and anthropogenic disturbance assessments.

At all sites, a field crew will document potential anthropogenic stressors in and around the area in a semi-quantitative fashion. A site will be evaluated using a modified version of the 2008 Human Disturbance Index (HDI) developed by the Colorado Natural Heritage Program (Rocchio 2007) and the California Rapid Assessment Method for Wetlands (Collins et al. 2008). The index ranges from 0-100 % where the large values indicate increased disturbance. As with the HDI, each disturbance will be scored and then the final calculated Natural Disturbance Index (NDI) is a weighted mean of the scores.

3 **Steps**

In order to get a more complete picture of each site and its surrounding landscape, crews should evaluate disturbance levels and sources as they are walking to each site and be aware of stressor types while doing field work. For this reason, under normal circumstances, crews should complete this form last as they are about to leave a site. Data collected to document anthropogenic stressors follow a modified version of the Human Disturbance Index that was developed by the Colorado Natural Heritage Program; crews will record natural disturbance in a separate section as these metrics are analyzed independently from the human disturbance measures.

3.1 Equipment

- HDI forms
- NDI forms
- pencil

3.2 Procedures

Human Disturbance

The Human Disturbance Index form (see below) is divided into three categorical sections: Alterations within buffers and Landscape Context, Hydrological Alterations, and Physical Disturbances. To use the form:

1. Score each metric in every category to best match the condition description.
2. The Adjacent Land Use (Buffer) and Onsite Land Use (Physical Disturbance) metrics require additional steps to compute. These metrics are measured by documenting surrounding land use(s) in the site and within a 100m buffer, respectively. To calculate these scores, estimate the % area under each land use type (see Forms below). Do this separately for both Adjacent Land Use and Onsite Land Use metrics. Multiply these percentages by their corresponding coefficients. Add these products to reach a single total for each metric. Use the resulting subtotals to select the corresponding scores for the Adjacent and Onsite land use metrics on the main Human Disturbance Index form.
3. To calculate each category (e.g., Physical Disturbance) subtotal score, sum the two highest (worst) metric scores, divide by 20, and multiply by 100.
4. Each category is assigned a weight. To calculate a final score for the site, multiply the category score by each respective weight, then sum the products to reach a final site score. The final score will fall between 0 and 100 with 0 being the most “pristine” and100 representing a highly disturbed site.
5. The calculations in Steps 2-4 can largely be done automatically in Excel or with a Visual Basic script. The Network recommends taking advantage of an automated process in order to minimize errors that might be more common if done manually in the field.

Natural Disturbance

To complete the Natural Disturbance form:

1. Use the Key to assign a disturbance level to each of the seven metrics (plus “other”).
2. In the Comments field, indicate any qualifications to the assigned rating or any additional information that you want to convey about individual metrics

4 **Forms**

VCSS Human Disturbance form

Site ID	Start Date:	Transect Name	Start Time	Botanist	
				Recorder	

Score each metric based on corresponding description.

Alterations within Buffers and Landscape Context	Score
1a. Average Buffer Width This metric is measured by estimating the width of the buffer surrounding the assessment area. Buffers are natural vegetated areas with no or minimal human-use. Buffer boundaries extend from the assessment area edge to intensive human land uses which result in non-natural areas. Some land uses such as light grazing and recreation may occur in the buffer, but other more intense land uses should be considered the buffer boundary. Irrigated meadows may be considered a buffer if the area appears to function as a buffer between the assessment area and nearby, more intensive land uses such as agricultural row cropping, fenced or unfenced pastures, paved areas, housing developments, golf courses, mowed or highly managed parkland, mining or construction sites, etc.	
0pts Wide > 100 m	
3pts Medium 50 m to <100 m	
7pts Narrow 25 m to 50 m	
10pts Very Narrow < 25m	
1b. Adjacent Land Use This metric is measured by documenting surrounding land use(s) within 100 m of the outer buffer boundary. To calculate a Total Land Use Score estimate the % of the adjacent area within 100 m of the buffer boundary under each Land Use type and then plug the corresponding coefficient (Table 1) with some manipulation to account for regional application) into the following equation: *Sub-land use score* = ∑ LU x PC/100 where: LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type. Do this for each land use within 100 m of the buffer edge, then sum the Sub-Land Use Score(s) to arrive at a Total Land Score. For example, if 30% of the adjacent area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).	
0pts Average Land Use Score = >95	
3pts Average Land Use Score = 80 to <95	
7pts Average Land Use Score = 40 to <80	
10pts Average Land Use Score = <40	
1c. Percentage of Unfragmented Landscape Within One Kilometer This metric is measured by estimating the area of the largest block of unfragmented area in a one km buffer surrounding the assessment area and dividing that by the total area. This can be completed in the office using aerial photographs or GIS.	
0pts Embedded in 90–100% unfragmented, roadless natural landscape	
3pts Embedded in 60–90% unfragmented, roadless natural landscape	
7pts Embedded in 20–60% unfragmented, roadless natural landscape	
10pts Embedded in <20% unfragmented, roadless natural landscape	
1d. Buffer Condition The condition of a buffer is assessed according to the extent and quality of its vegetation cover and the overall condition of its substrate. Evidence of direct impacts by people are excluded from this metric and included in the Land Use Calculations. Buffer conditions are assessed only for the portion of the site border that has already been identified or defined as buffer, based on 1a. If there is no buffer, assign a score of 10.	
0pts Buffer is dominated by native vegetation, has undisturbed soils, with little or no human use.	
3pts Buffer is characterized by an intermediate mix of native and non-native vegetation, but mostly undisturbed soils and is apparently subject to little or no human visitation.	
7pts Buffer is characterized by substantial amounts of non-native vegetation AND there is at least a moderate degree of soil disturbance/compaction, and/or there is evidence of at least moderate intensity of human visitation.	
10pts Buffer is characterized by barren ground and/or highly compacted or otherwise disturbed soils, and/or there is evidence of very intense human visitation.	

PAGE ___ of ___

VCSS Human Disturbance form

Site ID	Start Date:	Transect Name	Start Time	Botanist	
				Recorder	

Score each metric based on corresponding description.

Hydrological Alterations	Score
2. Hydrological Alterations Measured by evaluating land use and human activity within or near the assessment area which appear to be altering hydrology of the site. (See Table 1)	
0pts No alterations. No dikes, diversions, ditches, flow additions, pugging, or fill present in assessment area that restricts or redirects flow	
4pts Low intensity alteration such as roads at/near grade, pugging, small diversion or ditches (<1 ft. deep) or small amount of flow additions	
12pts Moderate intensity alteration such as 2-lane road, low dikes, pugging, roads w/culverts adequate for stream flow, medium diversion or ditches (1–3 ft. deep) or moderate flow additions.	
20pts High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable to lowering water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions	
Physical Disturbance	**Score**
3a. Substrate/Soil Disturbance Select one or double check and average. This metric evaluates physical disturbances to the soil and surface substrates of the area. Examples include filling and grading, plowing, pugging (hummocking from livestock hooves), vehicle use (motorbikes, off-road vehicles, construction vehicles), sedimentation, dredging, and other mechanical disturbances to the surface substrates or soils.	
0pts No Apparent Modifications	
3pts Past Modification but Recovered; OR Recent but Minor Modifications	
7pts Recovering OR Recent and Moderate Modifications	
10pts Recent and Severe Modifications	
3b. Onsite Land Use This metric is measured by documenting onsite land use(s) occurring in the assessment area. Follow the same procedures as in Metric 1a. Adjacent Land Use	
0pts Average Land Use Score = >95	
3pts Average Land Use Score = 80 to <95	
7pts Average Land Use Score = 40 to <80	
10pts Average Land Use Score = <40	

PAGE ___ of ___

VCSS Human Disturbance form

Site ID	Start Date:	Transect Name	Start Time	Botanist	
				Recorder	

Table 1. Land Use Coefficient Table[1]

Current Land Use	% Site	% Adjacent
Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation		
Unpaved Roads (e.g., driveway, tractor trail) / Mining		
Agriculture (tilled crop production)		
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)		
Logging or tree removal with 50-75% of trees >50 cm dbh removed		
Hayed		
Moderate grazing		
Moderate recreation (high-use trail)		
Selective logging or tree removal with <50% of trees >50 cm dbh removed		
Light grazing / light recreation (low-use trail)		
Fallow with no history of grazing or other human use in past 10 yrs		
Natural area / land managed for native vegetation		

Natural Disturbance form

Natural Disturbances

Evidence may be observed while walking through the site, to and from the site, or from best observation location

-Site to 1 km scale-

		Code	Comment	KEY
Beaver, lodge, dam, canal, runway, food harvesting, gnawing of woody materials viable beaver habitat (forage, slope, distance to water)?	Beaver:			1 - *High* : Majority (> 50%) of site has recent evidence
Observation or evidence of elk, moose, deer, or big horn sheep, such as wallows, hoof punching, Do not include herbivory from domestic animals.	Native Ungulates:			2 - *Medium* : Some recent or old (>10yr) evidence on site
	Frost Heave:			3 - *Low* : No sign on site at least some evidence in (~1km) area around site
Castings, burrows, etc	Rodents:			
Blackened/burned trees, downfall caused by fire, etc. Do not try to identify the source or cause	Fire:			4 - *None* : No signs in site or in (~1km) area around site
Evidence of beetles (any species), dead or dying trees	Pest &Pathogens:			6 - *Other*
Rock debris, felled trees Do not try to identify the source or cause	Landslide:			(explain in notes)
Please provide detail in Notes	Other:			

Notes for Natural Disturbance:

PAGE ___ of ___

5 **References**

Rocchio, J. 2007. Floristic quality assessment indices for Colorado plant communities. Unpublished report prepared for the Colorado Department of Natural Resources and US EPA Region 8. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A.Wiskind. 2008. California Rapid Assessment Method (CRAM) for Wetlands. Version 5.0.2. 151 pp.

SOP AlpineVCSS Soils

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

In addition to vegetation measures, soil at each site will be characterized to assess the potential for erosion and compaction of top soils, the storage, cycling, and abundance of nutrients and water available to plants, and the potential for acidification of the soil from the deposition of pollutants. This SOP describes the method for conducting surveys of soil condition and bulk density and collecting soil cores in the field. Procedures for bulk density follow the USDA soil quality test kit guide (1999) and procedures for the remaining soil tests follow guidance by Robertson et al. (1999). Soil cores will be sent to a cooperating laboratory for the analysis of soil texture (0-20 cm), nutrients and mineral concentrations (e.g., P, Mg, Mn, Al , Ca), soil pH, carbon and nitrogen content, % organic matter, and cation exchange capacity.

3 Steps

3.1 Soil Surface Condition

For each peak, a brief survey should be done to describe soil condition and potential for erosion in the area. There are three main classes to describe: surface flow, rills and gullies, and pedestals and terracettes and each of these can range from extreme degradation to none (Table 1). This survey should be done when first arriving at a site and the average conditions across the entire peak area are recorded (from the peak to 10 m below peak).

Table 1. Classes for characterization of soil surface conditions (adapted from Herrick et al. 2005)

Degree of Degradation	Surface Flow Evidence	Rills and Gullies	Pedestals and Terracettes
	Erosion caused by overland flow, i.e., as water moves across the soil surface. Evidenced by litter, soil or gravel redistribution along flow-paths, especially small debris piles. Wind-scoured areas (may create blowouts) are recognized by removal of finer particles of the topsoil, sometimes leaving gravel, rock, or exposed roots on the surface. Deposition areas are often associated with vegetation or topographic relief.	Rills are small eroded rivulets that are generally linear and do not necessarily follow microtopography. A gully is a channel that has been cut into the soil by moving water; they generally follow natural drainage patterns. Gullies and rills are a natural component of many landscapes, but excessive grazing, vehicles or road drainages may cause excessive formation or expansion	Pedestals are rocks or plants that appear elevated because of soil loss from wind or water erosion around them (also by frost heaving or soil/litter deposition). Terracettes are small benches of deposited soil behind obstacles. Both are important indicators of movement of soil by water and/or wind. Terracettes caused by livestock or wildlife movements, e.g., across hillsides, are not considered erosion, so they should not be considered here.
Extreme (XX)	Extensive with active erosion and unstable soils (water and/ or wind caused); connections between flow paths lead to wide area affected	Rill formation is severe, well defined, and widespread. Gullies, when present, are actively down-cutting without vegetation to stabilize slopes and bed.	Many rocks and/ or plants pedestalled; exposed plant roots are common. Abundant across the area.
Moderate to Extreme (MX)	Cut/ eroded and depositional areas are common; occasionally connected.	Rill formation is moderate but active and well defined throughout most of the area.	Some rocks and plants with occasionally exposed roots; not ubiquitous across the area.
Moderate (MM)	Erosion is minor with some evidence of erosion and deposition, but not widespread across large areas.	Some intermittent rill formation, not widespread, but in the most exposed areas only.	Some pedestals, but only in major flow paths and exposed slopes; occasional terracettes.
Slight to Moderate (SM)	Flow patterns are stable and short; minor erosion evidence only (few and infrequent).	No recent formation of rills. Gullies, if present, are stabilized by vegetation on slopes and in the bed. (Older features have rounded or muted edges.)	Some evidence of past pedestals in flow patterns, but recent pedestals and terracettes are rare.
None to Slight (NS)	Minimal evidence of current or past soil movement.	No current rill formation. Drainages are natural, stable channels.	Little to no evidence of pedestals or terracettes. (Uncommon or absent)

3.2 Soil texture bulk density

Soil texture and bulk density describes the physical structure of the soil and influence many ecosystem processes, particularly water movement in soils (Elliot et al. 1999). Soil texture and density will be measured during the initial site visit and thereafter every 5-10 yr. Bulk density ranges between 0.6 and 1.8 g cm^{-3} and more typically ranges between 1.0 and 1.4 g cm^{-3}. Soil texture measures the percent composition of sand, silt, and clay (Elliot et al. 1999). Both measures can be used to better interpret other soil parameters and to better describe variation among sites. Soil texture will be measured in the laboratory and bulk density will be measured in the field and laboratory

Field Equipment

- Plastic wrap
- 140-cc syringe
- 1 L of water
- soil knife
- sealable bags and marker pen
- 2-mm sieve
- Permanent marker

Laboratory equipment

- scale (0.1 g precision)
- 1/8-cup (30 mL) measuring scoop
- paper cup or bowl
- access to a microwave oven

Procedures

(1) Dig a bowl shaped hole approximately 3 in deep x 5 in diameter using a soil knife (Figure 1) ~ 2m below the 3 x 3 m quadrat cluster on the north aspect of the peak. Choose a spot that is as level as possible to allow water to fill the hole evenly. Avoid compacting the soil in the hole while digging. Place all of the soil and gravel removed from the hole in a plastic bag.

Figure 1. Excavated hole for soil bulk density methods. The hole is lined with plastic, rocks have been replaced back into hole, and it is ready to have water added. Photograph reproduced from USDA soil quality test kit guide (1999).

(2) Using a 2-mm sieve, sieve the soil in the plastic bag into another plastic bag to separate the gravel. Collect the soil in a plastic sealable bag. Put the rocks and gravel aside to be used in Step 2. Seal and label the plastic bag with date, target region code, peak code, and aspect (e.g., “July 14, 2009 US-RMN-JSM North”). If the soil is too wet to sieve, bring the gravel and soil back to the laboratory to dry and sieve and ignore the part in Step 3 about replacing rocks.

(3) Line the hole with plastic wrap as shown in Figure 1. Leave some excess plastic wrap around the edge of the hole. Place the sieved rocks and gravel carefully in the center of the hole on top of the plastic wrap. Assure that the pile of rocks do not protrude above the level of the soil surface.

(4) Add water to hole. Use the 140 cc syringe to keep track of how much water is needed to fill the lined hole. The level of the water should be even with the soil surface. The amount of water represents the volume of soil removed. Record the total amount of water in cubic centimeters (1 cc = 1 cm^3) on the Soil Data worksheet.

(5) Where possible, back fill hole with soil, litter or debris to reduce future erosion.

(6) Repeat procedure on the east, west, and south aspect.

Steps done in the office/Laboratory.

(7) Weigh the soil sample in its bag. Enter the weight on the Soil Data worksheet.

(8) Weigh an empty plastic bag to account for the weight of the bag. Enter the weight on the Soil Data worksheet.

(9) Extract subsample to determine water content and dry soil weight. Mix sample thoroughly in the bag by kneading it with your fingers. Take a 1/8-cup level scoop subsample of loose soil (not packed down) from the plastic bag and place it in a paper cup (a glass or ceramic cup may be used).

(10) Weigh the soil subsample in its paper cup. Enter the weight on the Soil Data worksheet. Weigh an empty paper cup to account for its weight. Enter the weight on the Soil Data worksheet.

(11) Place the paper cup containing the subsample in a microwave and dry for two or more four minute cycles at full power. Open the microwave door for one minute between cycles to allow venting. Weigh the dry subsample in its paper cup and enter the weight on the Soil Data worksheet.To determine if the soil is dry, weigh the sample and record its weight after each 4+ minute cycle. When its weight does not change after a drying cycle, then it is dry.

(12) Mail or deliver the dried soil samples to the following address requesting soil texture analysis (current as of Jan 2009; check address at later dates):

Dr. James Self
Soil, water, and plant testing laboratory
Colorado State University
Room A319, Natural and Environmental Sciences Building
200 West Lake Street
Fort Collins, Colorado 80523-1120

Table1. Sample soil data worksheet for bulk density

Bulk Density and Soil Water Status for Gravelly Soils (excavation method)										
	Sample site	(n) Volume of water (cm^3)	(E) Weight of field moist soil + bag (grams)	(F) Weight of bag (grams)	Subsample for determinng soil water content				** (M) Soil H_2O content (g/g)	*** Soil bulk density (g/cm^3)
					(G) Weight of paper cup (grams)	(I) Weight of paper cup + soil (g)	(K) Dry weight of soil + cup	* (L) Dry weight of soil (grams)		
1										
2										
3										
4										
*Dry wt. of soil subsample = (K - G)				**Soil H_2O content = (I - K)/L						
***Soil bulk density = [(E - F)/(1 + M)]/(n) n = volume of soil in cm^3										

3.3 Soil pH, chemistry, and soil organic matter

Soil organic matter, carbon, pH and plant nutrient concentrations can provide a powerful index of productivity and ecosystem processes and are often determinants of vegetation structure (Sollins et al. 1999). Global and local disturbances can alter soil chemistry which may result in altered vegetation composition. Soil cores will be taken during the initial site visit and thereafter every 5-10 yr and analyzed for a complete matrix of plant nutrients, % organic matter, cation exchange capacity, pH and total carbon and nitrogen. When funds are available, soil cores can be taken more frequently (annually) and a minimum analysis may include pH, total nitrogen and total carbon.

Equipment

- Soil corer (marked at 20 cm)
- whirlpaks or plastic bags
- Soil knife or trowel

Procedures

(1) Select three random locations within a 3 m x 3 m plot array but not in any of the vegetation plots. Go to the first location.
(2) Remove surface vegetation and litter to expose mineral soil.
(3) Carefully drive the soil corer to 20 cm depth. Remove corer and place soil from corer into whirlpak labeled with date, park, site, and transect. Use soil knife or trowel to assist in the removal, as needed.
(4) When possible, fill hole with litter and any loose dirt to reduce future erosion.
(5) Move to the second and third random location and repeat steps 2-4, placing all three cores from one plot array into a single bag. This will result in 1 composite sample per aspect and four samples per summit.
(6) Close whirlpak/bag and place in shade.

(7) The samples can be kept closed in plastic bags for a few days as long as they are kept cool. However, if you cannot ship samples to the laboratory within a week, the samples should be air-dried. If this is the case, find a location inside (housing/laboratory/office), place samples on a table, open the top of sample bags, and let sit until dry (or until you ship them). If there is a fan available, running it above the samples will hasten this process.

(8) When possible, pack the sample and others in a box. Mail to the following address requesting analysis for pH, electrical conductivity, cation exchange capacity, organic matter, nitrate-nitrogen, phosphorus, potassium, zinc, iron, manganese, copper, total nitrogen and carbon, calcium and aluminum. After the first visit or when money is limiting, this list can be reduced to pH, total carbon, and total nitrogen. Address is current as of Jan 2009, but please confirm address prior to mailing.

Dr. James Self
Soil, water, and plant testing laboratory
Colorado State University
Room A319, Natural and Environmental Sciences Building
200 West Lake Street
Fort Collins, Colorado 80523-1120

3.4 Soil samples for optional survey design

For the optional alpine survey, repeat all tests above with the following replication:

- Soil surface condition: done at macroplot scale.
- Soil texture and bulk density: 2 cores from random locations outside the subplot but within the macroplot.
- Soil chemistry: 1 composite core taken from 3 random locations outside the subplot but within the macroplot.

4 References

Elliott, E.T., J.W. Heil, E.F. Kelly, H.C. Monger. 1999. Soil structural and other physical properties in G.P. Robertson (Ed). Standard Soil Methods for Long-Term Ecological Research. Oxford University Press. Cary, NC, USA. p 74-88

Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M Burkett and W.G. Whitford. 2005. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico and University of Arizona Press, Tucson, Arizona. 2 vol., 236pp. available online at http://usda-ars.nmsu.edu/

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5 Rocky Mountain I&M Network

Vegetation Composition, Structure and Soil Monitoring Protocol
Standard Operating Procedures AlpineVCSS Phenology
Version 1.0 (1 December 2009)

SOP AlpineVCSS Phenology

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

The timing of reoccurring events in a plant life-cycle, or phenology, can provide an indicator of global climate change. In alpine systems, the growing season is short and the timing of leaf out and flowering is strongly influenced by the timing of snowmelt. To monitor phenology in our sentinel sites, we plan to record the life-stage for five regional indicator species while surveying the summit area sections. The indicator species were chosen based on the lists from the National Phenology Network (NPN 2009) and a few species were selected that are common across the region and are highly visible in the alpine. These and include: *Dryas octopetala* (eightpetal mountain-avens), *Taraxacum officinale* (common dandelion), *Eritrichium nanum* (alpine forget-me-not), *Silene acaulis* (moss campion), and *Claytonia megarhiza* (alpine springbeauty).

3 Steps

3.1 Equipment

- Species list, key, and photographs
- Phenology datasheet
- Compass

3.2 Procedures

1. Divide the summit area (10 m elevation below highest point) into 8 summit area sections (e.g north upper, north lower, etc) following the GLORIA Field Manual. While surveying the summit area section, look for whether the indicator species are flowering (Table 1).

2. When there are numerous individuals and at different phenophases (flowering, setting seed, etc), determine whether most individuals are flowering.

Table 1. Sample phenology datasheet

Name: Park: Target Area: Summit Code:						
Summit Area Section	*Date*	*Dryas octopetala*	*Taraxacum officinale*	*Eritrichium nanum*	*Silene acaulis*	*Claytonia megarhiza*
5mN		Y N D	Y N D	Y N D	Y N D	Y N D
5mE		Y N D	Y N D	Y N D	Y N D	Y N D
5mS		Y N D	Y N D	Y N D	Y N D	Y N D
5mW		Y N D	Y N D	Y N D	Y N D	Y N D
10mN		Y N D	Y N D	Y N D	Y N D	Y N D
10mE		Y N D	Y N D	Y N D	Y N D	Y N D
10mS		Y N D	Y N D	Y N D	Y N D	Y N D
10mW		Y N D	Y N D	Y N D	Y N D	Y N D
Comments:						
When individual plants differ, note if most plants are flowering by circling D, for dominant. To be considering flowering- in at least one location on the plant, an open fresh flower is visible. Flowers are considered "open" when the reproductive parts are visible between open flower parts. Do not include dried flower parts that remain on the plant.						

4 References

National Phenology Network (2009). USA-NPN Plant Phenology Program. http://www.usanpn.org/ accessed 3/18/2009. Tuscon, AZ

SOP AlpineVCSS Treeline

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

Climate models predict that forests will expand upslope into alpine areas as temperatures continue to warm and changes at the forest-alpine ecotone will have large effects on C storage, nutrient cycling, wildlife habitat, and water dynamics (Field et al. 2007). Here, we describe a simple procedure to photograph the krummholz and treeline at each sentinel site.

Krummholz is a characteristic growth form of trees in the alpine, where trees are stunted, deformed, and resemble bushes due to great environmental stress, such as high wind and low temperatures. At lower elevations, where more favorable conditions exist, the same tree species that form into krummholz grow upright. Common krummholz species in the Rocky Mountains include *Picea engelmannii*, *Pinus aristata*, and *Pinus albicaulis*. The krummholz line is the upper-most limit in elevation that trees in krummholz form exist and treeline is the upper-most limit in elevation that upright trees exist.

3 Steps

3.1 Equipment

- Camera
- GPS unit

3.2 Procedures

Follow the procedures below to photograph the krummholz and treeline from each GLORIA peak in the N, S, E, and W directions.

(1) Stand at the highest point on the peak (marked by rebar) and use a compass to determine N. Use the correct declination for the area.
(2) Determine photograph location: Looking N, determine if the krummholz and treeline are visible. If they are proceed to step (3). If they are not, walk directly N to where the krummholz and treeline are visible. Use GPS to mark location and record waypoint and mark on GPS log. In some cases, the most visible treeline will be on a neighboring slope.
(3) Take a photograph. Record photo number and time on photograph log. Ideally, both krummholz line and treeline will be visible from this location.
(4) Repeat steps 1-5 for the E, S, and W directions.
(5) When revisiting a site after 5 years, take the GPS locations and past photographs with you to replicate the photograph as closely as possible.

4 **References**

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SOP AlpineVCSS N Deposition: Measuring Nitrogen Deposition Using Ion Exchange Resin Collectors; *Optional*

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

The atmospheric deposition of nitrogen (N) in the Rocky Mountain tundra has increased in recent decades to greater than 6 kg/ha (NADP). Annual N loadings may provide a critical covariate in trend analyses (as a driver for change) and spatial variation in N loadings may add to our understanding of different vegetation patterns within and across parks. Here, we outline an inexpensive method to measure annual wet deposition in resin columns adapted from the United States Forest Service (Fenn and Poth 2004). This is an optional method and should be considered in areas where there are not nearby NADP stations or other data available to estimate N load.

3 Steps

3.1 Equipment

To make and extract 36 IER columns (this is enough for 8 collectors and 1 blank at four GLORIA peaks in one park) you will need the following:

- 36 1.27 cm inner diameter x 35.6 cm polyvinyl chloride [PVC] tubes
- 36 7.1 cm inner diameter x 35.6 cm PVC tubes used to protect IER column
- 36 PVC cap 1.27 diameter with 10 holes drilled into it to allow for drainage
- 36 7.1 cm diameter PVC cap
- Large bag of polyester floss
- 32 funnels with 20 cm diameter or 20 cm rain collector funnel

- 10 m mesh screen cut into 32 30 x 30 cm squares to be placed in the funnel to keep out debris.
- 10 L Distilled water
- 36 PVC fittings
- 60 mL of resin per collector (mixed anion/cation exchange resin), with a total ion exchange capacity of 33 cmolc, is sufficient to collect N equivalent to a field deposition 416 kg N ha1 of nitrogen (e.g., Amberlite MB 150)
- 100 ml graduated cylinder
- Laboratory style support clamp (that can fit PVC tubes)
- Latex gloves
- Scoop
- Scissors
- Cable ties
- Drill
- 36 rebar or stakes 60 cm length
- Mallet to pound rebar or stakes
- 20 L 2 M KCl

3.2 Procedures

Constructing a ion exchange resin (IER) column

1. Wear latex gloves
2. Drill 2 small holes at the top of the 1.27 cm PVC tube (big enough for the cable tie, ~ 3 mm diameter)
3. Drill 2 small holes in the rim of the funnel
4. Drill 2 holes into 7.1cm PVC
5. Drill ~10 holes into PVC cap to allow for drainage
6. Place 1.27 cm PVC into support clamp (IER column) with the holes at the top
7. Place a small amount of polyester floss into the bottom of the 1.27 cm PVC tube
8. Cap tube with PVC cap with holes cut into it to allow for drainage
9. Use scoop to measure 60 ml of resin in graduated cylinder
10. Pour resin into PVC tube on top of the polyester floss
11. Place a small amount of polyester floss onto the top of the resin
12. Label column on outside using a sharpie with a column number using a combination of deployment year and unique code (eg., 200901)
13. Cut mesh into ~30 x 30 cm square
14. Place mesh over top of funnel and use cable tie around the outside of the funnel to secure it in place
15. Place funnel into IER column
16. Thread cable tie through each hole in the funnel and attach to the IER column, then place IER column into 7.1 cm protector tube and thread cable tie through the outer tube, close (to secure the funnel and protector in place)
17. Write column code on the protector tube

18. Repeat to create 8 collectors per peak
19. Repeat procedures 1-17 but instead of a funnel, cap the protector tube with a PVC cap to create a IER field blank

Deploying IER columns in the field

At each GLORIA site, deploy 8 collectors with 2 pairs at each of the N, S, E, and W quadrant during the summer.

1. In the N quadrant, move to approximately 2 m from the top of the 5 m plot array towards the high point of the peak
2. Drive a stake or rebar ~ 15 cm into the ground
3. Secure IER collector to rebar with PVC fittings and cable ties so that there is some room for drainage (~ 5 cm from ground)
4. Find rocks from outside of plot area and place them around IER collector to disguise it and add some shelter
5. Note collector location, date and time deployed, and column number
6. Move to approximately 2 m from the bottom of the 5 m plot array and repeat step 2-5
7. Move to the S, E, and W quadrant and repeat steps 1-6
8. Place an IER field blank near the high point of the peak
9. Leave IER collectors in the field for up to 1 year
10. When collecting IER columns, remove from the protector and funnel, and cap. Note date, time, location, and column number
11. Bring capped columns back to the laboratory

Laboratory Analyses

1. Place IER column in support clamp and place 500 ml beaker below column
2. Remove cap on top
3. Pour 100 mL DI water through column and into the beaker to rinse. Toss water in beaker
4. Pour 200 mL 2 M KCl through column into beaker
5. Repeat step 4 for a second extraction
6. Swirl extraction solution in beaker and pour into 4 pre labeled scintillation vials.
7. Place 2 vials into freezer. These are backups and can be thrown out when laboratory analyses are completed and data has been QA/QCed.
8. Place 2 vials into refrigerator.
9. If reusing the beaker: Rinse beaker with tap water than at least 3 times with DI water
10. Repeat steps 1-9 for all IER columns, including blanks.
11. When all extractions are completed, send samples to a cooperating laboratory for analyses of nitrate and ammonium. A cooperative agreement or contract will be needed for analyses and it is important to use a laboratory with low detection limits. The University of Colorado, Kiowa Laboratory could perform these analyses in 2009 the approximate cost was $4 per sample.

Data Processing

1. The laboratory should provide nitrate and ammonium values for each column and blanks as a value of mgN/L.
2. For each peak, subtract the value in the blank from all 8 columns.
3. Convert mgN/L to kgN/ha using the known volume of extract (0.4 L) and surface area of the PVC column (1.26 cm2). 1 ha = 100000000 cm2

   X mg N/L * 0.4 L = Y mg N
   Y mg N/ 1.26 cm2 * 100000000 cm2/ 1 ha * 1 kg/ 1000000 mg = Z mg N/ha

4 References

Fenn, M. E., and M. A. Poth. 2004. Monitoring nitrogen deposition in throughfall using ion exchange resin columns: a field test in the San Bernardino Mountains. Journal of Environmental Quality **33**:2007-2014.

SOP AlpineVCSS Data Analysis: Sentinel Sites Statistical Analysis

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

To examine *status* at GLORIA sentinel sites, we will use descriptive statistics and linear mixed effect models or nonparametric equivalents to examine the difference in parameters among parks, summits, and summit aspects. Models will contain fixed factors (summit, aspect) and random factors (plot nested in aspect). Multivariate methods, such as analysis of similarity and ordinations, will use percent cover of all species to examine the differences in community structure among summits and aspects. We will explore the relationship between physical factors, such as elevation and soil chemistry, and vegetation structure using linear regression and tests of correlation. Where appropriate these physical factors may be used as covariates in linear models. To determine which factors or drivers affect a given parameter, we will use model selection procedures and determine the best fit models using Akaike's Information Criteria (AIC) (Akaike 1973, Burnham and Anderson 2002). We are particularly interested in understanding how levels of grazing, temperatures, and N deposition may alter community structure. When two to three years of data are available, we may begin to examine and detect *change* at sentinel sites. To do this, we will use the same statistical methods described above but add year as a fixed factor. This will allow us to determine whether parameters, such as species richness, differ among years. We will explore *trends* at GLORIA sentinel sites, when four or more years of data are available. To examine trends we will conduct repeated measures analyses where "plots" are the subject that is repeated over time.

3 **Steps**

General Guidelines for Data QA/QC and parameters measured:

1. Prior to data analysis, all data should be entered and QA/QC should be performed within the guidelines of *SOP DM* Data Quality Control. Check notes and range of values for all parameters. Also check that you have data for the appropriate level (plot, aspect, or summit).
2. Derive variables according to equations listed in Table 1.

Table 1. Parameters measured, units, QA/QC and derivations, unit of analyses, and suggested statistical tests

Parameter	Raw/Derived	units	QA/QC	unit of analyses	Statistical tests
Cover of scree, rock, vascular plants, lichens, bryophytes, bare ground, litter	Raw	%	the sum of all 7 categories should add up to 100%	$1m^2$ quadrat; $10m^2$ plot; summit area sections	univariate: linear mixed multivariate: anosim or permanova on Bray Curtis dissimilarity matrix
Species cover (vascular plants)	Raw	%	value for each vascular species present; not less than 0; includes layers so can be greater than 100	$1m^2$ plot; $10m^2$ plot; summit area section	univariate: linear mixed multivariate: anosim or permanova on Bray Curtis dissimilarity matrix
Species number	Derived	species	count number of vascular species present in summit area	Summit and summit area sections	linear mixed model
Diversity Index	Derived	shannon-weiner index, H'	H'= Sum (relative abundance of each species/ ln(relative abundance); upper limit ~4	1 and $10m^2$ plots	linear mixed model
Eveness	Derived	Peilou index, J	J'=(diversity)/log(number of species); between 0 and 1	1 and $10m^2$ plots	linear mixed model
Mean Coefficient of Conservation	Derived	index C	between 1-10; the mean of the coefficient of conservation assigned to each species present	Summit and summit area sections	linear mixed model
Florisitic Quality Index	Derived	FQA	FQA=C * square root(number of species)	summit	linear mixed model
Species frequency counts	Derived	%	count the number of cells out of 100 where species is present; there should be a value for all species present	1 m^2 quadrat	NA
Relative frequency	Derived	%	Divide species frequency by total frequency. Sum of all species should be 100%.	1 m^2 quadrat	linear mixed model
Species presence/absence	Raw	categorical	presence of species in each grid cell of 1 m^2 quadrat	100 cells w/in plots	NA
Date of first flower	Derived	Julian day	estimated from date of visit; seasonal trends in climate	Summit area section	descriptive statistics

Parameter	Raw/Derived	units	QA/QC	unit of analyses	Statistical tests
Number of exotic species present on summit	Derived	species	count number of species present in peak area	summit	linear mixed model
Identity of exotic species present	Raw	categorical	species list	summit	NA
Percent cover of exotic species	Raw	%	not less than 0; includes layers so can be greater than 100	summit	linear mixed model
browsing presence/absence	Raw	categorical	presence of browsing in each grid cell of 1 m^2 quadrat	100 cells w/in plots	NA
scat presence/absence	Raw	categorical	presence of browsing in each grid cell of 1 m^2 quadrat	100 cells w/in plots	NA
trampling presence/absence	Raw	categorical	presence of browsing in each grid cell of 1 m^2 quadrat	100 cells w/in plots	NA
browsing frequency	Derived	%	Number of cells (0- 100) where browsing is present	plot	linear mixed model
scat frequency	Derived	%	Number of cells (0- 100) where scat is present	plot	linear mixed model
trampling frequency	Derived	%	Number of cells (0- 100) where trampling is present	plot	linear mixed model
hourly temperature	Raw	degC	-40 deg > value < 50	aspect	NA
mean daily temperature	Derived	degC	mean of 24 hourly records from 1:00 to 24:00hrs	aspect	NA
minimum daily temperature	Derived	degC	min of 24 hourly record	aspect	NA
maximum daily temperature	Derived	degC	max of 24 hourly record	aspect	NA
mean annual temperature	Derived	degC	mean of hourly record from Jan1-Dec31	aspect	linear mixed model; covariate
maximum annual temperature	Derived	degC	max of hourly record from Jan1-Dec31	aspect	linear mixed model; covariate
minimum annual temperature	Derived	degC	min of hourly record from Jan1-Dec31	aspect	linear mixed model; covariate
number of days above 100 degF in a given year	Derived	days	count of days between Jan1-Dec31 where max daily temperature >100 degC	aspect	linear mixed model; covariate

Parameter	Raw/Derived	units	QA/QC	unit of analyses	Statistical tests
first/last date of snow cover	Derived	dates	first/last dates of continuous snow cover. Snow cover is present when standard deviation in daily temperature=0 degrees	aspect	linear mixed model; covariate
number of days of continuous snow cover	Derived	days	Julian date of last snow cover Julian day -first snow cover	aspect	linear mixed model; covariate
first/last date of hard freeze	Derived	dates	first/last dates where minimum hourly temperature > -3 degC	aspect	linear mixed model; covariate
accumulated growing degree days	Derived	growing degree days	use base of O degC; sum of (mean daily temperature-base) for days when mean>0	aspect	linear mixed model; covariate
diurnal temperature range	Derived	degC	Difference between daily max and min temperatures	aspect	linear mixed model; covariate
sand, silt and clay	raw	%		aspect	covariate
texture	derived	NA	classification based on % sand, silt, and clay	aspect	NA
bulk density	raw	g/m3		aspect	NA
pH	raw	pH		aspect	linear mixed model
cation exchange capacity	raw	$cmol_c$/Kg soil		aspect	linear mixed model
micro and macronutrients	raw	%		aspect	linear mixed model
organic matter	raw	%		aspect	linear mixed model
C:N	derived	ratio	%C:%N	aspect	linear mixed model
surface flow evidence	raw	ordinal	5 classes: extreme (XX), moderate to extreme (MX), moderate(MM), slight to moderate (SM), none to slight(NS)	summit	
rills and gullies	raw	ordinal	5 classes, see above	summit	
pedestals and terracettes	raw	ordinal	6 classes, see above	Summit	

Parameter	Raw/Derived	units	QA/QC	unit of analyses	Statistical tests
distance to road	derived	m	derived from GIS	summit	
human disturbance index	derived	%	derived from anthropogenic disturbances calculated; range from 0 -100 (highly disturbed)	summit	
slope	raw	degrees		summit	
elevation	raw	m		summit	
nitrogen load (ammonium and nitrate)	raw	kg/ha		aspect	
beaver disturbance	raw	categorical	class 1-4 based on high to no disturbance; 1: high >50% of site has evidence, 2: medium >10% or old evidence, 3: low no sign on site but some within 1km; 4: no signs in site or within 1km	summit	
native ungulate disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	summit	
frost heave disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	summit	
rodent disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	summit	
pest & pathogens disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	summit	
landslide disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	summit	
fire disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	summit	
natural disturbance	derived	index; NDI	derived from weighting natural disturbance categories; range from 0-100 (highly disturbed)	summit	

General Guidelines for Statistical Analyses:
Load R (2008) and the vegan (Oksanen et al. 2009) and nlme packages (Pinheiro et al. 2008).

Univariate analyses:

- For status of sites and differences among sites, or aspects linear mixed models can be used. The summit and aspect are fixed factors, plots are considered random factors. A sample code to test for differences in the status of graminoid cover is:
  model= lme (graminoid_cover~ summit*aspect, random=~1|plot)

- To examine change in a parameter over multiple years of data, but less than four, "year" can be added as a fixed factor. A sample code to test for changes in graminoid cover is:
  model= lme (graminoid_cover~ summit*aspect*year, random=~1|plot)

- To examine trend in a parameter over more than four years use a repeated measures mixed model. A sample code to test for trend in graminoid cover is:
  model=lme (graminoid_cover~ summit*aspect, random=~year|plot, correlation=corAR1())

- To examine correlation among two variables (graminoid cover, soilN) use:
  cor.test (graminoid_cover, soilN)

It is important to test that the data meet the assumptions of the statistical test you are performing prior to analysis and interpretation. It is critical to examine the residuals and determine if it is necessary to transform the variables and/or remove outliers. In some cases, nonparametric equivalents to mixed models (Kruskal-Wallis) can be performed.

Multivariate analyses:
The vegan package (2009) can be used for calculating diversity indices and for creating dissimilarity indices, ordinations, and permutational tests of similarity. Bray Curtis dissimilarity matrices are most appropriate for vegetation abundance data because it weights the most dominant species and ignores plots with similar absences or joint zeros. ANOSIM (analysis of similarity) is a multivariate equivalent of ANOVA and is conducted on the dissimilarity matrix.

Reporting:
We recommend that annual reports from the AlpineVCSS protocol include graphical and tabular summaries of statistically significant and biologically meaningful differences among summits and aspects, and the following:

- Number and dates that sites were visited
- Bar graphs of species richness and floristic quality index (mean ± 1 standard error) by summit
- Bar graphs of percent cover of exotic invasive species, graminoids, and forbs by summit.

- Scatterplot or line graph of daily mean, maximum, and minimum temperature at each summit.
- Table or text reporting number of days with soil temperatures above 100 °F, first and last days of continuous snow cover, and first and last date of hard freeze.

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SOP AlpineVCSS GRTS design: Creating a Probability-Based Design for Alpine Surveys; *Optional*

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

While our initial monitoring efforts will focus only on the sentinel sites, if and when time and budgets allow, we hope to increase our ability to make park-wide inferences by adding a survey design component to our monitoring approach. Probability-based surveys provide unbiased estimation of both status and, with repeated visits, trend across a resource (Larsen et al. 1995) and when implemented successfully allow for unbiased inference from sampled sites to un-sampled elements of the resource of interest (Hansen et al. 1983). The goal of the optional survey design for the AlpineVCSS is to determine the *status* of alpine vegetation and soils in GRSA, GLAC, and ROMO in a given year. Below, we describe each of the steps required to develop a GRTS survey design and provide an example using alpine areas in GRSA. The SOPs that follow this describe the associated field methods and analysis for these survey sites.

3 Steps

Defining the target population

Our goal is to determine status in vegetation structure, species composition, natural and anthropogenic disturbance and soil condition in alpine habitats. For the AlpineVCSS we defined the target population by elevation (above 1980 m in GLAC and 3500 m in GRSA and ROMO) and community types, limited to non-aquatic vegetated communities above timberline. The elevations were best estimates based on ecological literature, maps, and park definitions. In the alpine regions of GRSA, GLAC, and ROMO there are numerous habitats that are not significantly vegetated by vascular plants, such as talus fields, cliff faces, and glaciers, and these are not included in our target population. We do not include wetlands, primarily alpine wet meadows, because they are included in the target population of the ROMN Wetland Ecological Integrity Protocol (Schweiger et al. in preparation). Within the target population, we are interested in a number of ecological types (subpopulations) of vegetation. The nomenclature of subtype varies by park because we use the classifications presented in the respective vegetation maps but all are based on the National Vegetation Classification System vegetation alliances. In GRSA these include three subpopulations: alpine fell-field alliances (fell-field tundra), alpine turf alliances (dry and moist meadow tundra), and alpine willow and spruce shrubland (shrub tundra). Alpine turf alliances are the most common, covering approximately 950 hectares or 58% of the resource.

Defining the sample frame

Once the target population is defined, the sample frame was developed within GIS by intersecting the target population with known or expected areas of sensitive or protected sites and developed park infrastructure. After this, a detailed cost surface estimate was used to incorporate information about difficult access in backcountry settings. The ROMN cost-surface model computes relative travel times to sites based on factors such as the presence of trails, vegetation type, and slope angle (Frakes et al. 2007). In essence, this limits the target population to accessible areas where there are no buildings, roads, or sensitive resources. The cost surface model is continuous, but we used it to determine 8 discrete cost classes based on the hours required to access an area: 0-0.5, 0.5-1.0, 1.5-2.0, 2.0-2.5, 2.5-3.0, 3.0-3.5, and 3.5-4.0 hours. The target population was then classified by ecological type and the cost class for that polygon. In the case of GRSA this resulted in 28 unique categories, with alpine turf alliances of greater than 3.5 hours cost covering the largest area of the target population (15%). The resulting sample frame from GRSA is shown in Figure 1.

Selecting sites

After defining the target population and establishing a sample frame, survey sites are selected from within the sample frame. As with all ROMN survey designs (Britten et al. 2007), the alpine tundra survey uses a Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 2003, 2004). For the alpine surveys, we included 40 base sites and 120 oversample sites. The number of sites was chosen because it is operationally possible and we estimate that estimates of status require sample sizes in the range of 35–50 per reporting unit to generate a confidence interval around ±10% (Britten et al. 2007). If a base site is determined to be non-target during fieldwork, for instance the site is a wetland, it will be replaced by the next available site with the same subpopulation type in the oversample list. Using a GRTS approach, the sites were allocated proportionally to each class within the sample frame with a slight bias towards sites that are easier to access. Later design-based data analyses will correct for these biases. The resulting design includes a map of site locations and for each site there is corresponding probability that it would be included in the design. The final survey design was chosen to reduce the sample variance of inclusion probabilities. The AlpineVCSS design was created in R using the ‘spsurvey’ package (Kincaid and Olsen 2008). Copies of original files are preserved and maintained by ROMN including the statistical (R) code containing the original settings and functions, the sample frame shapefile(s) and summary data, and the design points. A sample R code for GRSA is provide in Table 1.

Table 1. Sample R code for the GRTS survey design

```
library(spsurvey)
att <- read.dbf("GRSA_Alpine_SampleFrame")
names(att) <- tolower(names(att))
head(att) # look at attributes that can be used to define unequal weight categories

####
DETAILS FOR DESIGN GRSA_uneqldsgn1, Sample size model:  proportional allocation based on % of area  in
cost class biased by selecting areas that are easier to access
####

GRSA_Alpine_uneqldsgn1_specs <-
list(none=list(panel=c(Base=40),
        seltype="Unequal",
        caty.n=c(
'Alpine Fell-Field Alliances-120min'=2,
'Alpine Fell-Field Alliances-150min'=3,
'Alpine Fell-Field Alliances-180min'=3,
'Alpine Fell-Field Alliances-210min'=2,
'Alpine Fell-Field Alliances-60min'=1,
'Alpine Fell-Field Alliances-90min'=2,
'Alpine Turf Alliances-0min'=1,
'Alpine Turf Alliances-120min'=5,
'Alpine Turf Alliances-150min'=4,
'Alpine Turf Alliances-180min'=3,
'Alpine Turf Alliances-210min'=3,
'Alpine Turf Alliances-30min'=3,
'Alpine Turf Alliances-60min'=2,
'Alpine Turf Alliances-90min'=4,
'Alpine Willow (Spruce) Shrubland Alliances-0min'=0,
'Alpine Willow (Spruce) Shrubland Alliances-120min'=0,
'Alpine Willow (Spruce) Shrubland Alliances-150min'=1,
'Alpine Willow (Spruce) Shrubland Alliances-180min'=0,
'Alpine Willow (Spruce) Shrubland Alliances-30min'=0,
'Alpine Willow (Spruce) Shrubland Alliances-60min'=1,
'Alpine Willow (Spruce) Shrubland Alliances-90min'=0),over=120))

set.seed(1234567)
GRSA_uneqldsgn1<- grts(
          design=GRSA_Alpine_uneqldsgn1_specs,
          DesignID='GRSAalpine',
          type.frame='area',
          src.frame='shapefile',
          in.shape='GRSA_Alpine_SampleFrame',
          att.frame=att,
          #stratum= 'vegcost',
          mdcaty= 'vegcost',
```

```
                                        #startlev=5,
                                        #maxlev=8,
                                        #maxtry=50,
             prjfilename='GRSA_Alpine_SampleFrame',
             out.shape='GRSA_Alpine_uneqldsgn1')
dsgnsum(GRSA_Alpine_uneqldsgn1) # summarizes design file
```

Timing of sampling (index period)

Index-period sampling focuses the time of sampling on the most ecologically relevant period(s) for a given response measure so the data collected will function as a useful barometer of a vital sign or of the condition of target populations within a given sampling interval (Landers et al. 1998, Messer et al. 1991, Larsen et al. 1995). We define the index period for the AlpineVCSS protocol as the week(s) nearest to the peak of the growing season. Although it would be best to visit all sites on the same phenological date (e.g., 30 days into the growing season), this date changes each year and would be operationally impossible. Rather, we expect sampling to occur during the snow-free period in the alpine (June-Aug). Annual crew schedules will be set and adjusted to accommodate the differential growing seasons at GRSA, ROMO, and GLAC and in the context of the targeted site list for that year, date of snow-melt and site elevation.

Sample population

A sample population is the realization of a monitoring effort and may differ from the target population because of logistical and financial constraints and the realities of field work. We expect that within the AlpineVCSS protocol, the final sample population will be the vegetation and soil at survey sites within ecological site types that were successfully measured during the snow-free period in the alpine tundra. An example of a sample population might be, “accessible vegetation and soil without standing water during typical peak phenology in mid-July within alpine fellfield, alpine turf, and alpine shrublands at GRSA.” The sample population resulting from the survey design will be explicitly defined in all data analyses and interpretation.

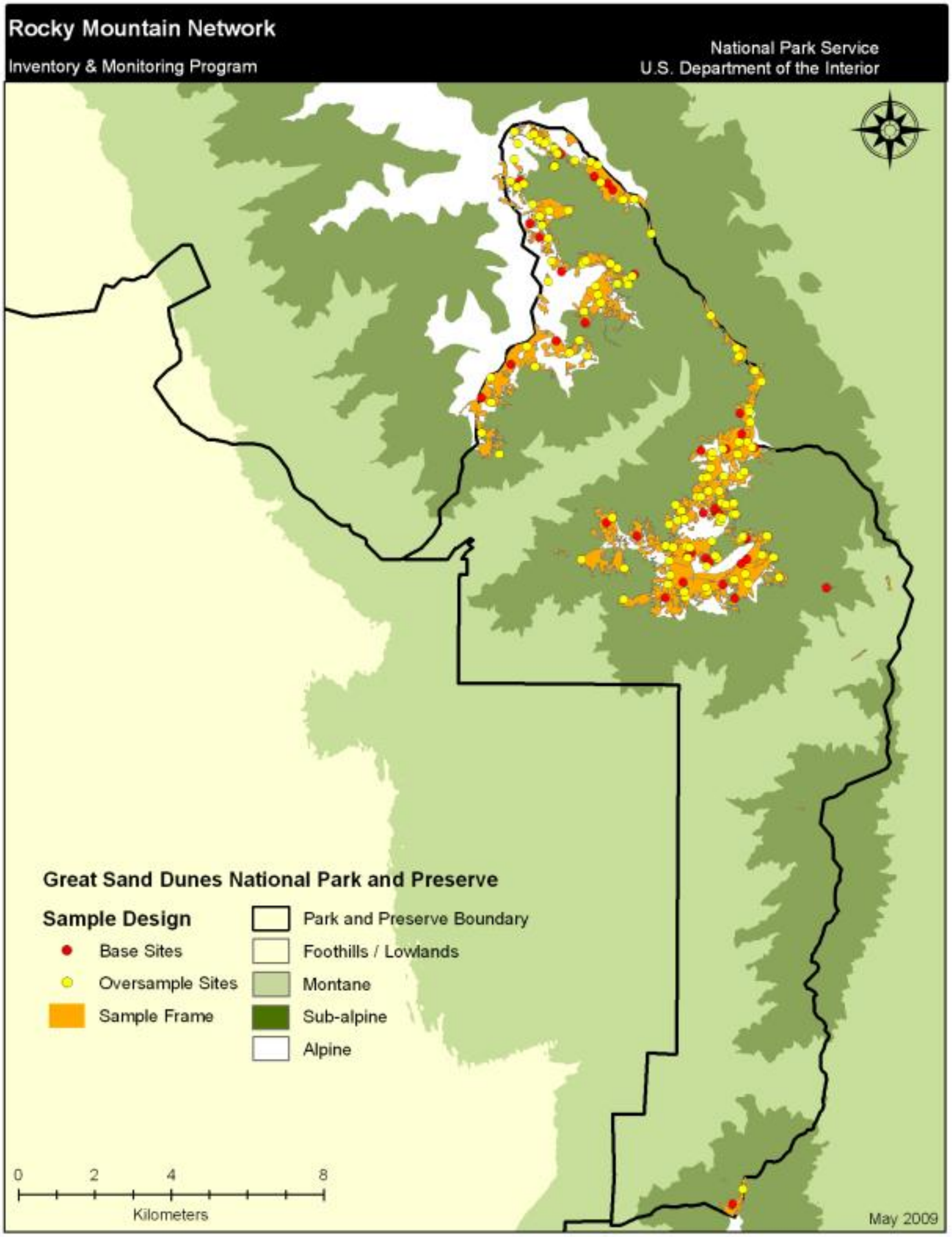

Figure 1. Sample frame and sites for survey designs in GRSA

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SOP AlpineVCSS Site Suitability: Determining Target Status of Survey Site in the Field; *optional*

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

The location of our long-term monitoring sites is determined from a randomized design executed on the target sample frame as defined for each park. Because this selection is made in the office, prior to any field visitation, there may be circumstances that cause a design-selected location to be unsuitable for sampling. Upon arrival at a potential sampling site, field crews should use the following guidelines to determine suitability of the location for sampling.

3 Steps

Evaluate each site to determine that it meets accessibility and suitability requirements as follows:

Accessibility

- No potential safety hazards (e.g., steep slopes >45^{o}, crossing railroad tracks)
- No potential interference with sensitive resources (e.g., grave markers, artifacts, identified sensitive areas)
- No direct obstructions to plot locations and/ or associated sampling equipment at these locations (e.g., water body, river, road, railroad, sensitive resources)

Suitability

- Is the site representative? Do not sample if local features directly and significantly alter site characteristics (e.g., monument and transect on a road or transect/ plots within or adjacent to a pen, work area, or other heavy management use area).

- Is the site above treeline? Is the site within the target population—sites with a high cover of scree or bedrock and low cover of vascular plants (<25%) are not included.
- Do not sample if the site is inundated by water frequently and continuously enough so that the vegetation community is becoming different from the surrounding upland vegetation communities (i.e., wetland species emerging or becoming dominant at the site).
- Do not sample if a paved road (in the interest of safety) or any heavily used dirt road or trail is within the 10 x 10 m macroplot.
- When sites are deemed inaccessible and/ or unsuitable, refer to *SOP VCSS* Replacing Sites rules to relocate the plot.
- If these steps do not eliminate the interference with safety or the design, then reject the point as a sample site, *record why* the site was rejected on a Sample Site Description Form, and select the next replacement site on the list for the same ecological type you are replacing (i.e., from the list of "oversample sites").

3.1 Resource protection overview

National guidance for sensitivity restricts general public accessibility to geological and geophysical information and data concerning wells; the nature and specific location of (a) endangered, threatened, rare, or commercially valuable species, (b) minerals or paleontological objects, or (c) objects of cultural patrimony; the nature and location of any archaeological resource for which the excavation or removal requires a permit or other permission; or the specific location of any significant caves (FOIA, 2002).

Therefore, the protocol will:

- Contain measures for identifying and flagging sensitive information
- In cases where sensitive information is intentionally or unintentionally located in the field, provide a means of collecting data that does not jeopardize the sensitive resources.

ROMN staff and cooperators will often be working in areas with sensitive cultural resources (these include, but are not limited to: bones, fossils, weapons, bullets, tools, human remains, etc.) and less frequently, sensitive natural resources (e.g., rare plant species or sensitive wildlife habitat). If avoiding these resources results in inability to properly sample the site (using above criteria), the site should be rejected and a new site selected (from the over-sample list for that ecological type).

In cases where sensitive resources are near the edge of a site, or when simple movement of the plot will eliminate any potential effects on the resource, use the described method for relocating sites (see *SOP AlpineVCSS* Replacing Sites).

Under no circumstances should you convey the location of sensitive objects to anyone besides official NPS staff. Under no circumstances should you manipulate, move, or otherwise alter sensitive cultural resources.

Natural

Crew members need to be aware of the locations and identification of rare and/or protected species because monitoring sites may intersect with a known population of species of concern. Additionally, crew members should be able to recognize rare species if they discover individual(s) at a site being sampled. In all cases, when details of the location of these species are known, that information should not be shared with the public.

Wilderness management principles, including within *de facto* Wilderness, include important mandates guiding activities within large portions of GLAC and ROMO. Use of some mechanized equipment is restricted in these areas. ROMN monitoring protocols are designed to support compliance with Wilderness management regulations; in all cases, when working within Wilderness, motorized access is restricted and minimum necessary tools are mandatory.

Cultural / Archeological

Sensitive cultural resources abound within ROMN, and I&M field staffs have a critical responsibility to protect these resources and avoid unnecessary impacts due to monitoring activities within the parks. Examples of such artifacts include peel-trees at GRSA, rocks on the sand-sheet at GRSA, historic ranching/ homesteading artifacts at GLAC, and ROMO, and other historic sites, including scientific sites at ROMO and GLAC.

Paleologic

Similarly, sensitive paleologic resources are widely distributed across ROMN parks, and I&M field staffs have a critical responsibility to protect these resources and avoid unnecessary impacts due to monitoring activities within the parks.

Reporting: In cases where an important or very sensitive natural, cultural, or paleologic resource has been discovered, record the location with a waypoint in the GPS, take photographs, and take notes about the object(s) and location of the discovery. Report this information to the park unit staff.

4 **References**

Freedom of Information Act (FOIA). 1. 5 U.S.C. 552 (2000 & Supp. III 2003).

SOP AlpineVCSS Replacing Sites: Moving or Replacing Alpine Survey Sites; *Optional*

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

When a site is first visited, it must be evaluated for accessibility and suitability; criteria are provided in *SOP AlpineVCSS* Site Suitability. When there is an "obstruction," use the following rules to relocate the plot. If these steps do not eliminate the interference with safety or the design, then reject the point as a sample site, *record why* the site was rejected on a Sample Site Description Form, and select the next replacement site from the list of oversample sites. In order to maintain the designed sampling intensity in each season, and across the panel, when a site is rejected (or removed) it should be replaced with another site from the original sample design. *Skipping sites or selectively placing a new site is not allowed.*

2.1 Steps to Move Site

To maintain the integrity of the survey design, strict rules regarding the shifting of a survey site must be followed. A site may only be shifted by a distance equal to the estimated GPS error (average of 4m) plus the average positional accuracy in the base mapping methods (average of 9m) used for the primary elements of the sample frame, plus (if needed) half of the longest axis of the field plot (7m). This value is approximately **20 meters**.

(1) Move the center monument 10m along the 90° azimuth; if this does not eliminate the problem, move to 20m along the 90° azimuth line.

(2) If moving in a 90° azimuth direction does not remove the interference, then move 10m from the original location along the 180° azimuth; if this does not eliminate the problem, move to 20m along the 180° azimuth line.

(3) If moving in a 180° azimuth direction does not remove the interference, then move 10m from the original location along the 270° azimuth; if this does not eliminate the problem, move to 20m along the 270° azimuth line.

(4) If moving in a 270° azimuth direction does not remove the interference, then move 10m from the original location along the 0° azimuth; if this does not eliminate the problem, move to 20m along the 0° azimuth line.

(5) If none of these solutions work, then reject the point as a sample site and follow the steps outlined below. If one of the steps does work, record where the new center is located and use the GPS log to mark a waypoint at that location.

2.2 Steps to Replace Site

(1) Complete a Site Description Form clearly noting site as "Rejected."

(2) Locate the site list and map.

(3) Select the next site on the over-sample list and add it to the visit schedule for this panel. Be sure to select a site from the oversample list within the same subpopulation as the rejected site.

SOP AlpineVCSS Plots: Plot Layout and Site Description for Alpine Survey Sites; *Optional*

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

The goal of the optional survey design is to determine the *status* of alpine vegetation and soils in GRSA, GLAC, and ROMO in a given year. This SOP describes the procedure for laying out plots in an alpine survey site. Prior to implementing the steps detailed here, the crew needs to determine whether the site center point is in the target vegetation type or needs to be replaced (*SOP AlpineVCSS* Site Suitability and *SOP AlpineVCSS* Replacing Sites).

The overall approach involves delineating three plot types, laying out using a compass and several field tapes. The macroplot measures 10 m x 10 m (100 m^2) and contains a subplot (16 m^2) and four microplots (1 m^2) (Figure 1). Basic layout involves setting up two field tapes orthogonally to one another and oriented along the cardinal directions.

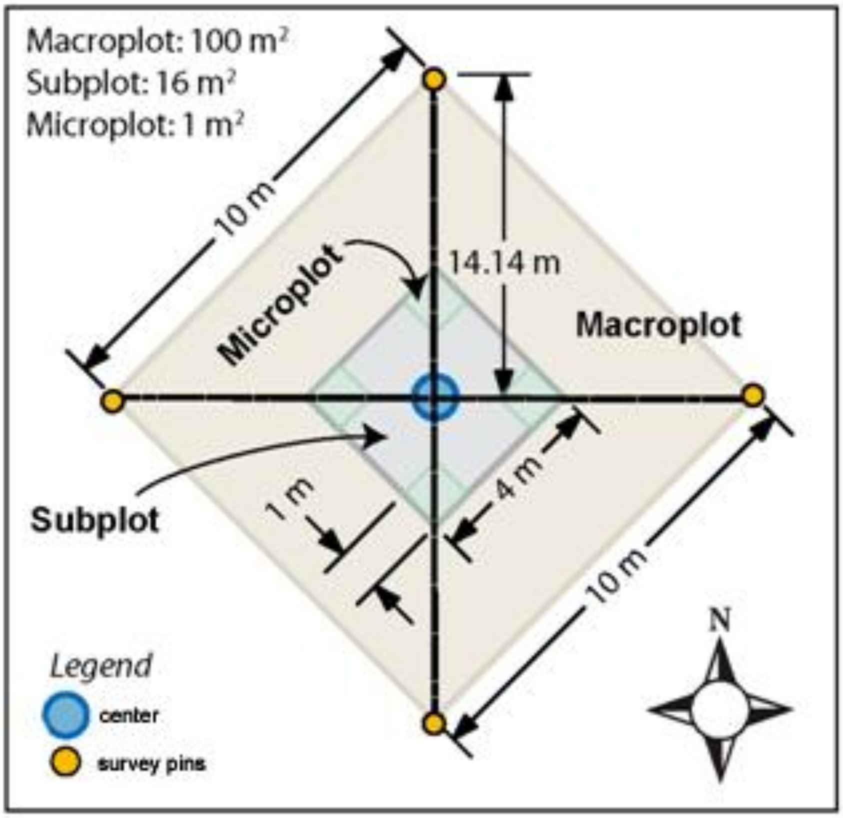

Figure 1. Diagram illustrating location and dimensions of nested plots laid out for alpine survey sites.

3 **Steps**

3.1 Equipment

- Compass with declination properly set
- Field tapes (one 100 m tape and two 50 m in length)
- 1 m^2 PVC plot frame
- Survey stake, pins or large diameter nails to temporarily fix tapes.
- GPS
- Survey flags

3.2 Procedures

Setting up a macroplot, microplot, and subplots

1. Move to the center of the plot. Use GPS to mark this location and record location on GPS log. Place a survey stake in the ground at this location.
2. Using compass, run the end of 100 m tape (tape #1) due north (0°) for exactly 14.14 m from the center (Figure 2). Double check that tape is set along the correct azimuth.

3. Temporarily pin end of tape using nail or survey stake; walk tape spool due south (180°) 28.28 m and checking that tape is set along the correct azimuth.
4. Using compass, run the end of 50 m tape (tape #2) due east (90°) for exactly 14.14 m. Check that tape is set along the correct azimuth.
5. Temporarily pin end of tape using nail; walk tape spool due west (270°) a distance of 28.28 m. Double check that tape is set along the correct azimuth.
6. Connect corners of macroplot using remaining length of tapes #1 and #2.
7. Measure out 2.83 m from the center along each tape and temporarily mark with survey flags. These points correspond to the outer corners of the subplot and microplot corners.
8. Attach end of tape #3 to one corner and extend to connect all sides.
9. Look at tapes to confirm that the dimensions are correct where the subplot is 4 m x 4 m and macroplot is 10 x 10 m.

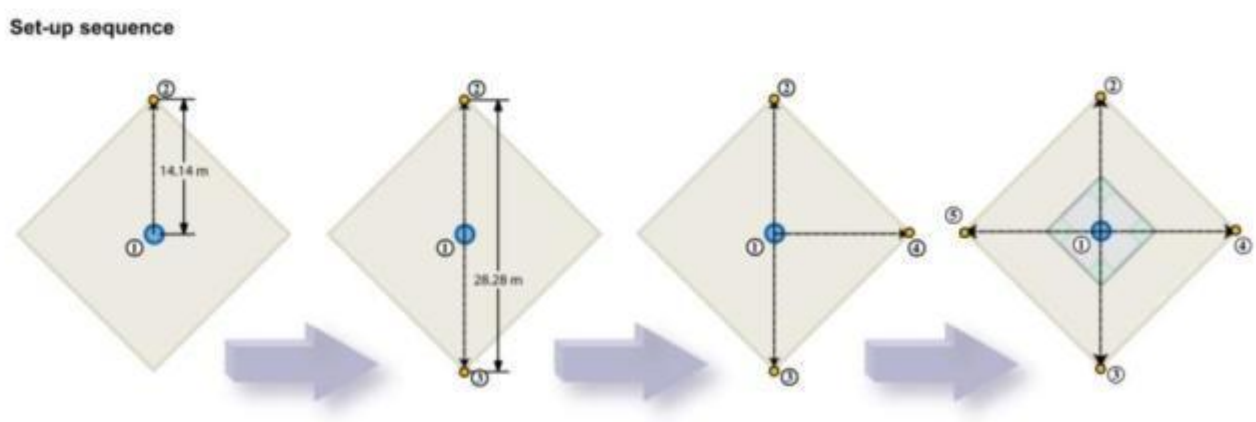

Figure 2. Sequence of steps for plot layout

Site and Sampling Event Description

After or during the plot set up, the crew should record details about the site location, date, time, weather, and topography on a site event datasheet. This will include the following fields:

- Park
- Site Code
- Date
- Name of Recorder
- Name of Botantist
- Brief description of site
- Travel directions and access time
- Name of the person that established the site
- Location; UTMX, UTMY, UtmZone, and datum

- EstHError: Enter error from GPS unit (measure of horizontal accuracy of averaged points taken).
- Aspect: Enter aspect (azimuth) from center of site.
- Slope: Enter slope (percent) from center of site.
- GeneralEcoSite Type: Choose from fellfield, alpine turf, willow shrubland, or other.
- Notes: Enter any additional comments about this sampling location.

SOP AlpineVCSS Photographs: Photo Point Documentation for Alpine Survey Sites; *Optional*

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

This SOP describes the general procedure for taking and documenting digital photographs taken on site. Photographs have two primary purposes. First, they can be used to assist future crews in relocating plots particularly when they include notable landmarks such as rock outcrops or large trees. Second, photographs can also provide useful information regarding broad ecological processes such as tree or shrub invasion (Jakubos and Romme 1993).

The protocol involves collecting 8 photo points at fixed azimuths from the center of the plot module. Additional photographs may be taken at the discretion of crews. Examples include notable landscape features such as large trees or rock outcrops, which can be used as witness features. Photographs should also be taken of obvious anthropogenic or natural disturbances including any large patches of invasive species.

3 Steps

3.1 Equipment list

- Digital camera
- Small dry erase board and marker
- Scrap of cloth or tissue to use as eraser
- Compass, with declination properly set.

3.2 Procedures

For all photographs

- Before taking photos at a site, be sure to collect GPS waypoints of the center monument location; and **record** one close-up image (photo) of the GPS unit with date and time on the screen. This is done to enable GPS-photo linking.
- Use a white-board placed within the foreground of the image to **record** park, site, and sample unit information within the image (see details below). *Carefully align the board to minimize glare and reflection (e.g., angle slightly downward).*
- Do **not** use the automatic date/time stamp feature on the camera. Date and time data are embedded in the exif data area by most digital cameras. If the image is being cataloged and documented, it has value – imprinting the image reduces the image quality and hence the image value. The exception may be for projects collecting massive numbers of photos – imprinted dates and time could facilitate data linking.
- Set camera to the highest resolution and "uncompressed" ("tif" or "raw") format; be sure the camera memory can still hold 30-40 images (allows working two sites between downloads). The resolution/ size trade-off can be manipulated if working in the backcountry and memory space is an issue. It is best to decrease the resolution for web use or thumbnails in the office using software, rather than in the field. Publication quality photos will be taken at a minimum of 4 megapixels. If the camera will allow, the resolution will be set at 1760 x 1168 or higher. The quality will be set for "super fine" or "high."
- Unless specified otherwise, all photographs will be in *landscape format* (wider than tall).
- Ideally, *no more than ¼ (25%) of the photo should be sky*, and no more than ¼ (25%) of the photo should be obstructed (e.g., by nearby trees, rock outcrops, etc.); however, this may not be possible in all circumstances.
- Set the view (zoom) on the camera to the widest angle.
- Record the image number (i.e., camera code) along with the site and sample unit information in the photograph log.
- Download photos after completion of each site, or as soon as possible when working away from the necessary equipment (e.g., in the backcountry). After file download is confirmed, delete the files from the camera.
- Any time the camera battery needs to be replaced, check to make sure the time and date are set correctly.

Site Overview Photographs

After the plots are laid out (*SOP AlpineVCSS* Plots) take photographs from the center towards any witness features, such as large rock outcrops or trees.

When capturing the picture, hold the camera approximately 1.5 m above the ground surface (remember a maximum of ¼ sky); record the site/date information on the white board, e.g.,

GRSA-00##
"Overview"
YYYY MM DD

A second person should hold the white-board in the near foreground, about 5 m away, and angled away from the sun.

Anthropogenic and Natural Disturbance Photographs

When applicable, take photographs of any specific stressors encountered during the initial reconnaissance of the site. This includes features seen within the plot and within 100 m of the plot. Include the white-board in any photos, as described above (substitute a note about the disturbance, e.g. elk bed, for "overview"). Record photograph number and location in the photograph log.

Plot photographs

1. Prior to the start of data collection, but after tapes have already been laid out, take a sequence of photographs clockwise around the center of the plot module.
2. Standing over the center, a photograph will be taken in 8 directions (45° angles) starting at 0° (Figure 1).
3. Stand at center of the plot and use a compass to determine N (0°).
4. Hold the camera approximately 1.5 m above the ground surface (remember a maximum of ¼ sky).
5. Record the park, site, date, direction information on the white board.
6. A second person should hold the white-board in the near foreground, about 3 m away and angle the board away from the sun.
7. Take a photo and only make duplicates if weather, light, exposure or similar conditions require a second attempt. Be sure to record the image number on the photograph log.

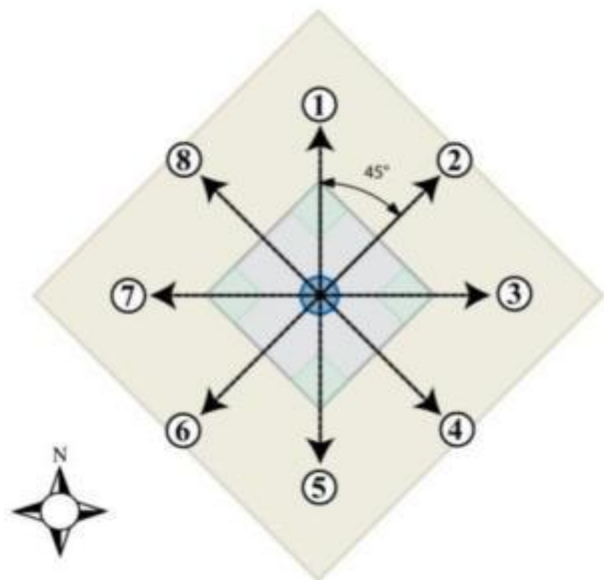

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Figure 1. Orientation of photo points taken at alpine survey sites.

3.3 Photo processing

1. Downloading the camera is similar to connecting any USB based peripheral. Connect the wires; turn the camera on; look for the camera using the Windows Explorer tool on the computer.
2. Locate the photo files and copy all of them.
3. Create a destination folder (/AlpineVCSS200XX/Data/Photos/YYYYMMDD) where YYYMMDD represents the date of uploading.
4. Paste the files into the new folder. This folder and contents should be immediately set to read-only.
5. Before removing the photographs from the camera, it is important to confirm that all photos have been copied and are uncorrupted. If there's a problem, delete from the computer and re-copy. Once working files are confirmed, delete all photos from the camera.

4 References

Jakubos, B., and W. H. Romme. 1993. Invasion of subalpine meadows by lodgepole pine in Yellowstone National Park, Wyoming, U.S.A. Arctic and Alpine Research **25**:382-390.

SOP AlpineVCSS Vegetation: Vegetation Sampling in Alpine Survey Sites; *Optional*

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

Monitoring plant species composition and cover is fundamental to understanding changes in alpine ecosystems. Cover measurements recognize the contribution of small species, are directly related to the biomass of most plant functional types, and "are easily visualized and intuitive" (Elzinga, Salzer and Willoughby 1998, p. 178). Moreover, cover measurements correlate with ecological processes (such as microbial composition and abundance, nutrient cycling and productivity). Finally, estimating cover remains one of the most common methods in vegetation studies allowing for comparisons between our work and other national and local inventories. This SOP outlines the procedures to record canopy cover of all vascular species in microplots and subplots. Species presence is recorded in the larger 10 x 10 m macroplot and used for more robust estimates of site diversity.

3 Steps

3.1 Equipment list

- 1 m^2 plot frame
- Clip board, pencil, and data forms
- Compass (with declination set to appropriate value)
- Local flora or identification guide(s)

- 50 m field tapes
- Plant press or notebook for unknown specimens
- Digital camera
- Hand-held estimation tools

3.2 Procedures

Microplot cover

1. Place 1 m^2 plot frame down in the microplot due N of the center (microplot #1). The frame should lie so that the survey flag is at the outer most corner of the plot (2.83 m from the center), and the meter tape from the center should run through the center of the plot leaving the opposite corner 1.83 m from the center.
2. Examine the plot for the relative cover of vascular plants, solid rock, scree, lichens on soil (not covered by vascular plants), bryophytes on soil (not covered by vascular plants), bare ground, and litter. These categories correspond to the top cover surface types in the GLORIA Field Manual and should sum to 100%.
3. Examine the plot and identify all vascular plant species. For each species, estimate the canopy cover class within the plot frame using the marks on the frame (10 x 10 cm sections = 1% of the area each) and hand-held estimation tools (circles and squares cut to $100cm^2$) to assist you.

Tools are used to assist in estimating cover because they are a known area; hold the tool over the plants in the plot to judge whether the cumulative cover of the species is half, one, or several (count) of these units. For small, well spaced species, create an index by approximating the number of individuals per $100cm^2$ (1%) area; once you establish an index, always use the same index value for that species (i.e., at other plots and other sites). Divide the plot into half or quarters to allow for sub-estimates when the vegetation is dense, diverse or otherwise make the estimation complicated. We are estimating canopy cover; this means that you need to estimate the cover of an individual, or bunch, or indexed set of individuals, based on the approximate, irregular, but nearly regular, circumference of the leafy canopy cover. Do not include dead branches (e.g., of shrubs), but do include “dead centers” of bunchgrasses (e.g., *Deschampsia* spp.). Do not try to estimate “interlacing” of leaves with open space, but estimate the cover of the unit based on the perimeter. In most cases, the total cover within the plot will make up greater than 100% because it incorporates vertical structure. See Figure 1 for a sample of cover determination.

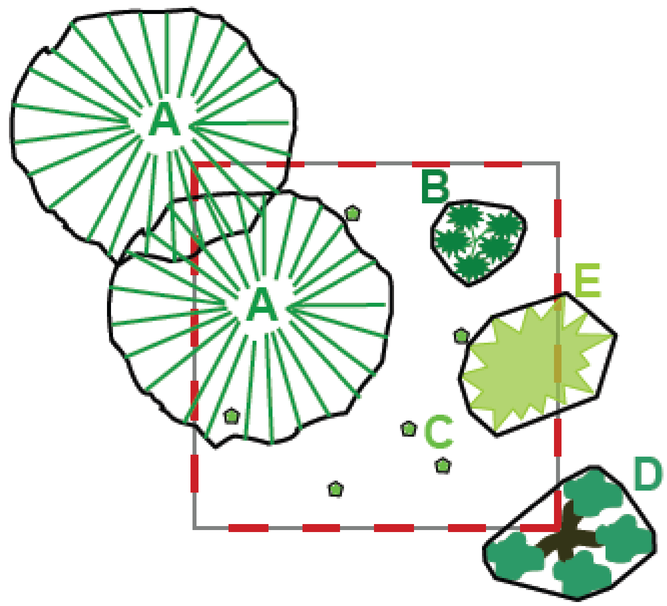

Figure 1. Foliage polygons, indicated in black lines, for different types of plants (all shapes are intended to be leaves, not flowers). The $1m^2$ plot frame is indicated in gray, with red-gray dashes each being 10 cm in length. Cover of the species as represented here would be: A, 35%; B, 5%; C, 2%; D, 0.0%; and E, 7% (adapted from Symstad et al. 2006).

Use an alpha-numeric code for unknown species with a number and letter indicating growth form (e.g. S, G, F, T, V for Shrub, Graminoid, Forb, Tree, Vine) Number these unknowns continuously so that Unknown forb #1 is the same at every site in the park (if it occurs there). For example: Unk.G.1 = unknown graminoid #1; Unk.F.1=unknown forb #1.

For common, but unidentifiable species in the plots, assign and record an unknown code as above. Then fill in an "unknown species" form (Figure 2), and make detailed notes on species characteristics including stem and leaf morphology, perennial or annual (if known), etc. Survey the surrounding area for a well developed example – use the digital camera to take a close-up picture (or, series of photos if needed to show attributes, e.g., leaf and flower – be sure to record the photo identifier(s) in the dataform). **Do not pick or collect any individuals**, *unless it is necessary for later identification, and we have permission of the park unit.* Then, carefully collect a sample including the an entire individual down to enough root to show root tops (~2-4 inches) and carefully place it in a prepared plant press. Instructions for pressing unknown plant specimens are found in Section 3.3. Specimens collected for identification must be destroyed once a determination has been made.

4. After recording cover data for species in microplots #1, work clockwise through microplots #2, #3, and #4 repeating steps 1-3.

Subplot cover

1. Repeat step 2-4 to collect surface types and vegetation cover in subplots (16 m^2) after completing cover in the microplots. The subplot includes all 4 microplots.

Macroplot species presence

1. After completing vegetation cover estimates in the microplots (1 m^2) and subplots (16 m^2), examine the macroplot (100 m^2). Document any species found in the macroplot that were not found in the smaller plots. Record only species presence, not cover.

3.3 Guidelines for pressing unknown plant specimens

Pressing plants can be used to preserve specimens until identification is possible. Plants should be pressed as soon as possible after they have been collected. They are more easily arranged in the press if they are not wilted. Specimens should be carefully shaken to remove any dirt or debris that may be attached to roots, stems, leaves or flowers. Gently rinse muddy plants to remove mud and blot rinsed plants dry with paper or cloth toweling before pressing.

If a plant press is available, fill the plant press from the bottom first, working toward the top layers. A double piece of newsprint should be laid on the 1st blotting paper and cardboard layer with the fold of the paper at one edge of the plant press. The newsprint is then opened and the plant is carefully arranged on the bottom sheet. Place a field collection label alongside the plant. This label should contain important information about the specimen, such as date of collection, identification and description, location of collection site (GPS reading of latitude and longitude), digital camera image, etc. The top layer of newsprint is then folded over the top of the plant, and then it is covered with another blotter sheet, then another piece of cardboard. **Note**: if without a plant press, an alternative option would be to carefully place a specimen between the pages of a book or notebook. The press is filled, one layer at a time, then compressed using bolts or straps.

A good pressing job requires practice and patience. You must smooth and flatten leaves individually. Most leaves should be arranged with their top surface facing upward, but turn 1 or 2 leaves upside down to show their undersurfaces. If the plant is too brushy, trim away some of the foliage, but not so much that the general character and shape of the plant is betrayed. Roots are generally spread in the manner that they occur underground. If they are too thick, slice them lengthwise in order to thin them for pressing. Arrange flowers in various positions so that all their features can be shown. Seeds, cones, and fruits are generally air dried separately in a ventilated location out of direct light.

After filling with specimens, the press should be placed in a warm, ventilated location for several days to allow the plants to dry completely. This process can be enhanced in a warming oven or a chamber with a warming light bulb designed for that purpose. If plants are particularly moist, or many plants are being pressed at once, it is a good idea to open the press each day and replace the newsprint with dry sheets so that the specimens don't mold. Check the plants each day and remove those that are completely dry. Thicker plants may take as long as two weeks to completely dry.

Unknown Species Information Form
(* Include Information from the 1st 6 lines (bold) on all collections*)

Park: ____________________ **Date:** ______________
Site code: ________________ **Site name/description:** ____________________________
Botanist: ____

Circle one: Macroplot Subplot Microplot1 Microplot2
Microplot3 Microplot4

Unknown Species Code: ___________________

Photo ID(s): Overview/ environment: __________, Whole plant: __________,
Inflorescence (macro): __________, Leaf (Macro) __________,
Leaf/ stem (macro):__________, Other char.__________: __________.

Notable features of the habitat (microhabitat characteristics):
____
____

Notable features of the growth form (plant type, rooting pattern, and general description):
____
____

Most salient feature (something unique to assist in recognition):
____

Leaf characteristics (type, margin, surface, colors):
____

Flower characteristics (inflorescence type; #sepals, petals, stamen, anthers; location, pubescence, color) :
____
____

Stem characteristics (shape, pubescence, markings, color, branching pattern):
____

Specimen collected: Yes No
____

Best Guess (at species ID):
____

Confirmed to be (post field verification/ ID):
____

Collected specimen storage location (for non-NPS herbaria, include contact information):
____
____

Figure 2. Sample of Unknown Species data form.

SOP AlpineVCSS Willows: Willow Structure and Herbivore Impacts in Alpine Survey Sites; *Optional*

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

This SOP provides step-by-step instructions for assessing the potential effects of herbivory from elk on woody shrubs in the site, focusing on two metrics: the proportion of browsed shoots in selected plants and willow height. The objective of sampling is to provide a quick but quantitative approach to evaluating the effects of native herbivores on willows in the site. The SOP is meant to address the specific management issue of elk over abundance on the condition of willow communities, which in the ROMN network, is primarily a concern in Rocky Mountain National Park.

3 Steps

3.1 Equipment

- Data form
- Pencils
- Clipboard

3.2 Procedures

1. Assess macroplot (100 m^2) for the presence of willows. If there are greater than 25 individuals in the macroplot, do all subsequent measures on the subplot (16 m^2). If there are fewer than 25 individuals in the macroplot, do all subsequent measures on the macroplot.

Herbivory

2. Starting at the N corner of the plot, move to the NE quadrat of the plot (delimited by the meter tapes).
3. Walk through the quadrat looking for upright willow shrubs (e.g., do not include low growing creeping forms such as *Salix arctica*). When a willow is encountered, identify the species, record a height class (Table 1)and estimate the % of dead stems (number of stems originating from below ground that were completely dead), % die back (dead crown), and % live stems or stem tips that have been browsed.

Table 1. Height class and corresponding height in meters for willows in alpine survey sites

Willow height class	Height (m)
1	<0.5
2	0.5- 1
3	1- 2
4	2- 3
5	> 3

4. Repeat step 3 to take measures on all willows in the quadrat, up to 25 individuals. If fewer than 25 individuals were measured, move in a clockwise direction through the quadrats (SE, SW, NW) until there are a total of 25 measures per species or all willows in the plot have been measured.

Woody Regeneration

1. Count and record the number of willow seedlings (<15cm tall) in each 1 m^2 microplot.
2. Count and record the number of willow saplings (15-50 cm tall) in the 16 m^2 subplot. Where possible, provide an estimate by species.
3. Count the number of mature shrubs (>50 cm tall) of each species in the macroplot or estimate to the best of your ability. Where dense canopies of shrubs make accurate counting difficult, count the number of discrete clumps and estimate the % of the macroplot covered by willows.

SOP AlpineVCSS Survey Data Analysis: Design Based Analyses; *Optional*

1 Change History

Previous version	Date	Author	Change description	Reason

2 Introduction

Design-based inference is fundamentally different than model-based approaches because design-based inference does not depend on an assumed model of the relationship between samples and the true population. In a design-based approach, expectations are extended over all possible samples based on the weighted values (i.e., measures, averages, etc.) contributed from each sampled site; independence is insured by the design process. Calculation of means are modified from simple mean calculations by weighting (multiplier) each site mean using the inverse of the inclusion probability (from the original design) as the weight; thus, the park-wide average is extrapolated from individual samples based on the area represented by each site in the original design.

3 Steps

1. Assure that data you are using were previously quality controlled and that you have parameter values for the appropriate level of analysis (Table 1);
2. Verify that summation and averaging steps were conducted properly; always use site level means for analyses (unless a specific application requires otherwise);
3. Retrieve inclusion probabilities for each point from original design files;
4. Calculate site weights as 1 minus the inclusion probability (1 – Prob);

5. Calculate a weighted mean by summing the product of each site weight and the value of interest (e.g., cover) then divide by the product of the sum of the weights and the number of sites. This is represented by the equation:

$$WMi = \Sigma\ (wt)(Xbar\ i) / Ni \qquad (8)$$

Where:

WMi = weighted Mean for Indicator 'i'
wt = 1 – Prob. of Inclusion (unique for each site; normalized so sum of weights = 1); data from original design
Xbar i = site level mean estimate (e.g., percent cover, frequency, etc.);
Ni = the number of sites;

Table 1. Parameters, units, and QA/QC for optional AlpineVCSS survey design

Parameter	Raw/Derived	Units	QA/QC	Unit of analysis
Cover of scree, rock, vascular plants, lichens, bryophytes, bare ground, litter	Raw	%	the sum of all 7 categories should add up to 100%	microplot and subplot
Species cover (vascular plants)	Raw	%	value for each vascular species present; not less than 0; includes layers so can be greater than 100	microplot and subplot
Species number	Derived	species	count number of vascular species present in summit area	macroplot
Diversity Index	Derived	shannon-weiner index, H'	H'= Sum (relative abundance of each species/ ln(relative abundance); upper limit ~4	macroplot
Evenness	Derived	Peilou index, J	J'=(diversity)/log(number of species); between 0 and 1	macroplot
Mean Coefficient of Conservation	Derived	index C	between 1-10; the mean of the coefficient of conservation assigned to each species present	macroplot
Floristic Quality Index	Derived	FQA	FQA=C * square root(number of species)	macroplot
dieback	raw	%	value for each species present for no more than 25 individuals per species	site
live stems browsed	raw	%	value for each species present for no more than 25 individuals per species	site
dead stems	raw	%	value for each species present for no more than 25 individuals per species	site
willow height class	raw	ordinal	class 1-5 based on height	site
willow seedlings	raw	willows		microplot
willow saplings	raw	willows		subplot
mature willows	raw	willows	value for each species present	site
cover of mature willows	raw	%		site

Number of exotic species present	Derived	species	count number of species present in peak area	macroplot
Identity of exotic species present	Raw	categorical	species list	macroplot
Percent cover of exotic species	Raw	%	not less than 0; includes layers so can be greater than 100	microplot and subplot
sand, silt and clay	raw	%		macroplot
texture	derived	NA	classification based on % sand, silt, and clay	macroplot
bulk density	raw	g/m3		macroplot
pH	raw	pH		macroplot
cation exchange capacity	raw	$cmol_c$/Kg soil		macroplot
micro and macronutrients	raw	%		macroplot
organic matter	raw	%		macroplot
C:N	derived	ratio	%C:%N	macroplot
surface soil aggregate stability	raw	categorical	class 1-6 based on dip cycles; see above	macroplot
subsurface soil aggregate stability	raw	categorical	class 1-6 based on dip cycles; see above	macroplot
distance to road	derived	m	derived from GIS	site
human disturbance index	derived	%	derived from anthropogenic disturbances calculated; range from 0 -100 (highly disturbed)	site
slope	raw	degrees		site
elevation	raw	m		site
beaver disturbance	raw	ordinal	class 1-4 based on high to no disturbance; 1: high >50% of site has evidence, 2: medium >10% or old evidence, 3: low no sign on site but some within 1km; 4: no signs in site	site

			or within 1km	
native ungulate disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	site
frost heave disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	site
rodent disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	site
pest & pathogens disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	site
landslide disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	site
fire disturbance	raw	ordinal	class 1-4 based on high to no disturbance; see above	site
natural disturbance	derived	index; NDI	derived from weighting natural disturbance categories; range from 0-100 (highly disturbed)	site