



Upper Columbia Basin Network Aspen Monitoring Protocol

Narrative Version 1.0

Natural Resource Report NPS/UCBN/NRR—2009/147



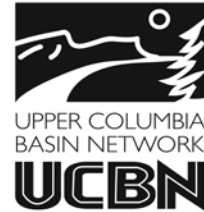
ON THE COVER

Populus tremuloides (Michx) near Stripe Rock at City of Rocks National Reserve
NPS Photograph from City of Rocks National Reserve, courtesy of Eva Strand

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September 2009

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

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Please cite this publication as:

Strand, E. K., S. C. Bunting, R. K. Steinhorst, L. K. Garrett, and G. H. Dicus. 2009. Upper Columbia Basin Network aspen monitoring protocol: Narrative version 1.0. Natural Resource Report NPS/UCBN/NRR—2009/147. National Park Service, Fort Collins, Colorado.

Change History

1. Version numbers increase incrementally by tenths (e.g., version 1.1, version 1.2, ...etc) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 ...). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.
2. Notify the UCBN Data Manager of any changes to the Protocol Narrative or SOPs so that the new version number can be incorporated in the Metadata of the project database.
3. Post new versions on the Internet and forward copies to all individuals with a previous version of the Protocol Narrative or SOPs. A list will be maintained in an appendix at the end of this document.

Version #	Date	Revised By	Changes	Justification
1.0				

Important Note: This sampling protocol consists of this protocol narrative and the standard operating procedures (SOPs), which are bound in a separate accompanying document.

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Executive Summary

The mission of the National Park Service is “to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations” (NPS 1999). To uphold this goal, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation’s natural heritage through science, natural resource inventories, and expanded resource monitoring (NPS 1999).

The Upper Columbia Basin Network has identified 14 priority park vital signs, indicators of ecosystem health, which represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales. Quaking aspen is a priority vital sign for two UCBN parks, Craters of the Moon National Monument and Preserve and City of Rocks National Reserve. The aspen monitoring protocol is a collaborative effort between the Department of Rangeland Ecology and Management at the University of Idaho, the National Park Service Upper Columbia Basin Network Inventory and Monitoring Program (UCBN), Craters of the Moon National Monument and Preserve and City of Rocks National Reserve. Aspen is a focal resource to these parks because of its biological and aesthetic significance. Aspen clones are among the most biologically rich plant communities in the Intermountain West and act as a keystone species (Kay 1997). Although aspen comprise only a small percentage of the land cover in the parks, the community type contributes significantly to species diversity and richness (Shive and Peterson 2001, Madison et al. 2003). Declining aspen habitats will cause losses of vertebrate species and vascular plants as well as invertebrates and nonvascular organisms (Campbell and Bartos 2001). Aspen stands furthermore provide forage for wildlife and domestic livestock in western landscapes and declines in aspen may require adjustments in stocking rates. Aspen is an important attraction for campers, naturalists, and recreationists in the otherwise semi-arid landscapes of Craters of the Moon National Monument and Preserve and the City of Rocks National Reserve.

This protocol details the why, where, how, and when of the UCBN’s aspen monitoring program. As recommended by Oakley et al. (2003), it consists of a protocol narrative and a set of standard operating procedures (SOPs), which detail the steps required to collect, manage, and disseminate the data representing the status and trend of aspen regeneration and density within the NPS UCBN parks. The protocol is a “living” document in the sense that it is continually updated as the monitoring techniques and sampling design evolve. Changes to the protocol are carefully documented in a revision history log. The intent of the protocol is to ensure that a seamless and scientifically credible story about the aspen populations within the parks, their supporting habitat and environmental conditions can be told to park visitors and park managers alike. The next few years of monitoring results will enable us to establish baseline data to find answers to questions related to temporal variability in suckering, recruitment, mature aspen stem density, number of dead stems and conifer density. Initially we will continue to refine the power analysis to optimize the number of samples necessary for detecting trend with statistical confidence while minimizing the sampling efforts and costs. For future years, the focus will shift toward trend analysis, in which biologically meaningful declines or increases within the park units as well as within individual stands will be detected, providing ecological decision support information and enabling development of appropriate management strategies.

Acknowledgements

Funding for this project was provided through the National Park Service Natural Resource Challenge and the Servicewide Inventory and Monitoring Program. We thank the Oregon Museum of Science and Industry (OMSI) and members of its 2005 Salmon Camp program for field assistance. We thank the staff of Craters of the Moon National Monument and Preserve and City of Rocks National Reserve for contributions and critique of this monitoring protocol and for assistance during field reconnaissance. Sincere thanks to Kathryn Irvine and Leigh Ann Harrod for providing invaluable statistical expertise to this monitoring protocol. Many thanks to Leona Svancara, data manager for the Upper Columbia Basin Network from 2004-2006 who developed the initial data management framework for this protocol. We further thank Gina Wilson for the initial mapping of the City of Rocks National Reserve vegetation and all those who have contributed to field sampling over the years. Tom Rodhouse provided helpful comments throughout the development of this protocol. We sincerely thank two anonymous reviewers for constructive suggestions on how to improve content and clarity of this protocol.

Background and Objectives

This document presents a protocol for monitoring the status and trends of indicators of aspen ecological condition in two Upper Columbia Basin Network (UCBN) parks: City of Rocks National Reserve (CIRO) and Craters of the Moon National Monument and Preserve (CRMO). The protocol details an aspen clone sampling strategy, including a sampling design and field methods, which will enable the UCBN to achieve monitoring and sampling objectives identified in this document and in the network monitoring plan (Garrett et al. 2006).

Aspen Life History and Ecology

Quaking aspen (*Populus tremuloides*, Michx.) of the willow (Salicaceae) family is the most widespread deciduous tree in North America, ranging from Alaska in the north to Mexico in the south, from the Atlantic to the Pacific coast of North America (Little 1971), and from sea level to 3700 m altitude (Mitton and Grant 1996). Although the geographic range is large, aspen's high evapotranspirative demands limits the species to areas where the annual precipitation exceeds 400 mm (DeByle 1985). According to Perala (1990) quaking aspen occurs where annual precipitation exceeds evapotranspiration. After the retreat of continental and alpine glaciers during the Pleistocene, poplar, willow, and various shrubs were among the first pioneers (Pielou 1991), explaining the current spotty distribution of aspen in the high elevation mountainous areas of western landscapes. The life cycle of quaking aspen in the West is unique. Although aspen is a prolific producer of viable seed, conditions required for successful germination and establishment of aspen are rare in the West (Kemperman and Barnes 1976; Romme 1982; Mitton and Grant 1996). Many botanists argue that significant sexual reproduction in aspen has not occurred in the western United States within the last 10,000 years, since the last glaciations (Einspahr and Winton 1976; McDonough 1985). An example of recent successful establishments of aspen seedlings followed the severe fires in Yellowstone in 1988, which apparently provided a 'window of opportunity' of suitable substrate and climate conditions (Romme et al. 2005).

The primary means of aspen reproduction in the West is via vegetative root suckering (Bartos 2001). Vegetative reproduction in aspen clones requires disturbance to promote suckering. Mortality of individual aspen stems caused by disturbance interrupts the balance between the two hormones auxin and cytokinin such that when mature aspen trees are killed or stressed the flow of auxin is suppressed and cytokinin can begin to stimulate root suckering (Bartos 2001). According to Barnes (1975) aspen clones can exist as self-regenerating organisms for thousands of years through periodic disturbance. Although aspen clones are long-lived, individual aspen stems are short-lived, normally living 100-150 years (Shepperd et al. 2001) with some occasionally exceeding 200 years (Mueggler 1989). Sexual regeneration requires prolonged moist conditions and is extremely rare for intermountain western aspen. An aspen clone lost from the landscape will generally not regenerate from seed (Mitton and Grant 1996).

Aspen stands in the western mountains commonly occur in conjunction with conifer species such as western juniper (*Juniperus occidentalis*; Wall et al. 2001; Roth 2004), Douglas-fir (*Pseudotsuga menziesii*; Heide 2002; Kaye et al. 2003; Roth 2004) or subalpine fir (*Abies lasiocarpa*; Smith and Smith 2005) but have also been observed to occur as uneven-aged aspen stands where aspen appears to persist as a stable, self-regenerating ecosystem. These stable aspen systems are unsuitable for conifers or are far away from conifer seed sources (Mueggler 1989).

In biophysical settings where aspen is seral to conifer species, slow-growing shade tolerant conifers begin to overtop aspen late in succession and will eventually outcompete and lead to the loss of aspen from the stand (Shepperd et al. 2001). Shepperd et al. (2001) show that aspen growth rates are independent of the presence of conifers in early to mid-succession and estimate that conifers will begin to out-compete aspen at a stand age of 100-150 years.

Aspen stands are preferred habitats for native ungulates such as deer (*Odocoileus* spp.), elk (*Cervus elaphus*), and moose (*Alces alces*) who utilize aspen woodlands for preferred forage (Beck 2003; Barnett and Stohlgren 2001; Kaye et al. 2003; Shirley and Erickson 2001; Binkley 2008), shade, and cover. Browsing by wildlife and livestock has been shown to inhibit successful regeneration in aspen stands (Bartos and Campbell 1998; Kay and Bartos 2000; Kaye et al. 2005). Aspen regeneration is particularly affected within elk winter range in areas where elk are not hunted (Hart and Hart 2001) but browsing impact can vary dramatically across the landscape (Suzuki et al. 1999; Binkley 2008). Ripple and Beschta (2007) show that aspen regeneration in Yellowstone National Park is positively correlated with wolf numbers resulting from cascading trophic relationships. The presence of large predators (wolves) alters the foraging behavior of ungulates such that browsing is reduced and aspen and willow regeneration and growth is increased (Ripple and Beschta 2007).

Within the past decade, drought has been reported to incur mortality in aspen in Colorado (Worrall et al. 2008) and in Canada (Brandt et al. 2003; Frey et al. 2004). Aspen dieback in Canadian parklands has been correlated with stand age, drought and freeze-thaw events, defoliation, wood-boring insects, and fungal pathogens (Brandt et al. 2003; Frey et al. 2004). In Colorado, mature stands on south facing slopes at low elevation have been found particularly susceptible to disease and insects as a result of high temperatures and acute drought. Rising temperatures and drought have also been correlated with increased forest mortality in the southwestern U.S. (van Mantgem and Stephenson 2007; van Mantgem et al. 2009).

Park Descriptions

Craters of the Moon National Monument and Preserve (CRMO) is located in south central Idaho 24 kilometers southwest of the town Arco on the Snake River Plain of Idaho (long 113°35'W, lat 43°30' N). Over the past 15,000 years lava eruptions have created a rugged landscape characterized by cinder cones, spatter cones, lava tubes and fields, and other basalt lava deposits of varying age. The last volcanic event occurred 2000 years ago and future events are expected. The National Park Service began management of the Craters of the Moon National Monument and Preserve (CRMO) in 1924. Today the area encompasses over 30,000 hectares and is co-managed by the National Park Service and the Bureau of Land Management. Elevations in the monument range from 1600 m at the southwestern lava fields to 2356 m at the top of Pioneer Mountain, in the north. The annual average of precipitation is 395 mm and falls primarily during the winter and spring, in the form of snow in the winter. Temperatures reflect the high desert climate with an average high temperature of 29 ° C (84° F) in July and an average low of -12 ° C (10° F) in January.

The unique land formations of CRMO engage a large number of visitors each year in exploring the volcanic features, hiking, camping, and viewing flora and fauna within the park. Hunting or livestock grazing are not allowed within the park boundary. In spite of the rugged landscape

dominated by relatively recent lava flows, CRMO offers a variety of habitats such as sagebrush steppe, grasslands, aspen/conifer woodlands, limber pine/antelope bitterbrush, riparian shrubs, and wet meadows. Aspen in CRMO typically occurs in riparian areas, as pure or mixed upland aspen/conifer stands in concave areas of moisture accumulation and as short shrubby snow-bank aspen near ridges. Conifer species such as, Douglas-fir, limber pine (*Pinus flexilis*) and occasionally Rocky Mountain juniper (*Juniperus scopulorum*) occur in varying amounts in many aspen stands. Understory species characteristic of upland aspen stands in CRMO include Kentucky bluegrass (*Poa pratensis*), Idaho fescue (*Festuca idahoensis*), basin wild rye (*Leymus cinereus*), pine grass (*Calamagrostis rubescens*), lupine (*Lupinus* spp.), yarrow (*Achillea millefolium*), Indian paintbrush (*Castilleja* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), aster (*Aster* spp.), white hawkweed (*Hieracium albiflorum*), mountain big sagebrush (*Artemisia tridentata* subsp. *vaseyana*), mountain snowberry (*Symphoricarpos oreophilus*), wax currant (*Ribes cereum*), Woods' rose (*Rosa woodsii*), and chokecherry (*Prunus virginiana*). Although livestock grazing is not permitted in CRMO browsing and grazing by wildlife is apparent. Large herbivores in CRMO include mule deer (*Odocoileus hemionus*), elk, and moose.

City of Rocks National Reserve (CIRO), characterized by spectacular granite rock formations, is located in south central Idaho near the town of Almo (long 113°40'W, lat 42°05' N). The reserve encompasses 5,800 hectares of which 1,760 hectares consist of private inholdings. Elevation in the reserve ranges from 1,722 m in the eastern-most part of Circle Creek valley to 2,703 m at the top of Graham Peak, in the north. The annual 250-380 mm of precipitation falls primarily during the winter and spring, with a persistent snow-pack during most of the winter. Summer temperatures may vary from above 38° C (100° F) to near-freezing temperatures at night.

City of Rocks National Reserve (CIRO) has been a landmark for travelers since the early 1840's when the first emigrants traveled through the area on the California Trail and The Salt Lake Alternate Trail. City of Rocks was designated a national reserve in 1988 and is currently managed cooperatively by the National Park Service and the Idaho Department of Parks and Recreation. Historical uses of the area such as hunting and livestock grazing are 'grand-fathered' into the current-day management. Today the park attracts a large number of visitors that enjoy hiking, biking, horseback riding, camping, and especially rock climbing.

CIRO is located at the northern edge of the Great Basin and includes habitat types such as pinyon/juniper woodlands, conifer/aspen woodlands, curlleaf mountain-mahogany woodlands, riparian shrubs, herbaceous wetlands, sagebrush steppe and high elevation meadows. Aspen in CIRO typically occurs in riparian areas, as pure or mixed upland aspen/conifer stands and as short shrubby snow-damaged aspen near ridges. Conifer species such as single leaf pinyon pine (*Pinus monophylla*), Utah juniper (*Juniperus osteosperma*), Douglas-fir, subalpine fir and limber pine occur in varying amounts in most aspen stands. Understory species characteristic of upland aspen stands in CIRO include Kentucky bluegrass, bulbous bluegrass (*Poa bulbosa*), Idaho fescue, smooth brome (*Bromus inermis*), sweet cicely (*Osmorhiza chilensis*), western meadow-rue (*Thalictrum occidentale*), lupine, yarrow, sticky purple geranium (*Geranium viscosissimum*), tall larkspur (*Delphinium exaltatum*), sagewort (*Artemisia ludovisiana*), common dandelion (*Taraxacum officinale*), common mullein (*Verbascum thapsus*), nettleleaf horsemint (*Agastache urticifolia*), Indian paintbrush, aster (*Aster* spp.), wax currant, and green rabbitbrush (*Chrysothamnus nauseosus*).

The diverse habitats support a large number of wildlife species. Mountain lion (*Puma concolor*), mule deer, cliff chipmunk (*Tamias dorsalis*), and pinyon mouse (*Peromyscus truei*) are examples of the many mammals in the park. Reptiles include among many others the western rattlesnake (*Crotalus viridis*), Great Basin gopher snake (*Pituophis catenifer*), western fence lizard (*Sceloporus occidentalis*), and the northern desert horned lizard (*Phrynosoma platyrhinos*). Rocks and cliffs provide excellent habitat for a variety of raptors while woodlands, steppe, and riparian areas attract grouse, jays, nighthawks and a variety of songbirds.

Rationale for Monitoring Aspen Clones in the Upper Columbia Basin

Second only to riparian ecosystems, aspen communities are the most biologically diverse areas in the Intermountain West (Kay 1997). Although aspen covers only a small portion of the western landscapes, this plant community supports a disproportionately large array of species in relation to its area. The consequence being that aspen declines cascade into losses of vertebrate species and vascular plants (Winternitz 1980; Jones 1993; Campbell and Bartos 2001; Chong et al. 2001; Rumble et al. 2001). Native ungulates such as deer, elk, and moose utilize aspen for preferred forage (Beck 2003; Barnett and Stohlgren 2001; Shirley and Erickson 2001), shade and concealment. Aspen has furthermore been described as an indicator of ecosystem integrity (Woodley et al. 1993) and portrayed as a keystone species. A keystone species, as defined by Wilson (1992), is a species that, if removed, would “cause a substantial part of the community to change drastically.”

Aspen is an important resource to City of Rocks National Reserve and Craters of the Moon National Monument and Preserve because of its biological and aesthetic significance. Although aspen comprises only a small percentage of the land cover in the parks, the community type contributes significantly to species diversity and richness (Shive and Peterson 2001; Madison et al. 2003). Aspen brings visitors to the western mountains and parks, improves local economies, inspires poets and artists, and is portrayed in modern stories as well as tribal myths (McCool 2001). Aspen is an important attraction for campers, naturalists, and recreationists in the otherwise semi-arid landscapes of City of Rocks National Reserve and Craters of the Moon National Monument and Preserve.

The overall goal of the UCBN vital signs selection process was to develop a comprehensive monitoring program such that it will yield information “greater than the sum of its parts.” Following recommendations by Noss (1990) and others, the UCBN aimed to develop an ecologically integrated program by selecting vital signs that span a range of spatial and temporal scales and multiple levels of ecological hierarchy (Figure 1). Aspen exhibits a slower rate of change than other vital signs chosen and covers a greater spatial extent in two Network parks. Information gained from monitoring aspen will contribute to the weight of ecological knowledge about natural resources at CIRO and CRMO and to regional management strategies for the conservation of aspen. In particular, aspen in CIRO and CRMO is occurring in areas that are approaching or are currently below the precipitation threshold of 400 mm per year suggested by DeByle (1985) for where upland aspen can sustain long-term. In the case of a locally changing climate resulting from global climate change, aspen in these parks may be one of the first species to respond to such climate warming. It is not currently known how aspen will react to a warming

climate, and the trends observed, as part of this monitoring protocol, may become invaluable data contributing to future aspen management in the western United States.

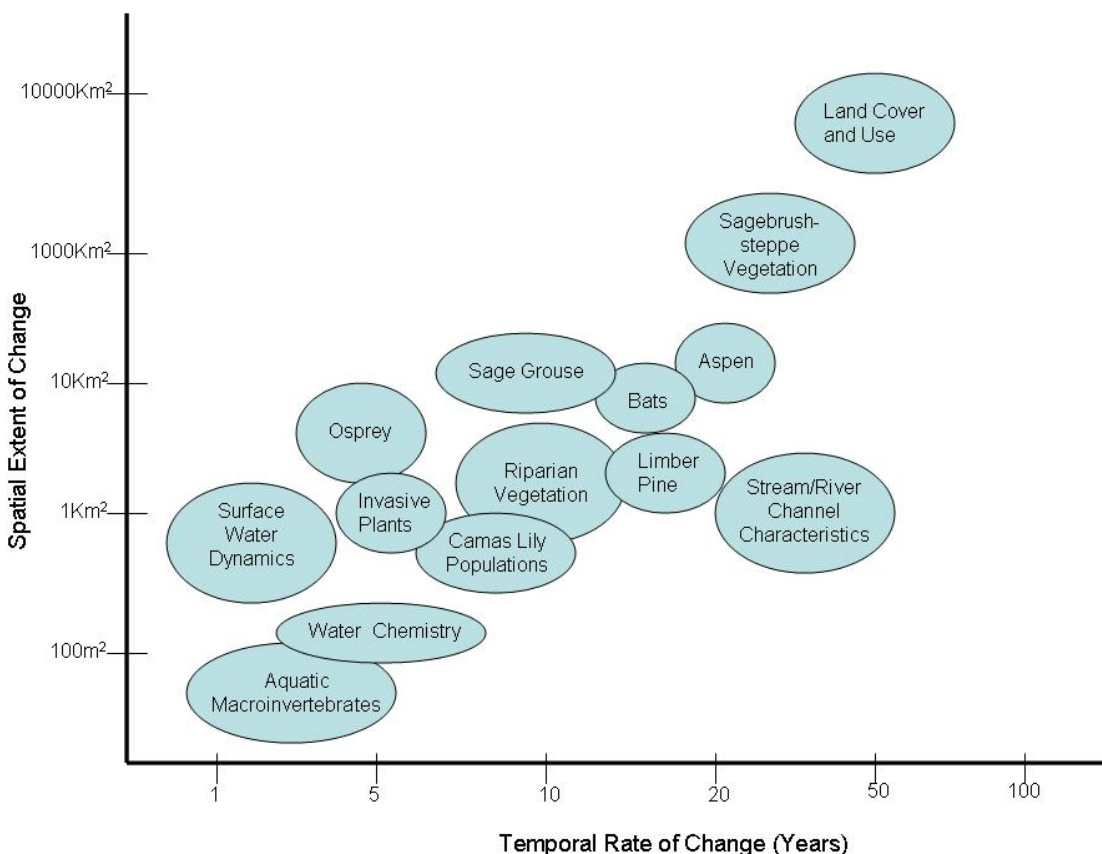


Figure 1. High priority vital signs organized according to the spatial extent and temporal rate of predicted or anticipated change in UCBN ecosystems. Rates of change in UCBN aspen stands are expected to span kilometers and decades.

Quaking aspen is currently declining across the western United States. Aspen decline compared to historical distribution range from 49% in Colorado to 96% in Arizona, with an estimated loss of 61% in Idaho (Bartos 2001) within the past century. Data presented by DeByle et al. (1987) imply that rates and extents of wildfire rejuvenation of aspen stands has been rare during the last 100 years in the western states, and that fire suppression has been very effective in the last 50 years. Jones and DeByle (1985) suggested that moderately intense fires at 20-130 year intervals with a mean interval of 50 years would be sufficient to sustain healthy aspen stands in the West. Native ungulates and domestic livestock utilize aspen for preferred forage (Beck 2003, Barnett and Stohlgren 2001, Shirley and Erickson 2001). Browsing by wildlife and livestock has been shown to inhibit successful regeneration in aspen stands (Bartos and Campbell 1998; Kay and Bartos 2000). Aspen regeneration is particularly affected within elk winter range in areas where elk are not hunted (Hart and Hart 2001). A reduction of 40-80% in aspen regeneration has been reported in Yellowstone National Park and Rocky Mountain National Park (Hart and Hart 2001).

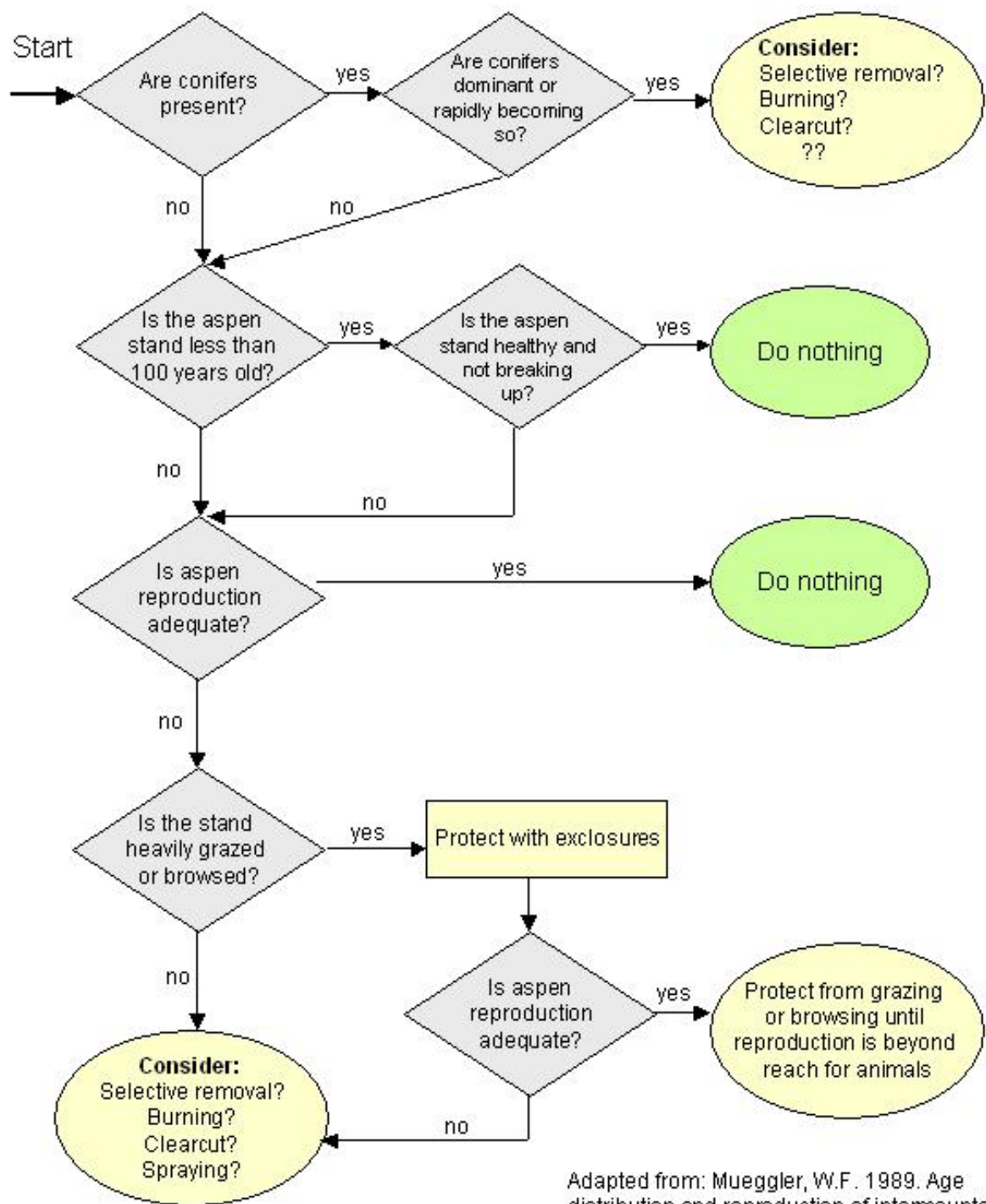
Another phenomenon affecting western aspen is referred to as ‘aspen die-off’ and is different from the slow decline in aspen populations that has been occurring over the past century. In

cases of ‘aspen die-off’ mature aspen stems are dying with no apparent regeneration in the form of suckering (Rocky Mountain Research Station 2008). Scientists and managers are currently researching the causes and working on finding solutions to this die-off, currently affecting as much as 10% of western aspen stands (Cleaves 2006).

Conditions identifying aspen stands at-risk have been suggested by Bartos and Campbell (1998). These conditions include aspen stands where the regeneration (stems 1.5-4.5 m tall) is <1,200 stems/hectare, conifer canopy cover is over 25%, total aspen canopy cover is less than 40% or where the majority of the stems are over 100 years in age. The desired future condition for aspen stands within CIRO and CRMO is defined as stands that do not exhibit the traits for aspen stands at-risk as described above. The at-risk thresholds suggested by Bartos and Campbell (1998) were developed in Utah and long term monitoring and data analysis of aspen stands in CIRO and CRMO may yield thresholds that are different and specific to these parks. Preliminary visual examination of time series aerial photography (1950, 1977, 1990, and 2004) for a central area in CIRO, reveals a reduction in aspen density within several clones although the extent of the clones through time appear similar.

Initial signs of aspen decline manifest itself as reduced regeneration within the clone, decreasing number of aspen stems, and increasing counts of conifer stems and dead aspen stems. It is desirable to detect these initial signs of aspen decline at an early stage where management may more effectively reverse a negative trend. Monitoring aspen regeneration and stem density of live and dead aspen stems and conifers is important for determining when active management could be considered for restoration and the long-term maintenance of aspen stands in CIRO and CRMO. Data provided by this vital signs monitoring protocol will enable the parks to engage in adaptive and proactive management with the goal of long-term preservation of aspen habitats within the parks.

In the event that management action would become desirable for long-term aspen maintenance, Miller et al. (2005) emphasize the importance of asking the right questions before selection of management technique. What is the desired future condition? What factors are affecting proper ecological function? What is the current state of the site? What is the predicted outcome of a treatment? Shepperd (2001) suggests a series of management techniques available for potential restoration of aspen stands, including commercial harvest, prescribed fire, mechanical root stimulation, removal of vegetative competition, protection of regeneration from herbivory, and regeneration from seed. When selecting a management strategy it is important to consider the history and the trajectory of the aspen clone as well as the biophysical setting within the landscape (Shepperd 2001; Kashian et al. 2007). The scale of a treatment is also important. For example, a smaller area treated may become heavily browsed by ungulates while if a larger area is treated the increased browsing will be dispersed across the landscape with less impact on individual young aspen stand. Mueggler (1989) provides a potentially useful decision support diagram for selecting an appropriate management strategy for aspen stands (Figure 2). A long-term monitoring program for detecting status and trends in aspen regeneration and population density at CIRO and CRMO will directly measure the population characteristics most important to park mission, visitor experience, and desired future conditions, and will provide necessary data to provide feedback to adaptive management programs.



Adapted from: Mueggler, W.F. 1989. Age distribution and reproduction of intermountain aspen stands. Western Journal of Applied Forestry 4(2):41-45

Figure 2. Management decision support chart for upland aspen, adapted from Mueggler (1989).

Objectives

The overarching programmatic goal of the UCBN aspen vital signs monitoring program is to obtain information that will aid in informed management decisions pertaining to the perpetuation of the quaking aspen populations in CIRO and CRMO. Currently, little information is available about aspen regeneration and stem density. Given the current region-wide aspen decline and aspen die-off it is of great importance to assess the current status of the aspen populations in CIRO and CRMO. Identification of aspen stands at risk is the first step towards selecting management strategies that may help to prevent loss of this biologically and socio-economically important resource within the parks. The UCBN is also interested in pursuing broader ecological questions about the population ecology of quaking aspen, such as the relationship between aspen regeneration and live and dead stem density, and trends in climate variables (e.g., annual precipitation, temperature, growing degree days, snow pack) placed within the context of predicted climate change. Given the lack of available ecological data on aspen at CIRO and CRMO, the following fundamental questions continue to drive much of the UCBN's inquiry into aspen population ecology:

- Are the aspen populations stable, declining, or increasing?
- Are aspen clones regenerating; at what level? What is the long-term trend in regeneration of park aspen populations as well as individual stands?
- What is the aspen density of live and dead aspen stems? Is the live and dead stem density declining or increasing in the parks and in individual stands?
- What is the status and trend in conifer density within aspen stands?
- What is the variability of regeneration in plots within an aspen stand and between different aspen stands?

In light of these questions and the broader goals outlined above, this protocol will address the following specific measurable monitoring objectives:

- Estimate current status and long-term trend in regeneration of park aspen populations as well as individual stands within CIRO and CRMO.
- Estimate status and trend in aspen abundance, as measured by stem density in size classed of live and dead trees, within aspen stands.
- Estimate the status and trend in dead standing aspen stems.
- Estimate the status and trend in conifer density within aspen stands.

The following statistical sampling objectives have been developed for this protocol:

- Estimate with 90% confidence the mean, $\hat{\mu}$, within $\pm 25\%$ of the true mean, μ , for aspen stem density (stems/ha) of suckers, regeneration, mature trees and dead stems.
- Detect with $>80\%$ certainty (power, or $1-\beta$) a change $\geq 25\%$ between any two sequential time periods (5 years) of mean aspen live or dead stem density estimates with a 0.10 acceptable false-change (α) error rate.

We believe that sampling to detect a 25% change in aspen stem density between two sequential time periods of 5 years is adequately conservative to prevent loss of aspen clones. The selection of 90% confidence and 80% certainty was agreed upon by the protocol design team because these levels are traditionally acceptable in statistical analyses.

Sampling Design

The sampling design described in this monitoring protocol is being implemented in two parks, City of Rocks National Reserve (CIRO) and Craters of the Moon National Monument and Preserve (CRMO). Clearly, this protocol may be suitable for monitoring aspen in other areas in the western United States, or other semi-arid areas, where the management objective is to maintain aspen stands on the landscape. The first step in this process is to identify aspen stands in the target study areas, which can be accomplished by interpretation and on-screen digitizing on recent aerial photographs, classification of satellite images, field reconnaissance, or commonly a combination of these approaches. During these initial steps towards development of a monitoring protocol, personnel skilled in GIS and remote sensing are essential. It can be expected that the identification and mapping of aspen stands and evaluation of the variability in measured variables will occupy one field season. The number of personnel required will depend on the size of the study areas but in general one GIS/remote sensing specialist, one plant ecologist, and at least one field assistant is recommended for completing the initial mapping of the aspen resources within the area of interest.

Sampling Design Rationale

The objectives and sampling design were developed through a process that involved site reconnaissance, pilot data collection and analysis, and thoughtful consideration of park and network information requirements. The development team consisted of the protocol authors, as well as other UCBN I&M and park interpretive staff. Pilot data were collected at CIRO in June 2005 through the field assistance of the Oregon Museum of Science and Industry Salmon Camp Program, and in both CIRO and CRMO in July 2006 by personnel from the Department of Rangeland Ecology and Management at the University of Idaho.

The decision to focus on stem counts in different size classes of aspen and conifer species, including dead aspen stems, originated in two existing aspen monitoring protocols by Kilpatrick et al. (2003) and Jones et al. (2005). Aspen stems that are beyond the reach of browsers (~1.7 m) but are not yet mature trees reaching the crown (1.7 – 5 m tall) are considered new regeneration into the aspen population (Bartos and Campbell 1998). Information about stem density in five size classes will provide necessary ecological data to determine if the aspen regeneration is adequate, and if the clone is deteriorating, indicated by a decreasing trend in live stems and an increasing trend in dead stems. The protocol will furthermore provide information about the trend in conifer density within the stands and in the park units.

The target population for monitoring is all upland aspen stands located within the park boundaries. In the summer of 2006 aspen stands were delineated on aerial photos or using a Global Positioning System (GPS) unit in the field in CRMO (Figure 3) and CIRO (Figure 4). Each aspen stand serves as the observational unit. Aspen in the riparian corridor, short shrubby snow damaged aspen, stands which are smaller than 0.3 ha in area, or aspen stands on private lands were excluded from the sampling frame. Therefore, some of the stands in Figure 3 and 4 were not selected for sampling.

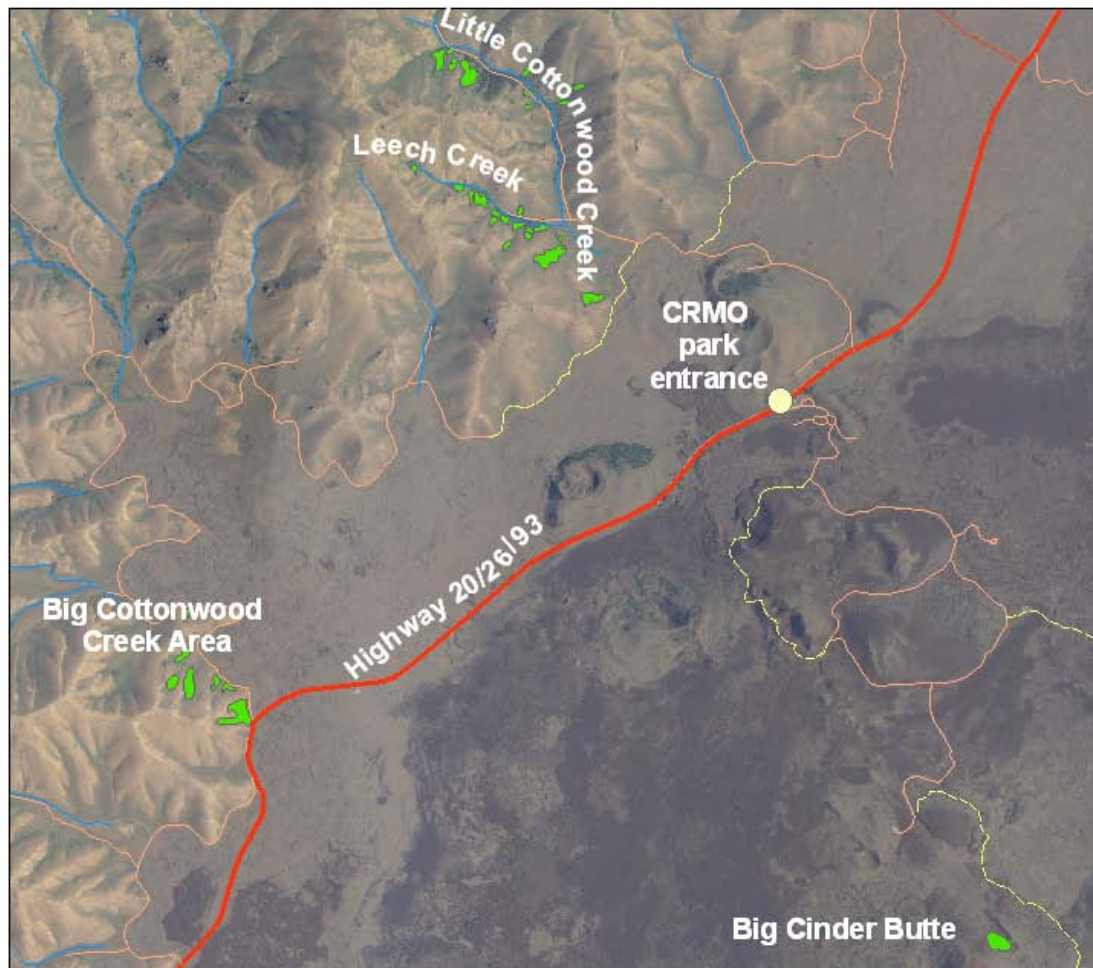
We deviated from the guidelines by Kilpatrick et al. (2003) and Jones et al. (2005) for the placement and shape of the sampling units within the stands. Kilpatrick et al. (2003) uses circular plots placed along a transect. The first circular plot is placed in the oldest part of the stand and

consecutive plots are placed at a random distance from the initial plot in a random direction. If the edge of the stand is reached a new random direction is followed. The sampling continues until a power of 0.8 has been achieved. Although this method has attractive components the risk is too high of reaching a power of 0.8 prematurely because the initial sampling might by chance have occurred in a homogeneous part of the stand. Jones et al. (2005) utilized permanent belt transects placed non-randomly in areas where aspen is regenerating. However, this approach leads to positively biased regeneration estimates and compromises overall scope of inference. Our approach involves random selection of plot locations within stands and allows all parts of the stand to be available for sampling. We also anticipated problems with pseudoreplication (*sensu* Hurlbert 1984) from spatial dependence between adjacent plots, which would lead to underestimation of variances. We estimated minimum distances of spatially independent plots by examining semi-variograms for each size class in pilot data from 2006, and used these distances to design the transect and plot layouts (Cressie 1991). This protocol utilizes circular plots organized along transects with four plots each at a distance determined via the variogram analysis. We chose to place the plots in transects of four plots per transect to enable easier relocation of plots.

Transects can be placed within the aspen stands in permanent or temporary locations (Elzinga et al. 2001). Implementation of permanent transects will require placement of permanent markers such as rebar with metal caps in the ground to accommodate relocation of the exact location in following years. The advantage of permanent sampling locations is the lower number of samples required to adequately characterize the change between two time periods particularly in situations where the year-to-year correlation between stem counts along transects is high (Elzinga et al. 2001). We opted to use only permanent transects because pilot studies show that the spatial variability of stem counts (particularly the younger size classes) is high. The number of transects placed in each stand is determined via power analysis to allow for detection of trend with statistical confidence and power while minimizing the sampling effort. The number of transects placed in each stand is further weighted by the area of the stand such that larger stands will have more transects than smaller stands.



Upland aspen stands



0 0.5 1 2
Miles

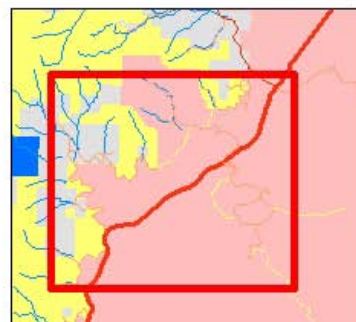
Transportation

Road Class

- Highway 20/26/93
- Undivided two-way road
- One lane road
- Jeep trail, 4WD
- Trail

Land steward

- BLM
- Forest Service
- National Park
- Private
- State



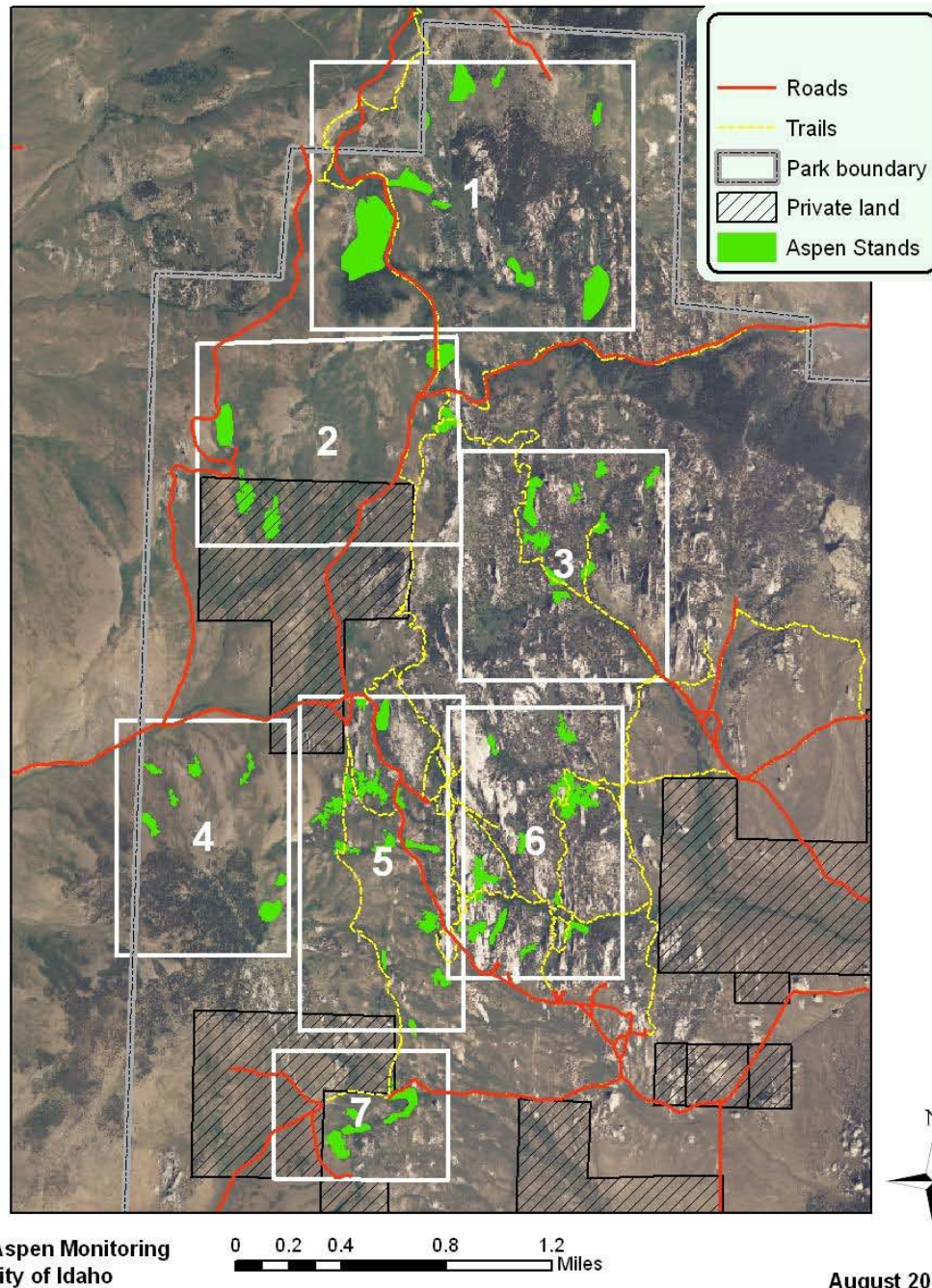
March 2009

FILE: C:\hps\crmo\CRMOStand2007.mxd

Figure 3. Map of aspen stands in Craters of the Moon National Monument and Preserve.



Aspen stands and sampling units



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Figure 4. Map of aspen stands in City of Rocks National Reserve divided into seven sampling units because of the large number of stands in this park. Some of the mapped stands do not fulfill the predetermined criteria for sampling.

When determining the temporal sampling interval the expected change between two sequential sampling periods must be considered. In the case of aspen stem counts of different size classes we can expect the largest temporal change in the smaller size classes (Class I - Suckers or seedlings <46 cm (1.5 ft) tall and Class II - Suckers or seedlings <46 - 152 cm (1.5-5 ft) tall). According to preliminary data (Figure 5) it takes 4-15 years for an aspen seedling to reach a height of 152 cm (5 ft). We determined that a sampling interval of 3-5 years will be sufficient to detect change in aspen regeneration. In the developmental stages of this protocol (the first two time periods) we will collect samples three years apart. We are aware that the growth rates are based on very limited data and as we gain a better understanding of the temporal change within aspen size classes this temporal rate will be adjusted. Currently we estimate a five-year sampling interval for the final long-term protocol.

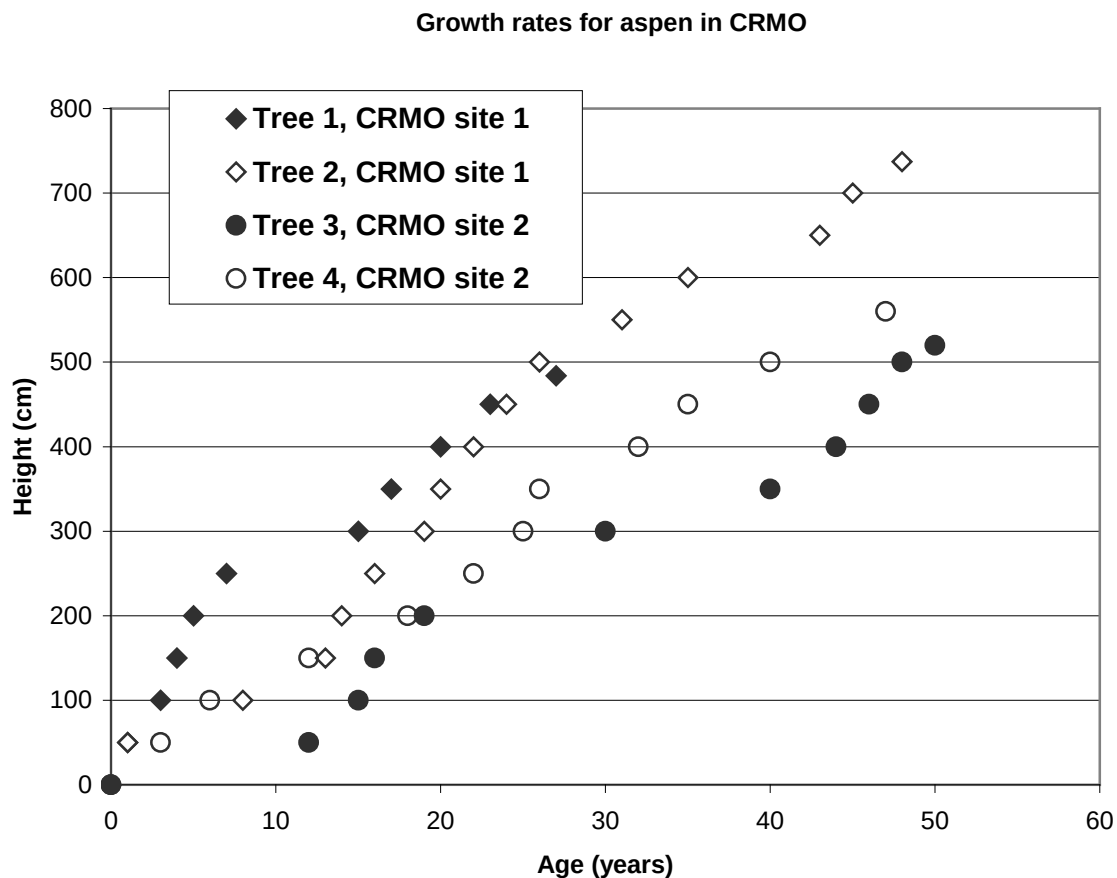


Figure 5. Growth rates of aspen in CRMO, sampling in 2006. The site locations are given in Table 1.

Pilot Data Sets

Sampling 2005 at City of Rocks National Reserve: In 2005 the Oregon Museum of Science and Industry (OMSI) Botany Research Team conducted baseline sampling. Aspen stem density was recorded in 5-m radius circular plots in 13 aspen stands. These data provided important information about within and among stand variability, which was used in power analysis computations.

Sampling 2006 at City of Rocks National Reserve and Craters of the Moon National Monument and Preserve: The goal for collecting pilot data this season was to gain a better understanding of the within stand variability of aspen stem density in different size classes. Five large aspen stands; two in Craters of the Moon National Monument and Preserve and three in City of Rocks National Reserve were non-randomly selected for intensive sampling. Twenty 4-m radius circular plots were spatially stratified within each stand to ensure that the entire stand area was included in the sampling. The plots were placed in three transects with an equal distance between plots in each transect. The distance between plots and transects was allowed to vary depending on the size of the aspen stand. Measurements in each plot included GPS coordinates, a stem count of all aspen and non-aspen trees and assignment of each stem into predetermined height classes (Table 1).

Table 1. Data from five sampled stands in 2006. Average and standard deviation of stem count within the five stands and four size classes are listed. Class A: <1.5 m (5 ft) tall, Class B: 1.5 m (5 ft) to 75% of the stand height (regeneration), Class C: Young trees taller than 75% of the stand height but not in the top of the canopy, Class D: Mature trees reaching the upper canopy. Notice that these size classes used in 2006 are different than those proposed for this version of the protocol.

Stand Date	Species	CRMO1-06 20060706	CRMO2-06 20060706	CIRO1-06 20060713	CIRO2-06 20060714	CIRO3-06 20060715
Easting NAD83		290537.8	290969.8	274456.2	274261.2	275769.2
Northing NAD83		4816928.9	4816267.9	4662413.3	4665932.3	4664348.3
Elevation m		1837.00	1,820.00	2,031.00	2,323.00	1,980.00
Slope %		45.00	38.00	25.00	15.00	10.00
Aspect		10.00	20.00	60.00	130.00	240.00
Stand height m		8.00	7.25	7.50	14.00	18.00
Stand size, m2		6,274.00	15,322.00	8,789.00	77,533.00	18,709.00
Correction for a finite pop.		0.916	0.967	0.941	1.000	0.973
Class A, average stems/ha Aspen		8,022.2	418.9	1982.6	1,110.1	480.9
Class A, stdev stems/ha Aspen		3,610.7	619.2	1549.2	1,029.5	340.9
Class B, average stems/ha Aspen		547.5	0.0	747.0	2,151.5	357.8
Class B, stdev stems/ha Aspen		508.4	0.0	721.0	1,613.0	341.6
Class C, average stems/ha Aspen		280.1	170.4	569.0	52.6	133.0
Class C, stdev stems/ha Aspen		286.1	190.0	573.9	109.4	201.3
Class D, average stems/ha Aspen		1,187.1	1,663.0	927.8	271.1	289.9
Class D, stdev stems/ha Aspen		602.9	681.8	736.7	520.8	310.6

Sampling Frames and Allocation of Samples

The target population for estimating the status and trend of aspen density at CRMO is the entire NPS-managed portion within legal boundaries (Figure 3). The majority of the stands are located in the Leech Creek and the Little Cottonwood Creek drainages and one aspen stand is located on the northeast-facing slope of Big Cinder Butte. The target population for estimating the status and trend of aspen density at the CIRO is the entire NPS-managed portion within legal park

boundaries, excluding all private in-holdings. The aspen stands are divided into seven sampling units (Figure 4). Stands that are smaller than 0.3 ha, are composed of short shrubby snow damaged aspen or are located directly within the riparian corridor are not considered for sampling in either park. The riparian zone was not sampled for aspen because the aspen here is a minor component among many other broad leaf shrub and tree species.

The starting point for each transect is randomly located within the stand boundary and transects are oriented north-south or east-west depending on the axis of the stand. In cases where the stand is small and oriented in a different azimuth than north-south or east-west, the transect is oriented along the longest axis of the stand. Four plots are placed along each transect with a distance of 25 m between plot centers. According to the variogram analysis within four stands (two in each park), plots that are at least 25 m apart can be considered spatially independent (Figure 6). The number of transects within each aspen stand is determined via the power analysis and then weighted by the areal extent of the stand. Altogether 108 plots are placed within CRMO arranged in 22 stands (Figure 7) and 156 plots are placed within CIRO arranged in 26 stands. Because of the larger number of stands in CIRO the area was divided into seven sampling units (Figure 8).

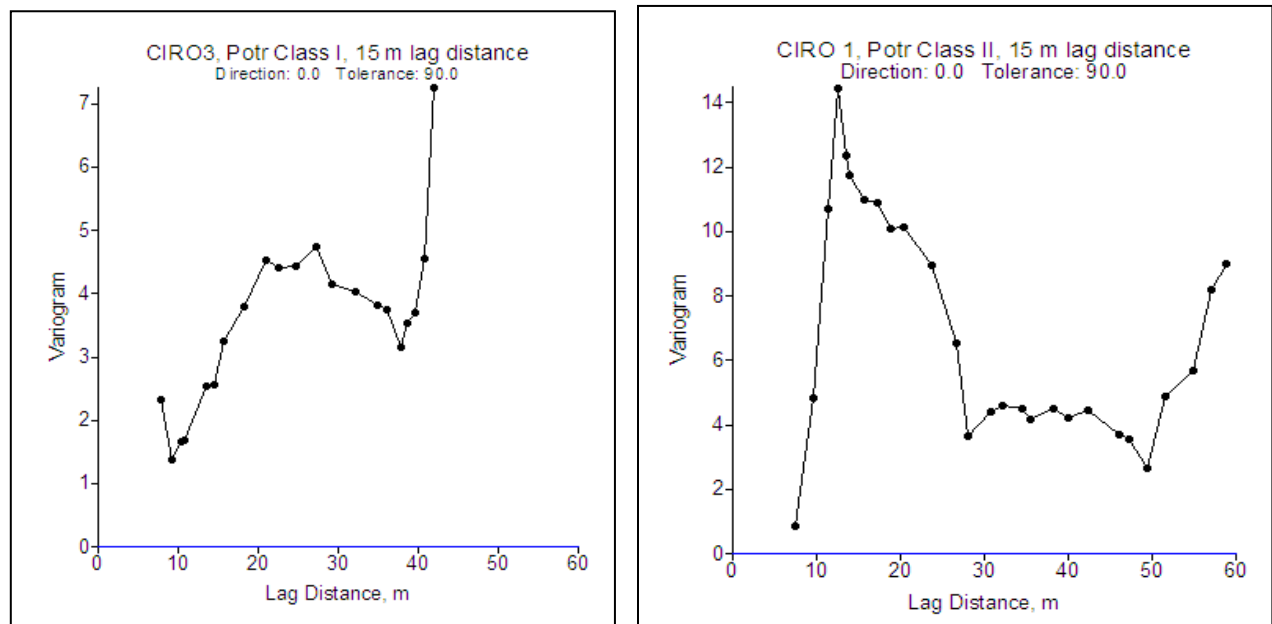
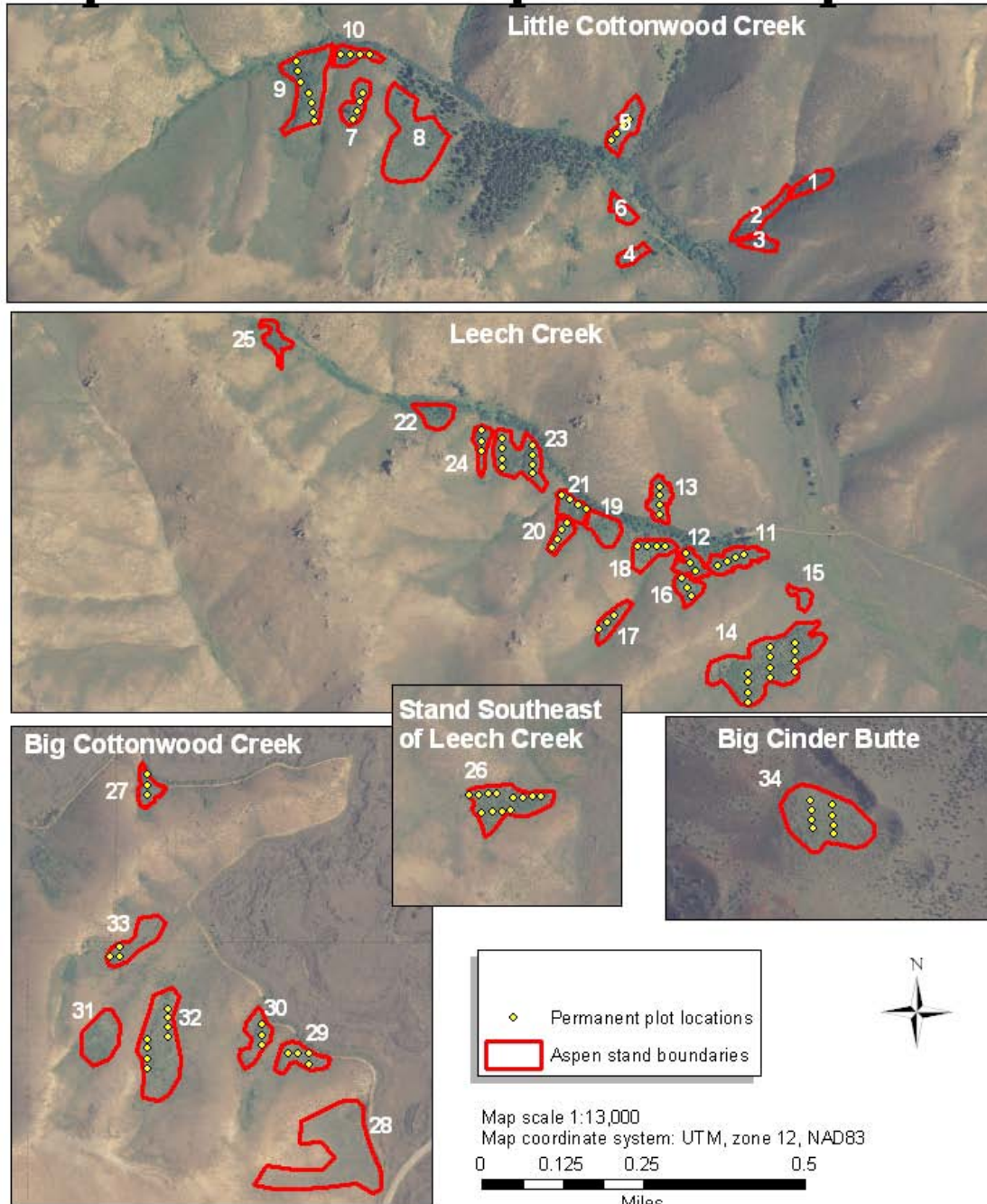


Figure 6. Semivariograms of aspen class I - suckers (left) and aspen class II- regeneration (right) in the stand CIRO3-2006. The semivariograms indicate that the spatial dependence in stem count between plots level out at a distance of 15-25 m. Plots that are spaced >25 m apart can therefore be considered spatially independent.



Aspen stands and permanent plots



UCBN Moscow, University of Idaho

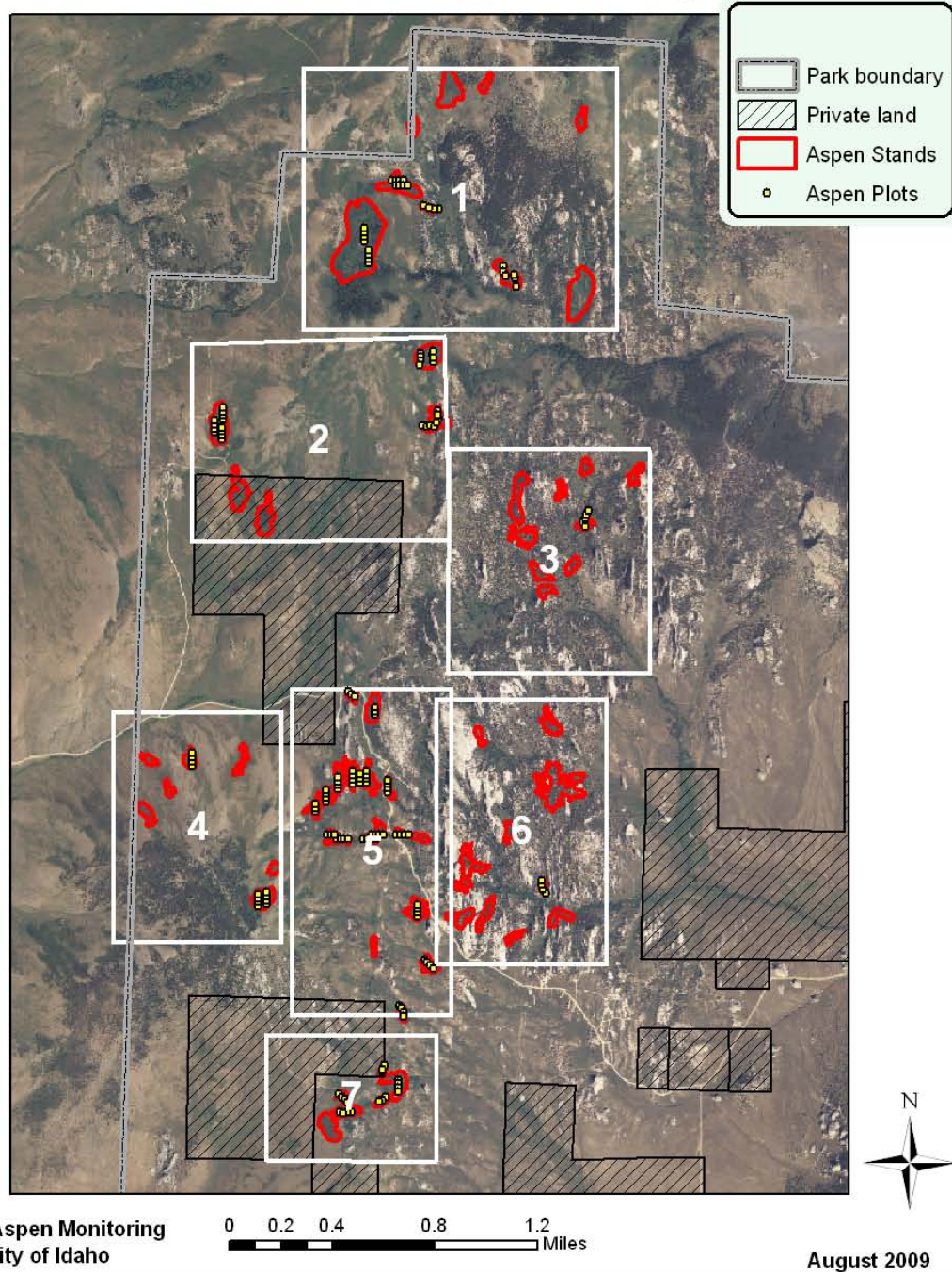
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March 2009

Figure 7. Aspen stands in Craters of the Moon National Monument and Preserve including placement of transects within stands. Altogether 108 plots in 22 stands are sampled.



Aspen stands and sampling units



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Figure 8. Aspen stands in City of Rocks National Reserve. The 57 stands are divided into seven sampling units. Unit 1, 4, 5, and 6 were visited and stands were sampled in 2008 and units 2, 3, and 7 were assessed and sampled in 2009. Altogether 156 plots in 26 stands are sampled.

Sampling Frequency and Timing

Following notation proposed by MacDonald (2003), a [1-4] panel design will be employed for each of the populations in both parks, in which each sampling occasion includes a panel of permanent transects that are revisited every five years, i.e. sampling in year 1 followed by 4 years without sampling. Sampling will occur with a three-year (e.g., a [1-2] panel design) time interval during the first time period to gain an understanding of variation in stem counts (particularly the younger classes) resulting from variable precipitation and other potential drivers. After this baseline is established we predict sampling will occur every five years (e.g., a [1-4] panel design), although this decision may change once we begin to understand the nature of variation. A convenient schedule for arranging field crews is to alternate visits to the CRMO and CIRO populations (Table 2). If inter-annual variability is low and the precision of each year's sampling is high, then we will initiate a less frequent revisit strategy.

The time of year at which sampling occurs is quite flexible because aspen stems within size classes remain recognizable over a broad period of time. Sampling is not recommended before leafout in the spring, or after the leaves have begun to fall in the autumn. The sampling period is therefore limited to the time period May 20 to September 15.

Table 2. Proposed [1-2] revisit design over the first time period followed by a [1-4] revisit design in which one panel is located in CRMO and two panels are located in CIRO.

	Sampling Occasion (Year)										
Panel	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CRMO	X			X					X		
CIRO1		X			X					X	
CIRO2			X			X					X

Response Design

Following recommendations by Kilpatrick et al. (2003) and based on data collected in 2005 and 2006, 4-m radius circular plots will be used at each sampling point. Kilpatrick et al. (2003) emphasize that the plot radius can be adjusted based on the homogeneity and density in the plot and recommend 40-80 m² plots for mature stands while 8-40 m² plots are recommended for recently burned successfully regenerating stands. Pilot data suggests that the stem count within 4-m radius plots for mature stands fall within these recommended guidelines. In the case that an aspen stand burns in a wild or prescribed fire, often initiating vigorous suckering, the plot radius can be decreased because all plot measurements are scaled to stems/ha. Circular plots require minimal setup in the field as the tape can be attached to a portable steel post in the middle of the plot and the field crew can walk around the plot at the desired radius counting aspen in different size classes. Circular plots have smaller edge-to-area ratios, which minimizes sampling errors associated with plot edges.

The distance between each plot is 25 m to minimize the risk that two adjacent plots are spatially dependent. This distance was based on analysis of variograms (Figure 6). The fact that all plots must be at least 25 m apart creates a constraint for the plot layout such that only a certain number of plots can be placed within a stand. Plots are placed along randomly located transects with 4

plots 25 m apart in each transect (Figure 9). If possible, transects are oriented north-south or east-west.

The number of aspen and conifer stems within pre-determined size classes (Table 3), that has 50% or more of the stem basal area at the soil level within the 4-m radius plot are counted. Conifer plants shorter than 10 cm above ground are not counted. Dead stems that are lying on the ground are not counted, however dead stems that are leaning or otherwise partially standing are counted if the stem is rooted, or has 50% or more of the stem basal area at soil level, in the plot. The reason for counting dead standing and leaning stems but not dead stems on the ground is that our objective is to monitor recent aspen mortality. Dead aspen stems on the ground may be several years old.

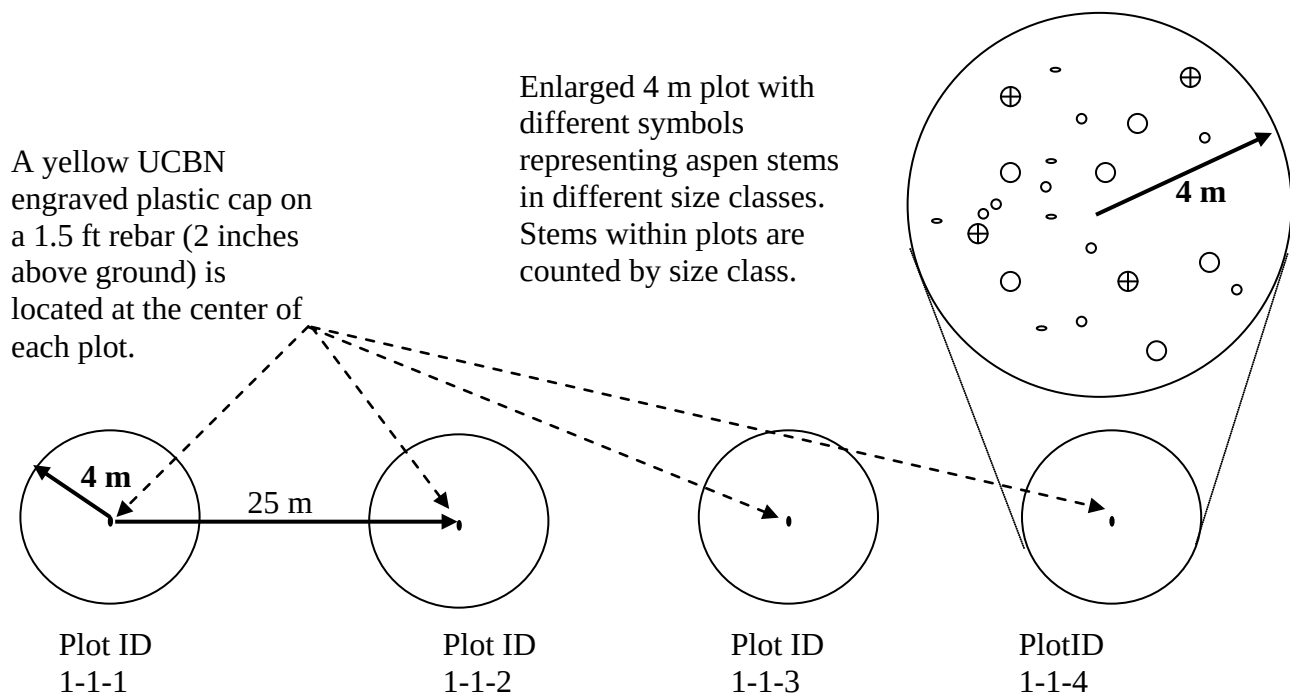


Figure 9. The start location is located in the center of plot 1 along a transect. Each plot along the transect is located 25 m apart, center to center. The direction of a transect is determined by the pre-defined azimuth (true north). Trees in different size classes (Table 3) are counted within each plots. The plot ID number is the stand number followed by the transect number followed by the plot number.

Table 3. Size classes of aspen and conifers.

Class I	Suckers or seedlings <46 cm (1.5 ft) tall. Conifer seedlings shorter than 15 cm (6 inches) are not counted due to uncertainty in survival
Class II	Suckers or seedlings <46 - 152 cm (1.5-5 ft) tall
Class III	Greater than 152 cm (5 ft) and up to 2.5 cm (1 inch) in dbh (diameter at breast height)
Class IV	Greater than 2.5 cm (1 inch) in dbh and shorter than 75% of the stand height
Class V	Greater than 2.5 cm (1 inch) in dbh and taller than 75% of the stand height
Class VI	Dead stems >2.5 cm (1 inch) in dbh

Aspen total stem density by size class can be calculated by plot, transect or stand by adding all individual aspen stems within the sampled area and then divided with the total sampled area (plot, sum of sampled area along transect, or sum of sampled area within stand). The computed stem density will be converted to stems/ha. The statistical analysis will be conducted to detect change and estimate trend within four combinations of size classes as follows: Suckers (Class I+II), Regeneration (Class III+IV), Mature trees (Class V) and Dead stems (Class VI).

Power Analysis

Power analyses were conducted at the stand level and at the park level to determine: 1) the number of plots required within one stand to estimate stem counts within size classes with a confidence of 0.9 and a power of 0.8, and 2) the power to detect a 25 percent increase and decline over 5 years within each park. The stand level and park level power analyses are here described in detailed.

Within Stand Power Analysis

Following Elzinga et al. (2001) we computed the required number of 4-m plots (n) for detecting a 25% difference in the true mean within aspen size classes within aspen stands as follows:

$$n = s^2 (Z_a + Z_b)^2 / (\text{mcd})^2$$

where: n = sample size
 s = sample standard deviation
 Z_a = Z-coefficient for a Type I error
 Z_b = Z-coefficient for a Type II error
 mcd = minimum detectable change in stem count since the initial sampling in year 1.

$$s = (s_1) \left(\sqrt{2(1 - \text{corr}_{diff})} \right)$$

s_1 = sampling standard deviation among sampling units at the first time period
 corr_{diff} = Correlation coefficient between sampling unit values in the first and second time period.

The standard deviation in stem count of aspen regeneration (Class III+IV) between 4 m radius plot samples within aspen stands have previously been assessed by Strand (2007) in the Owyhee Mountains, and in the pilot studies of 2005 and 2006. Strand (2007) found that the average standard deviation in stem count of the medium size class (2-10 m high) was 646 stems/ha based on 5-7 plots in 26 stands. The pilot study of 2005 sampled 13 stands with an average standard deviation of 602 stems/ha in the medium size class (regeneration). The five stands sampled in the pilot study of 2006 show a variable standard deviation (Table 1). The average standard deviation for these intensively sampled stands is 795 stems/ha. In general the standard deviation of Class III+IV is of the same magnitude as the mean for each stand.

Based on these previous studies in relatively large stands (2-3 ha) we computed the number of samples required for an adequate statistical test at different levels of confidence and power. We based the statistical calculation on methods described in Elzinga et al. (2001) described above. We estimated the number of samples for both temporary (Figure 10) and permanent (Figure 11) plots. In both cases we estimated the number of plots necessary for a 25% minimum change detection using 600 stems/ha as the standard deviation between plots. In the case of permanent

sampling units we estimated the correlation between time periods to 0.8. This value is currently not known and may be adjusted in the future as more data becomes available. This analysis reveals that 14 plots are necessary in the case of permanent sampling units while 70 plots would be required for temporary sampling units (confidence = 0.9, power = 0.8).

The results from this power analysis helped guide us to select permanent sampling locations to maximize the statistical power and confidence while minimizing the sampling effort. In stands of the size 2-3 ha 14-15 plots are required to determine a change in mean of 25% with a confidence of 0.90 and a power of 0.8. In the case of temporary plots number of plots required for the same confidence and power is 60-70, which is practically unreasonable.

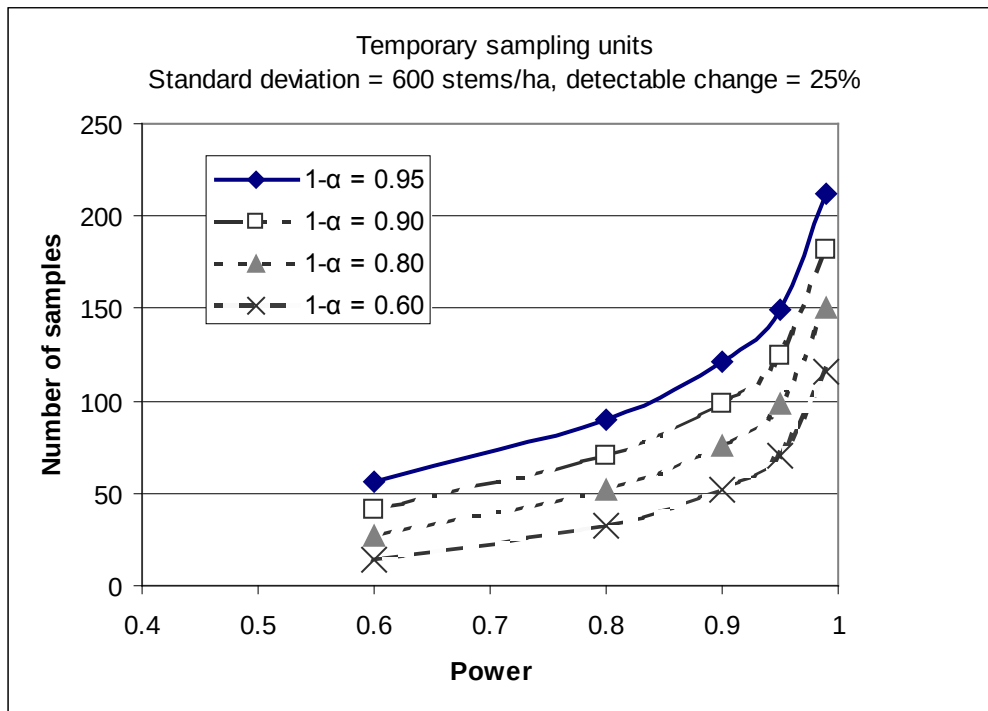


Figure 10. Sample size versus power for temporary plots.

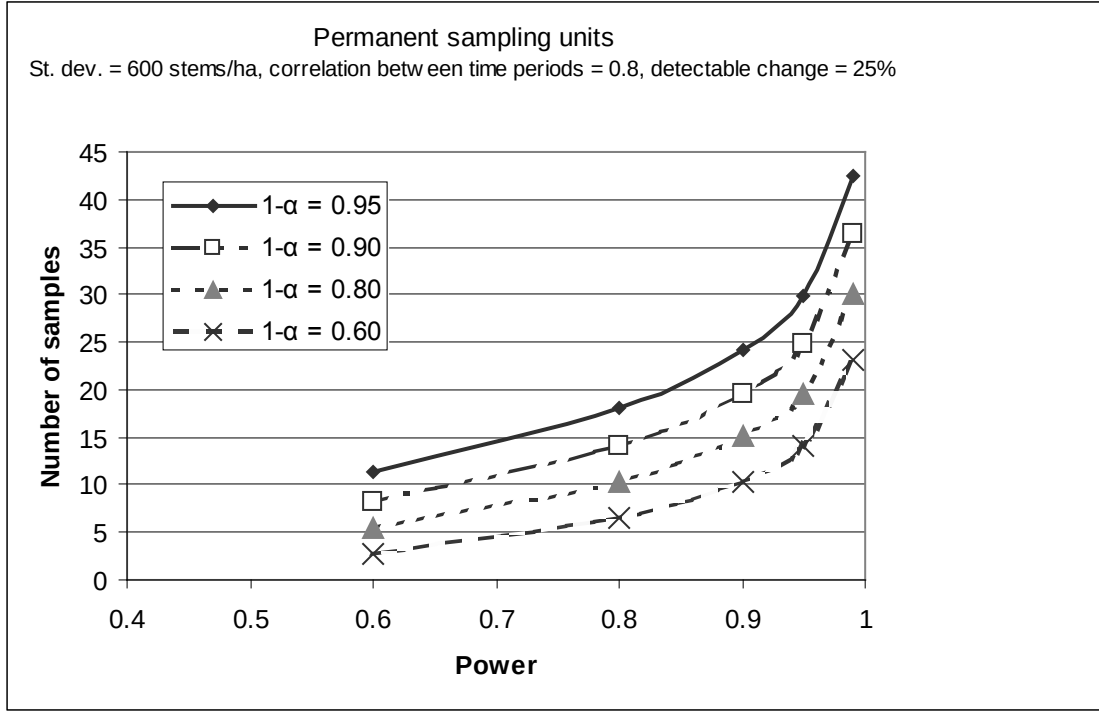


Figure 11. Sample size versus power for permanent plots.

Park Level Power Analysis

The power analysis at the park level was performed in the statistical software package SAS using proc GLMPower to calculate the power to detect a 25 percent increase and decline over 5 years. We assume a revisit design as displayed in Table 2; sampling during years 2007, 2010, and 2015. Thus, for an assumed decline/increase of 25% over 5 years the net change of 25% should be reached during year 2012. We assume a linear change on the log-scale, which corresponds to a multiplicative change on the original scale. For example, if we assume a -0.25 change over 5 years, this means a 25% decline on the original scale over 5 years. Or an annual change on the original scale of

$$(1 + (-0.25))^{1/4} = 0.93 \quad (1)$$

which is a 7% yearly decrease.

The following mixed model was derived based on Piepho and Ogutu (2002) for this protocol:

$$\ln(y_{ijk}) = \mu + w_j\beta + b_j + \alpha_i + w_j t_i + g_{k(i)} + c_{ij} + e_{ijk} \quad (2)$$

where $i = 1, \dots, m_a$; $j = 1, \dots, m_b$, and $k = 1, \dots, m_i$ i indexes the stand, j indexes the year of sampling, and k indexes the transects within a stand.

m_a = the number of stands in a sample;

m_b = the number of years in a sample;

m_i = the number of transects within stand i ;

w_j = is a constant representing the j th year (covariate);
 μ and β = fixed intercept and slope of the linear time trend;
 α_i = the fixed intercept of the i th stand;
 b_j = random effect of the j th year = 0 if no panel structure used (true for aspen in one park);
 t_i = random slope of i th stand, iid as $N(0, \sigma_t^2)$;
 $g_{k(i)}$ = random effect of transect within stand, iid as $N(0, \sigma_g^2)$;
 c_{ij} = random effect of site by year, iid as $N(0, \sigma_c^2)$;
 e_{ijk} = unexplained error, iid as $N(0, \sigma_e^2)$.

This model simplifies for the power analysis because we have no estimate of variability over time given only one year of data. Therefore, σ_b^2 , σ_c^2 , and σ_e^2 are all equal to zero. Also, we assume no panel structure for aspen such that $b_j = 0$. The model in equation 2 simplifies to the following:

$$\ln(y_{ijk}) = \mu + w_j\beta + \alpha_i + g_{k(i)} \quad (3)$$

This model assumes each stand has a unique intercept or fixed effect $\mu + \alpha_i$ and a common linear trend in time β . The error term is simply the variability of transects within stands ($g_{k(i)}$).

The power was calculated using proc GLMPOWER in SAS for $\alpha = 0.10$ and three years of data: 2007, 2010, and 2015. The stand effects were estimated using the data collected in CRMO during the field season 2007. The linear contrast coefficients for the time effect are estimated using proc iml in SAS.

```

proc glmpower data=noerror2;
class Stand Year Transect;
model LogY = Stand Year;
contrast 'linear' Year -.641533 -.116642 .7581754 ; /*2007, 2010, 2015*/
power
alpha=.10
stddev = .4 /*THIS ESTIMATE IS FROM THE SAS CODE AspenNested020308*/
Ntotal = 90
power = .;
run;

```

This power analysis yielded the following results for the regeneration and mature tree classes based on sampling in 22 aspen stands in CRMO in the field season 2007:

% Change	Regeneration class	Mature trees class
	Power	Power
-25 %	1	1
+25%	1	0.994
-10%	0.816	0.627
+10%	0.745	0.555

These results clearly exceed the original goal of achieving a power of 0.8 at and change in 25%.

NOTE: The power may be slightly over-estimated because we are unable to estimate the variance components for time based on the pilot dataset. These calculations can be updated after the second year of surveying to determine a more accurate power to detect a given change with $\alpha = 0.10$.

Thresholds and management support

Conditions identifying aspen stands at-risk have been suggested (Bartos and Campbell 1998) with the following specific thresholds: 1) aspen stands where the regeneration (stems 1.5-4.5 m tall) is $< 1,200$ stems/hectare, 2) total aspen canopy cover is less than 40%, 3) conifer canopy cover is over 25%, and 4) stands where the majority of the stems are over 100 years in age and decadent. Shepperd et al. (2001) observed regeneration of over 2000 stems/ha in regenerating aspen stands in Utah and 500-600 stems/ha in classes of larger trees.

This protocol directly measures the aspen regeneration as the stem count in several size classes and these values can be directly compared to the recommended minimum of 1,200 stems / ha. In future versions of this protocol we aim at developing site specific guidelines for stem density in the sampled size classes in both parks. Populated with park specific field data and results from trend analysis the decision support chart (Figure 2) may act as a guideline for management in the future.

Summary of the Benefits of the Selected Design

- The design directly reflects the study objectives.
- Simple random placement of transects permits valid inference to the target populations.
- Permanent rather than temporary plots results in a higher power and confidence and minimizes the sampling effort.
- Trampling (“response burden” or “conditioning”, Macdonald 2003), a common problem with permanent herbaceous vegetation plots, is not a problem in this situation.
- Placement of plots along transects 25 m apart minimize the chance of spatial dependence between plots verified via semivariogram analysis.
- Placement of plots along transects reduces the time it takes to relocate each plot in the parks.
- Sampling of all stands larger than 0.3 ha allows for detection of trend in the entire park units as well as in each stand. This is important since all stands are separate units, which are affected by different environmental conditions and stressors.
- The field methods (stem counts within fixed radius plots) are relatively easy to learn and are repeatable between field technicians after a training period.
- Thresholds for when active management may be desirable for the long-term maintenance of aspen stands are provided by this protocol.

Field Methods

Preparations for the Field Season

The first preparation is to revise procedures based on the experiences and results from the previous sampling period. After any revisions are completed, preparation involves gathering equipment, and fulfilling permitting and compliance requirements. Both study sites are NPS units, and permits will be provided through the NPS research permit and reporting system (<http://science.nature.nps.gov/research/ac/ResearchIndex>). GPS devices will be loaded with all permanent plot locations before the start of sampling and the PDAs are loaded with appropriate field forms. Batteries and spare batteries must be charged for all GPS units and PDAs, including backup units. Paper data entry forms will also be updated and photocopied. SOPs should be thoroughly reviewed by directing staff well in advance of training and field work. Because of the reliance on seasonal employees for field work, scheduling with partners, such as the University of Idaho College of Natural Resource or Student Conservation Association (SCA) should begin as early as possible and no later than February proceeding a spring sampling occasion. Arrangements must be made in coordination with CIRO and CRMO staff as well. Equipment needs are relatively modest, and once sufficient amounts are constructed or purchased, replacement will be infrequent. An equipment list is included in SOP # 1.

Locating and Establishing Sampling Transects

Driving directions to CIRO and CRMO are included in SOP # 4. Once on site, maps locating each sampling unit are included in SOP # 4. Spring weather extremes can cause challenging conditions, so make sure all team members are prepared with warm clothes and rain gear, sun hats, and plenty of water. Before the start of each field session, aspen stand locations will be organized into convenient and efficient routes through the study area, according to the number of field teams available. These routes will be illustrated on hard copy maps provided to each team. The precise location of each plot can be located using GPS and, if necessary, a metal detector to relocate the rebar metal monument placed at the center of each plot along transects. GPS units employed by the UCBN typically allow navigation accuracies of 1-3 m.

Transect starting points will be located using GPS, following procedures outlined in SOP # 3. When the team member navigating with the GPS unit first approaches the waypoint location, the person will focus on the coordinates and ignore the vegetation. Once the GPS unit registers “zero” (or otherwise shows that the coordinates have been reached exactly), the person stops immediately. The location is marked with rebar with an engraved plastic cap in the ground at the center of each plot along the transect. SOP # 4 describes the procedure for locating the first sampling plot and the following 2-3 plots along the transect located 25 apart from plot center to plot center.

The azimuth orientation for moving from plot to plot along the transect is the same for each transect within a stand but may vary between stands, i.e. transects are oriented in different bearings in different stands. The bearing and a map for each stand are included in SOP # 4. GPS used to locate the plot center of each consecutive plot, 25 m apart from center to center, along the transects.

Measuring Vegetation

Field crew training and calibration will occur in the field prior to each sampling occasion under the direction of the Project Leader, as detailed in SOP # 2. A stake is placed in the center of the plot and a measuring tape is attached to the stake. The tape is carried around the plot by one of the field assistants while another individual is recording the stem counts. As the field assistant holding the tape walks around the plot he/she counts the number of aspen and conifer stems within each size class that are located within the 4-m marker on the tape as specified in SOP # 5. All stems that enter the soil within, or have 50% or more of the stem basal area at soil level within the plot are counted. Plants with double stems are counted as one if the stems split above ground and two if the stems are split below ground. Conifer seedlings shorter than 10 cm tall are not counted because the survival and hence recruitment of such small plants is uncertain.

A digital photo is taken from a distance to gain an overview picture of the aspen stand. The GPS coordinates for the location where the distance photo is taken from is recorded during the establishment of the permanent plot and the same location is relocated for repeat photos in consecutive years.

Precision and Reproducibility

Precision, defined as “the closeness of agreement between independent test results obtained under prescribed stipulated conditions”, will be periodically assessed by each field team during each sampling occasion following recommended procedures outlined by Irwin (2006) and the Environmental Data Standards Council (2006). Duplicate counts of aspen and conifer stems will be made periodically during sampling in order to provide estimates of precision, reproducibility, and measurement error. Specifically, each field team will independently assess relative percent difference (RPD) on 10% of the transects, which involves one duplicate density measurement taken by an alternate observer. Transects chosen for RPD estimation will include some from the early, middle, and late periods of the sampling period (i.e. at the beginning of the first week, end of the first week, and end of the second week). Duplicate values will be recorded in the data entry form for each transect’s RPD measure. Additional details are addressed in SOP # 5.

Data Entry and Management

To the greatest extent possible, UCBN monitoring protocols use digital data collection strategies. With this aspen protocol, the preferred method of data collection uses mobile field computers running the UCBN Aspen database application, so that field data can be entered directly into the MS Access database. If logistical or environmental conditions prevent the use of mobile field computers, then the aspen data is collected on paper data sheets and entered into the UCBN Aspen database as soon after data collection as is practical. The field data sheet is described in detail in SOP #5. Paper data sheets may be preferred in cases where student volunteers are participating in data collection, and project logistics do not allow adequate time to fully train volunteers on use of the UCBN Aspen database. Both forms of data collection are relatively straightforward, since the appearance of data entry forms in the UCBN Aspen database is patterned after the layout of the paper data sheet. The basic layout of the paper data sheet involves a spreadsheet of columns of measured attributes and rows of plots along transects. Data sheets will be prepared for each field team prior to entry into the field, with team numbers, transect and plot ID’s, azimuths, and UTM coordinates already in place. Blank spreadsheets will

be available to accommodate any last minute changes in team organization or establishment of new permanent plots.

The preferred order of field operations and data entry steps are as follows:

1. Transect establishment
2. Counts of aspen and conifer stems by size class
3. Enter stem count data either into the UCBN Aspen database (on mobile field computer) or onto paper data sheet
4. Locate the next plot along the transect by moving in the bearing specified in SOP# 4, 25 m ahead.
5. Repeat steps 2-5 until there are no more plots along the transect. Most transects are composed of four plots, however occasionally there are fewer plots along the transect due to the shape and size of the aspen stand.
6. Locate a place from which there is a good overview of the stand. Take a digital photo from this point and record the GPS coordinates if it is the first time the stand is surveyed.

Data sheets (paper or digital) will be inspected by team leaders and the project leader at the end of each field day, as a key step in the quality assurance and quality control process (QA/QC). Data from all paper data sheets will be entered into the working copy of the UCBN Aspen database, a Microsoft Access application, as soon after data collection as is practical, and will also be treated as an additional opportunity to conduct QA/QC. Validation rules programmed into the database will help detect logical inconsistencies. Paper data sheets will be archived by the UCBN on a short-term basis only, up to 3 years, which will allow sufficient time for all possible QA/QC problems to be resolved, at which time the archived database, including backup copies and versions served off the NPS Data Store, will be the sole repository for legacy data for this project.

After the Field Season

Following the field season, equipment should be stored in the UCBN headquarters or if the project leader is a Principle Investigator from the University of Idaho in Moscow, Idaho the equipment can be stored with them. Currently all equipment is stored at the University of Idaho, Department of Rangeland Ecology and Management in Moscow, ID. Non-electrical equipment, including wire ropes, stakes, rulers, and compasses should be stored in well-marked plastic bins. Some of this equipment may be used by other UCBN protocols, so thorough organization and documentation of equipment will be important. Electronic equipment, including GPS units, should be stored in the UCBN or University of Idaho office. Batteries should be removed during the winter months to prevent corrosion and leaking. It is recommended that the GPS coordinates for the aspen plots are stored on the units since they are permanent and will not change between sampling periods.

Data Handling, Analysis, and Reporting

While the following section outlines procedures for aspen data handling, analysis, and report development, additional details and context for this chapter may be found in the UCBN Data Management Plan (Dicus and Garrett 2007), which describes the overall information management strategy for the network. The UCBN monitoring plan also provides a good overview of the Network's data management and reporting plan (Garrett et al. 2006).

Overview of Database Design

The UCBN Aspen database has been developed within Microsoft Access. The database structure conforms to the standards of version 3.2 of the Natural Resource Database Template (NRDT), and consists of a user interface front-end (holding user forms for data entry, review, and export) that is linked to a back-end database file (holding the core aspen data tables), an integrated UCBN data dictionary database file (holding various lookup tables shared across all UCBN protocols), and an integrated UCBN species database file (holding UCBN species data, from the NPSpecies database, also shared across all UCBN protocols). The general data management strategy will employ both a “working copy” of the database (used to enter the current season's data, then conduct error-checking and validation) and a “master version” of the database (used to store all validated data, to facilitate multi-year analyses, and to provide specific data report and export formats). Details of the database, including a description of core and peripheral tables, a logical model of table relationships, and a data dictionary, are presented in SOP # 6.

Data Entry

The preferred method for data collection involves use of the UCBN Aspen database running on a mobile field computer, allowing protocol data to be entered directly into the MS Access database application. If problems with field computer equipment prevent direct entry of data into the UCBN Aspen database, then the field data will be collected using paper data sheets, and data from paper data sheets will be entered into the MS Access database as soon after data collection as possible. Data entry forms in the UCBN Aspen database are patterned after the structure of the paper data sheet, and the database has built-in quality assurance components such as pick lists and validation rules to test for missing data or illogical combinations. Data entry should be viewed as an important step in the overall QA/QC process, and care should be taken to review all plot data while the observers are in the field.

Quality Review

After the data have been entered and processed, they need to be reviewed by the Project Lead for quality, completeness, and logical consistency. The working database application will facilitate this process by showing the results of pre-built queries that check for data integrity, data outliers and missing values, and illogical values. The user may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed, in which case the resulting errors are then documented and included in the metadata and certification report.

Metadata Procedures

Data documentation is a critical step toward ensuring that data sets are useable for their intended purposes well into the future. This involves the development of metadata, which can be defined as structured information about the content, quality, and condition of data. Additionally,

metadata provide the means to catalog data sets within intranet and internet systems, making data available to a broad range of potential users. Metadata for all UCBN monitoring data will conform to Federal Geographic Data Committee (FGDC) and NPS guidelines and will contain all components of supporting information such that the data may be confidently manipulated, analyzed, and synthesized. For long-term projects such as this one, metadata creation is most time consuming the first time it is developed – after which most information remains static from one year to the next. Metadata records in subsequent years then only need to be updated to reflect current publications, references, taxonomic conventions, contact information, data disposition and quality, and to describe any changes in collection methods, analysis approaches or quality assurance for the project.

Specific procedures for metadata development and posting are outlined in the UCBN Data Management Plan. In general, the Project Lead and the Data Manager (or Data Technician) will work together to create and update an FGDC- and NPS-compliant metadata record in XML format. The Project Lead should update the metadata content as changes to the protocol are made, and each year as additional data are accumulated. Edits within the document should be tracked so that any changes are obvious to those who will use it to update the XML metadata file. At the conclusion of the field season, the Project Lead will be responsible for providing a completed, up-to-date metadata interview form to the Data Manager. The Data Manager will facilitate metadata development by creating and parsing metadata records, and by posting such records to national clearinghouses as described below.

Sensitive Information

Part of metadata development includes determining whether or not the data include any sensitive information, which includes specific locations of rare, threatened, or endangered species. Prior to completing metadata, the Project Lead and Park Resource Manager should work together to identify any sensitive information in the data. Their findings should be documented and communicated to the Data Manager. We do not anticipate that sensitive information will be present in the aspen monitoring program at this time.

Data Certification and Delivery

Data certification is a benchmark in the project data management process that indicates that 1) the data are complete for the period of record; 2) they have undergone and passed the quality assurance checks; and 3) that they are appropriately documented and in a condition for archiving, posting, and distribution. Certification is not intended to imply that the data are completely free of errors or inconsistencies, which may not have been detected during quality assurance reviews.

To ensure that only data of the highest possible quality are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Lead is primarily responsible for completing certification. The completed form, certified data, and updated metadata should be delivered to the Data Manager, see the Operational Requirements section. Additional details of the certification and delivery processes are included in SOP # 6.

Data Analysis

Annual Status Summary

The design for each of the two parks is a three stage cluster sample. The primary sampling unit (PSU) is a stand. We are proposing to census the stands ($n = N$). The secondary sampling unit (SSU) is a transect. There are m_i transects per stand out of M_i possible. We propose to sample so that $m_i/m = A_i/A$ where m is the sum of the m_i 's, A_i is the area of the stand and A is the total area of all stands. That is, we are proposing to allocate transects to stands in proportion to the area of the stand. The tertiary sampling unit (TSU) is a plot. We are proposing 4 plots per transect 25 m apart—this makes the transect 75 m long.

The **design based** estimator of stems/ha is

$$\hat{\mu} = \frac{N}{n * m} \sum_{i=1}^n M_i \bar{y}_i = \sum_{i=1}^N \sum_{j=1}^{M_i} \sum_{k=1}^4 \frac{y_{ijk}}{4m}$$

The variance of $\hat{\mu}$ is estimated as

$$s_{\hat{\mu}}^2 = \Phi + \frac{1}{N} \sum_{i=1}^N \left(\frac{A_i}{A} \right)^2 \left(1 - \frac{m_i}{M_i} \right) \left(\frac{s_i^2}{m_i} \right) + \sum_{ij} k_{ij} \frac{s_{ij}^2}{4}$$

where s_i^2 is the transect-to-transect variance, k_{ij} is a constant that goes to 0 as the number of plots per transect goes to the total possible, and s_{ij}^2 is the plot-to-plot variance. The first term is zero because we are doing a census of stands and the finite population correction factor at that level goes to zero.

The **model based** estimator is the estimate of μ in a nested ANOVA. This is simply the mean of all the plot densities. In this case, the design and model based estimators are the same. The variance of the estimator is found from a nested ANOVA. This same ANOVA provides estimates of the transect-to-transect and plot-to-plot variances needed above.

Status results will be summarized after each year of data collection. Standard summary statistics will be presented with content similar to that shown in Table 1, and will include measures of central tendency ($\hat{\mu}$), and standard deviation ($\hat{\sigma}$) for stem density, expressed as stems per hectare, within size classes for aspen and conifer species summarized by transect and by aspen stand. See examples of summary tables for aspen stem density (Table 4) and conifer density (Table 5) below. Graphical representation of data in the form of charts and maps is also important in exploratory data analysis, particularly during the early stages of an analytical exercise. Graphical presentation can aid in communicating results and can trigger the generation of new, or the refinement of existing, hypotheses about pattern and process. As the monitoring

project continues and data from sequential time periods become available the power analysis will be revisited and refined to optimize the data collection and analysis efforts.

Table 4. Example of summary table for aspen stem density. Aspen stem counts by stand and the average number of stems per hectare in CIRO sampling unit 1, 4, 5, and 6 for 2008.

Stand #	Suckers (stems/ha)	Regeneration (stems/ha)	Mature (stems/ha)	Dead (stems/ha)
5	2,636	1,368	746	174
6	2,462	3,506	373	124
30	3,233	2,586	597	99
33	2,188	1,923	265	66
37	5,123	2,934	298	149
38	332	862	332	66
40	1,512	1,592	159	80
41	1,421	1,222	540	171
42	2,984	2,122	619	486
43	3,084	995	338	279
45	4,526	2,537	448	50
51	2,553	928	1,028	232
52	2,934	2,487	696	249
61	5,836	1,790	796	796
63	1,251	1,705	327	199
72	1,741	1,393	149	0
Average Stems/ha	2,644	1,837	493	212

Table 5. Example of summary table for conifer stem density. Conifer density in sampled aspen stands at CIRO in 2008.

Stand #	Seedlings (stems/ha)	Saplings (stems/ha)	Mature (stems/ha)	Dead (stems/ha)
6	0	298	99	0
30	0	199	0	0
37	40	159	239	40
40	0	199	265	66
41	66	265	133	0
43	119	119	80	40
45	199	199	0	0

Trend Analysis

Trend analyses will begin after the 2010 field season and will be conducted every five years thereafter according to the panel design as described in the preceding revisit design section. The null hypothesis (H_0) that there is no difference in stem count within individual parks will be tested with a repeated measures nested analysis of variance (ANOVA) for the suckers (class I+II), regeneration (class III+IV), mature stems (class V), and dead stems (class VI). Initially the trend analysis will be performed on data from only two points in time, however as more data becomes available (i.e., after three sampling periods) the trend analysis will be conducted using a

linear regression design to evaluate trajectories. All analyses will be performed in the statistical analysis software SAS and SAS codes are provided for each analysis step.

Reporting

A summary report will be produced each year a panel is sampled, with a more detailed report produced every five years. The annual report should:

- List the stands that were sampled during the current year.
- Provide a summary history of mean and standard deviation within size classes and species within the stands sampled during each year of the study, broken down by stand and park.
- Provide status and trend (after 2010) estimates of aspen regeneration, mature and dead stem density for each stand and park.
- Report the density of conifers within the stands.
- Provide a summary of the digital photographs taken during the field season.
- Evaluate data quality and identify any data quality concerns and/or deviations from protocols that affect data quality and interpretability.
- Evaluate and identify suggested or required changes to the protocol.

An annual report was produced following the 2008 pilot season and can be used as a template to guide future reports (Strand and Bunting 2009). A 1-2 page resource brief will also be prepared from this annual report that will be provided to superintendents, resource managers, and park interpretive staff. A template for the resource brief is included in SOP # 7. An NPS template for producing maps with ESRI ArcGIS or ArcView software is available at <http://imgis.nps.gov/templates.html>. Information from the annual summary report will also be provided to parks in time for park Government Performance Results Act (GPRA) goals reporting and for informing and evaluating park resource stewardship strategies. Tables 4 and 5 present an example status summary report of aspen and conifer stem density for the sampled stands in CIRO from Strand and Bunting (2009).

A more in-depth analysis and report will be produced every five years. In addition to the above, the five-year report will also provide density estimates during the previous time periods, assess changes in spatial patterns of the aspen density estimates, and identify any possible changes in conifer density within the stands and parks. The report will also evaluate operational aspects of the monitoring program, such as whether population boundaries need to be adjusted or the sampling period remains appropriate (the optimal sampling season could conceivably change over time in response to climate change).

Annual reports and 5-year analyses of status and trend will use the NPS Natural Resource Publications Natural Resource Technical Report series template, a pre-formatted Microsoft Word template document based on current NPS formatting standards. Template guidelines and documentation of the NPS publication standards are available at the following address: <http://www.nature.nps.gov/publications/NRPM/index.cfm>.

Current versions of the protocol, resource briefs, and annual and 5-year technical reports will be made available on the UCBN website (<http://science.nature.nps.gov/im/units/UCBN/index.cfm>).

The protocol and technical reports will also be available from the national NRPM website (<http://www.nature.nps.gov/publications/nrpm/nrr.cfm>). All NPS protocols are available from (<http://science.nature.nps.gov/im/monitor/protocoldb.cfm>).

Data Archival Procedures

Paper data sheets will be archived for three years, which allow ample time to complete QA/QC and certification steps for digital data. Long-term archiving will only be used for digital data. Upon certification, data and reports will be archived on the UCBN Network Attached Storage (NAS) unit, posted to the UCBN website, and posted to the national web-accessible secure databases hosted by the NPS Washington Areas Support Office (WASO) or National I&M program. These include:

- *NatureBib* – the master database for natural resource bibliographic references
- *NPSpecies* – the master database for biodiversity information including species occurrences and physical or written evidence for the occurrence (i.e., references, vouchers, and observations)
- *NPS Data Store* – a centralized data repository with a graphical search interface.

A review of archive and expendable data products will be undertaken by the project leader and data manager during season close-out each year. An example of an expendable data product is an intermediate draft of an annual report that was saved during report preparation.

Protocol Testing and Revision

A draft version of this protocol was tested in 2006 and the narrative is included with the development history log in SOP # 8. These field experiences and the analysis of data collected in 2006 were instrumental in forming recommendations for training, plot location, database design, measurement calibration, sample sizes, power analysis, and trend analysis. Subsequent protocol testing will occur during each field season and evaluation of existing protocols and recommended revisions will be documented in annual reports and during season close-out.

Revisions to this protocol and the SOPs are expected. We anticipate possible revisions to the detailed instructions to field crews, the number of transects sampled each field season, and the frequency of sampling. Population boundaries should be revised only if aspen distributions and management priorities shift significantly, and should be done only in consultation with park management and careful consideration of statistical consequences. Because aspen reproduces primarily via vegetative suckering it is not likely that the stand boundaries will change, at least not very fast. In aspen stands where the neighboring vegetative cover type is grasslands or shrub-steppe aspen may expand into these adjacent vegetative cover types. An evaluation of the current stand boundary will be performed every ten years via aerial photography. The stand boundary will be adjusted for stands that have expanded into the steppe. Aspen has been observed to reproduce via seed after severe disturbances such as the 1988 fires in Yellowstone National Park (Romme et al. 2005). In the event of such a major disturbance all stand boundaries in this protocol will need revision and new stands may potentially be created via sexual regeneration. In the case of a natural fire disturbance in aspen stands the long-term baseline data collected as a part of this protocol will serve as an invaluable reference for assessment of the ecological effects of the fire on aspen regeneration and conifer levels. Revisions will be carefully documented

using the protocol development and revision log in SOP # 8 and the change history log at the front of this protocol narrative and each SOP.

Personnel Requirements and Training

Personnel Requirements

This monitoring project requires, at a minimum, participation and leadership from the project leader and the UCBN Data Manager, as well as a skilled field team leader that can provide sufficient expertise in methodological and botanical field operations. The roles and responsibilities of each member of the aspen protocol team are outlined in the next section (Table 6). Additional assistance from park and network technical staff and summer volunteers, as well as seasonal crew members from the University of Idaho will ease the annual workload generated by this effort and ensure a high quality information product.

Field crews will consist of teams of two to three individuals, a team leader and one or two assistants. Field assistants must be able to work outdoors, learn GPS and data entry, and identify plants. Team leaders must have these skills, as well as an understanding of project objectives and experience with field work and GPS. Field assistants can be NPS volunteers, undergraduate students or high school student volunteers. High school student volunteers have been successfully trained to collect field data in other UCBN protocols (Rodhouse et al. 2007). Data collection for the aspen long-term monitoring requires careful counting of stems in pre-determined size classes. During pilot data collection and the field season 2007 we have observed that the required time for field staff to become comfortable classifying aspen and conifer stems consistently requires 1-2 days. During this time it is important that the new field staff works closely with the program leaders or experienced field staff. To improve quality and consistency in data collection we highly recommend that the field crew-members remain the same throughout the field season. Citizen volunteers or high school groups working only a day or two are not recommended for counting aspen stems as part of the sampling, however these kinds of groups could be involved in recording, and evaluation of repeatability. Other tasks such as placing and remarking permanent rebar markers are also suitable for short-term citizen science participation. Data management staff must be able to handle the described GPS/GIS and database tasks. Data analysis staff must be able to conduct the described annual summaries, power analyses, and trend analyses.

Experience during the 2006 field season provides a good estimate of staff time required for field sampling. In 2006, we completed team training and sampling at five aspen stands with twenty plots in each stand. Sampling within one plot was completed within 15 minutes. In the current protocol we have 108 plots in 22 different stands in CRMO and 156 plots in 26 stands in CIRO. This amounts to approximately 35 hours sampling time for the stands in CRMO for a crew of three field technicians. Adding another 25 hours for hiking and driving time on site and 20 hours for transportation to and from CRMO, the total sampling at CRMO can be estimated to 80 hours (or two weeks) per sampling season (panel 1). The 156 plots in CIRO will be divided into two panels with 95 plots sampled in the first year (panel 2) and 61 plots in the second year (panel 3). The plots in panel 3 are more remote and require more hiking but we anticipate that 2 weeks of sampling will be sufficient for each panel in CIRO. We strongly recommend that the field assistants, students or high school volunteers are provided with preliminary exposure to the program objectives, ecological and cultural background, and some opportunity to practice field methods before arriving on site to begin the formal training and calibration exercises.

Roles and Responsibilities

Table 6. Roles and responsibilities for implementing the aspen monitoring program in the UCBN. Current or anticipated staff and volunteers for 2009 are named here.

Role	Responsibilities	Name/Position
Project Leader	• Project oversight and administration • Track project objectives, budget, requirements, and progress toward meeting objectives • Facilitate communications between NPS and cooperator(s) • Coordinate and ratify changes to protocol • Assist in training field crews • Perform data summaries and analyses • Maintain and archive project records • Project operations and implementation • Certify each season's data for quality and completeness • Complete reports, metadata, and other products according to schedule	University of Idaho Project PI's or UCBN staff
Field Leader	• Train and ensure safety of field crew • Plan and execute field visits • Acquire and maintain field equipment • Oversee data collection and entry, verify accurate data transcription into database • Complete a field season report	University of Idaho Project PI's or UCBN staff
Technicians	• Collect, record, enter and verify data	Seasonal crew members, volunteers, UCBN or park interns
Data Manager	• Consultant on information management activities • Facilitate check-in, review and posting of data, metadata, reports, and other products to national databases and clearinghouses according to schedule • Maintain and update database application • Provide database training as needed	UCBN Data Manager
GIS Specialist	• Consultant on spatial data collection, GPS use, and spatial analysis techniques • Facilitate spatial data development and map output generation • Work with Project Lead to analyze spatial data and develop metadata for spatial data products • Primary steward of GIS data and products	UCBN Data Manager and Project Leader

Table 6. Roles and responsibilities for implementing the aspen monitoring program in the UCBN. Current or anticipated staff and volunteers for 2009 are named here (continued).

Role	Responsibilities	Name/Position
Network Coordinator	• Project Leader oversight • Administration and budget • Consultant on all phases of protocol review and implementation • Review of annual reports for formatting and completeness	UCBN Coordinator
Park Resource Managers	• Consultant on all phases of protocol review and implementation • Facilitate logistics planning and coordination • Communicate management and restoration plans and associated information to Project Lead • Review reports, data and other project deliverables	CIRO and CRMO resource management staff

Training and Calibration

All team members will train together. At the start of each field season, the project leader will calibrate procedures across the crews in the field. Under the guidance of an experienced team leader, each team will practice locating and setting up transects and plots, and taking measurements. Teams will measure other team's plots to make sure that measurements are consistent. Calibration will continue until each group is consistently counting within 5% of the "true" value (or 1 stem in plots with very low stem count), as established either by precision within successive counts, or, if necessary, as established by the project leader. Experience in 2006 and 2007 shows that this initial training can be accomplished during one morning, with the caveat that all participants have received some preliminary exposure to the project, objectives, and basic methods, prior to field training. We have however observed that precision and reproducibility in data collection is not reached until the field staff has collected data under the supervision of the project leader or an experienced field lead for 1-2 days. Each aspen plot is different and the field staff must master the classification of stems into the five live stem classes and dead stem class before reproducibility is reached. Consistency in field staff is therefore important during the field season of aspen data collection. Precision and reproducibility measuring exercises undertaken throughout the field effort will provide additional opportunity for refinement and calibration of field techniques.

Operational Requirements

Annual Workload and Field Schedule

The annual workload of this monitoring program is outlined in Table 6 of the preceding section on Roles and Responsibilities. Table 6 provides a good overview of the general roles and tasks (responsibilities) required to complete all aspects of this program following rigorous and comprehensive information management practices as outlined by the UCBN data management plan (Dicus and Garrett 2007). The SOPs provide a comprehensive step-by-step description of the annual workload and tasks required for completion, including data management tasks and product delivery. The annual round for aspen monitoring begins with the recruitment of field staff in January/February. At this time, final reporting, review and close-out activities are proceeding for the previous year. An evaluation of the protocol and any necessary changes must be made by April. Field work commences in late May or June, and data entry and QA/QC procedures begin immediately in July. Table 7 provides additional details of the annual schedule and Table 8 specifies the equipment needs. The budget in Table 9 demonstrates that adequate resources have been allocated to data management, analysis, and reporting activities.

Table 7. Annual schedule of major tasks and events for the UCBN aspen monitoring protocol.

Month	Admin.	Field	Data Mgmt
January	UCBN annual report and work plan complete, Begin recruiting and hiring UCBN seasonal personnel	Hire seasonal staff and schedule field visits, housing, and vehicles	
February	Administrative and modify existing agreements, if necessary		
March			
April		Prepare maps, field data sheets, and PDA field forms	
May		Prepare field and GPS equipment	
June		Begin training and field work	
July		Complete Field Work Clean and store equipment	Data entry and verification
August	Budget preparation for new fiscal year		Metadata production, Quality review
September	Close-out of fiscal year	Field season report complete	Preliminary analysis of current year's results, Annual resource brief prepared for UCBN Science Advisory Committee meeting
October	UCBN annual report and work plan drafted		Data certification complete; Data archival and posting
November	Cooperative task agreements prepared, if needed		Analysis of preceding year's results, reporting, and close-out, Report preparation,
December			Final annual report complete, Data archival and posting, Close-out complete.

Equipment Needs

Equipment needs are modest for this protocol. The list of equipment is included in Table 8 and instructions for constructing field hardware are included in SOP #1. All hardware materials have been purchased and are stored at UCBN or the University of Idaho. GPS units need to be maintained and replaced, if necessary, during the late winter/early spring well in advance of field season. The protocol budget includes cost for one vehicle for the 2-3 week field season. Camping is available at the Research Camp near Leech Creek at CRMO. Prior arrangements must be made to ensure that this camp is available during the weeks of field sampling. Additional camp sites are available nearby if the Research Camp is occupied, however arrangements must be made with CRMO staff. Housing and camping is available at CIRO. Prior arrangements, housing or camp site reservations must be made with the CIRO staff prior to the field season. The field staff is expected to provide personal camping gear.

Table 8. Equipment list for monitoring aspen populations in the UCBN.

Measuring Equipment	Navigation and Recording Equipment	Misc. Equipment
Logger's tape and plot center stake	GPS units	Digital camera
Rebar and engraved caps	Weatherized data entry forms	
Orienteering compass	Backup copies of data forms	
Clinometer	Mechanical pencils and clip boards	
Plant ID material	Mobile field computer with UCBN Aspen database loaded	
Hard copies of SOPs	Metal detector	

Budget

Table 9. The approximate annual budget for aspen monitoring in the UCBN. This budget does not include initial equipment costs because equipment was purchased in 2007.

UCBN Aspen Monitoring Budget	Time Allotted	% of time spent on DM*	Cost in Dollars DM*	Cost in Dollars
<i>Permanent NPS Personnel</i>				
Network Coordinator (GS12)	1 week report review	100%	\$2,000	\$2,000
	1 week field season prep; 1 week QA/QC, data archiving and close-out	100%	\$3,400	\$3,400
Data Manager (GS11)		60%	\$4,266	
	Project Coordination: 1 week prep for sampling, 2 week sampling, 2 weeks data analysis and report			
Project Leaders (PIs)				
	Steve Bunting			3,000
	Eva Strand			4,110
Fringe benefits (project leaders)	Steve Bunting (33%)			990
	Eva Strand (36%)			1,480
<i>Seasonal Personnel</i>				
Student Assistant	2 week sampling, 1 week data input and QA/QC	33%	\$250	\$1,800
Fringe benefits (student assistant)	9% fringe benefits for full-time students			162
<i>Park Personnel</i>				
Interpretive Staff	When available			In-Kind support
Resource Management Staff	When available			In-Kind support
<i>Citizen Scientists</i>				
Student Volunteers	When available			In-Kind support
Travel (field per diem and lodging for monitoring crew)				\$2,300
Vehicle (lease, rental, fuel)				\$2,100
Monitoring expenses				\$1,000
Subtotal UI (not including Network Coordinator and Data Manager)				\$16,942
Indirect costs UI 17.5%				\$2,964
TOTAL (not including UCBN paid staff)			\$9,916	\$19,906

* DM = data management

** More than 40% of the aspen protocol budget is dedicated to data management, analysis, and reporting activities.

Literature Cited

- Barnes, B.V. 1975. Phenotypic variation of trembling aspen in western North America. *Forest Science* 22(3):319-328.
- Barnett D.T., and T.J. Stohlgren. 2001. Persistence of aspen regeneration near the national elk refuge and Gros Ventre Valley elk feedgrounds of Wyoming. *Sustaining Aspen in Western Landscapes Symposium Proceedings*. Grand Junction, CO, June 2000: 27-37: USDA Forest Service Proceedings RMRS-P-18.
- Bartos, D.L. 2001. Landscape dynamics of aspen and conifer forests. *Sustaining Aspen in Western Landscapes Symposium Proceedings*. Grand Junction, CO, June 2000: 5-14: USDA Forest Service Proceedings RMRS-P-18.
- Bartos, D.L., and R.B. Campbell, 1998. Decline of quaking aspen in the interior west – examples from Utah. *Rangelands* 20(1):17-14.
- Beck, J. L. 2003. Elk summer range habitat, nutritional ecology, and carrying capacity in the Jarbidge Mountains, Nevada. Dissertation. University of Idaho, Moscow, ID.
- Binkley, D. 2008. Age distribution of aspen in Rocky Mountain National Park, USA. *Forest Ecology and Management* 255:797-802.
- Brandt, J.P., H.F. Cerzke, K.L. Mallett, W.J.A. Volney, and J.D. Weber. 2003. Factors affecting trembling aspen (*Populus tremuloides* Michx.) health in the boreal forest of Alberta, Saskatchewan, and Manitoba, Canada. *Forest Ecology and Management* 178:287-300.
- Campbell, R.B., and D.L. Bartos. 2001. Aspen ecosystems: objectives for sustaining biodiversity. *Sustaining Aspen in Western Landscapes Symposium Proceedings*. Grand Junction, CO, June 2000: 299-307: USDA For. Serv. Proc. RMRS-P-18.
- Chong, G.W., S.E. Simonson, T.J. Stohlgren, and M.A. Kalkhan 2001. Biodiversity: aspen stands have the lead, but will nonnative species take over? *Sustaining Aspen in Western Landscapes: Symposium Proceedings*. Grand Junction, CO, June 2000:261-271: USDA Forest Service Proceedings RMRS-P-18.
- Cleaves, D. 2006. Aspen die-off in the Rocky Mountains: what is causing massive aspen die-off in the western United States? Rocky Mountain Research Station. Resource brief from <http://spectre.nmsu.edu/dept/docs/forest/AspenDieOff.pdf> (accessed 2008). U.S. Department of Agriculture, Forest Service.
- Cressie, N.A.C. 1991. Statistics for spatial data. John Wiley, Chichester, U.K.
- DeByle, N.V. 1985. Water and watershed. Pages 153-160 in DeByle and Winokur, editors. *Aspen: ecology and management in the western United States*. USDA Forest Service General Technical Report RM-119.

- DeByle, N.V. C.D. Bevins, and W.C. Fischer. 1987. Wildfire occurrence in aspen in the interior western United States. *Western Journal of Applied Forestry* 2(3):73-76.
- Dicus, G.H., and L. K Garrett. 2007. Upper Columbia Basin Network Data Management Plan. Version 1.0, Natural Resource Report NPS/UCBN/NRR-2007/020. National Park Service, Moscow, ID.
- Einspahr D.W., and L.L. Winton. 1976. Genetics of quaking aspen. U.S. Department of Agriculture Forest Service Research Paper WO-25. Washington, D.C.: USDA.
- Elzinga, C. L., D. W. Salzer, J. W. Willoughby, and J.P Gibbs. 2001. Measuring and monitoring plant populations. U.S. Department of Interior, Bureau of Land Management, Denver, CO.
- Environmental Data Standards Council. 2006. Quality assurance and quality control data standard. Standard No. EX000012.1. Available from http://www.envdatastandards.net/files/705_file_QA_QC_01_06_2006_Final_.pdf (accessed 2008).
- Frey, B.R., V.J. Lieffers, E.H. Hogg, and S.M. Landhäusser. 2004. Predicting landscape patterns of aspen dieback: mechanisms and knowledge gaps. *Canadian Journal of Forest Research* 34:1379–1390.
- Garrett, L. K., T. J. Rodhouse, L. K. Svancara, and C. C. Caudill. 2006. Vital Signs Monitoring Plan, Upper Columbia Basin Network. Natural Resource Report NPS/PWR/UCBN/NRR—2006/001. National Park Service, Seattle, WA.
- Hart, J.H., and D.L. Hart, 2001. Interaction among cervids, fungi, and aspen in northwest Wyoming. *Sustaining Aspen in Western Landscapes: Symposium Proceedings*. Grand Junction, CO, June 2000: 197-205: USDA Forest Service Proceedings RMRS-P-18.
- Heide, S.C. 2002. Comparison of methods to detect conifer encroachment into aspen stands using Landsat 7 ETM+ satellite imagery. Thesis. University of Idaho. Moscow, ID.
- Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs* 54:187-211.
- Irwin, R.J. 2006. Draft Part B lite (Just the Basics) QA/QC Review Checklist for Aquatic Vital Sign Monitoring Protocols and SOPs, National Park Service, Water Resources Division, Fort Collins, CO, distributed online only at http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/PartBLite.pdf (accessed 2008).
- Jones B.W., 1993. The influence of grove size on bird species richness in aspen parklands. *Wilson Bulletin* 105(2):256-264.

- Jones, R., and N.V. DeByle. 1985. Fire. Pages 77-81 *in* DeByle and Winokur, editors. Aspen: ecology and management in the western United States. USDA Forest Service General Technical Report RM-119.
- Jones, B.E., D. Burton, and K.W. Tate. 2005. Effectiveness monitoring of aspen regeneration on managed rangelands. Report filed in Rangeland Analysis and Planning Guide, 1997. R5-EM-TP-004. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region.
- Kashian DM, W.H. Romme, and C.M. Regan. 2007. Reconciling divergent interpretations of quaking aspen decline on the northern Colorado front range. *Ecological Applications* 17(5): 1296.
- Kay, C.E. 1997. Is aspen doomed? *Journal of Forestry* 95(5): 4-11.
- Kay, C.E., and D.L. Bartos. 2000. Ungulate herbivory on Utah aspen: assessment of long term exclosures. *Journal of Range Management* 53(2):145-153.
- Kaye, M.W., T.J. Stohlgren, and D. Binkley. 2003. Aspen structure and variability in Rocky Mountain National Park, CO, USA. *Landscape Ecology* 18:591-603.
- Kaye, M.W., D. Binkley, and T.J. Stohlgren. 2005. Effects of conifers and elk browsing on quaking aspen forests in the central Rocky Mountains, USA. *Ecological Applications* 15:1284-1295.
- Kemperman J.A., and B.V. Barnes. 1976. Clone size in American aspens. *Canadian Journal of Botany* 54: 2603-2607.
- Kilpatrick, S., D. Clause, and D. Scott. 2003. Aspen response to prescribed fire, mechanical treatments, and ungulate herbivory. p 93-102 *in* Omi P.N. and L.A. Joyce, *editor*. Fire, fuel treatments, and ecological restoration. RMRS-P-29. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.
- Little, E.L., Jr. 1971. Atlas of United States trees: Vol. 1. conifers and important hardwoods. Page 202 *in* U.S. Department of Agriculture, Forest Service, Miscellaneous Publications 1146, 9 maps. Washington, D.C. Online. (<http://climchange.cr.usgs.gov/data/atlas/little/>). Accessed 19 April 2004.
- Madison, E., K. Oelrich, T. J. Rodhouse, and L. K. Garrett. 2003. Mammal inventories: City of Rocks National Reserve. University of Idaho, Moscow, ID.
- McCool, S.F., 2001. Quaking aspen and the human experience: dimensions, issues, and challenges. 147-160 *Sustaining Aspen in Western Landscapes Symposium Proceedings*. Grand Junction, CO, June 2000:147-160: USDA Forest Service RMRS-P-18.

- MacDonald, T. 2003. Review of environmental monitoring methods: survey designs. *Environmental Monitoring and Review* 85:277-292.
- McDonough W.T., 1985. Sexual reproduction, seeds and seedlings. *In* DeByle N.V., and R. P. Winokus R.P., editors. *Aspen: ecology and management in the western United States*. U.S. Department of Agriculture Forest Service General Technical Report RM- 119.
- Miller, R.F., J.D. Bates, T.J. Svejcar, F.B. Pierson, and L.E. Eddleman. 2005. *Biology, ecology and management of western juniper*. Technical Bulletin 152, Oregon State University Agricultural Experiment Station, Corvallis, OR.
- Mitton, B.J., and M.C. Grant. 1996. Genetic variation and the natural history of quaking aspen. *Bioscience* 46:25-31.
- Mueggler, W.F. 1989. Age distribution and reproduction of intermountain aspen stands. *Western Journal of Applied Forestry* 4(2):41-45.
- National Park Service (NPS), 1999. Natural resource challenge: the National Park Service's action plan for preserving natural resources. US Department of the Interior, National Park Service, Washington D.C. Online. (<http://www.nature.nps.gov/challengedoc.html>). (accessed 2008).
- Noss, R., 1990. Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology* 4:355-364.
- Oakley K.L., L.P. Thomas, and S.G. Fancy. 2003. Guidelines for long-term monitoring protocols. *Wildlife Society Bulletin* 31(4):1000-1003.
- Perala, D.A., 1990. *Populus tremuloides*. Pages 555-569 *in* Burns, R.M., and B.H. Honkala, technical coordinators. *Silvics of North America: 2. Hardwoods*. Agriculture Handbook 654. I.S. Department of Agriculture, Forest Service, Washington D.C.
- Pielou, E.C. 1991. After the ice age: the return of life to glaciated North America. Page 168 *in* The University of Chicago Press, Chicago, IL, 366 pp.
- Piepho H. P., and J.O. Ogutu. 2002. A simple mixed model for trend analysis in wildlife populations. *Journal of Agricultural, Biological & Environmental Statistics* 7(3):350-360.
- Ripple, W.J., and R.L. Beschta. 2007. Restoring Yellowstone's aspen with wolves. *Biological Conservation* 138:514-519.
- Rocky Mountain Research Station. 2008. Congressional briefing available from <http://www.fs.fed.us/rmrs/docs/congressional-briefing/issues/aspen-die-off.pdf> (accessed 2008).

- Rodhouse, T. J., M. V. Wilson, K. M. Irvine, R. K. Steinhorst, G. H. Dicus, L. K. Garrett, and J. W. Lyon. 2007. Camas lily monitoring protocol. Version 1.0. Natural Resource Report NPS/UCBN/NRR—2007/011. National Park Service, Fort Collins, Colorado.
- Romme W.H. 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. *Ecological Monographs* 52: 199-221.
- Romme W.H., M.G. Turner, G.A. Tuskan, and R.A. Reed. 2005. Establishment, persistence, and growth of aspen (*Populus tremuloides*) seedlings in Yellowstone National Park. *Ecology* 86:404-418.
- Roth, A. 2004. Fire patterns within a successional gradient of a sagebrush steppe/juniper woodland. Thesis. University of Idaho, Moscow, ID.
- Rumble, M.A., L.D. Flake, T.R. Mills, and B.L. Dykstra. 2001. Do pine trees in aspen stands increase bird diversity? p. 185-191, *Sustaining Aspen in Western Landscapes Symposium Proceedings*. Grand Junction, CO, June 2000: 185-191: USDA Forest Service Proceedings RMRS-P-18.
- Shepperd, W.D. 2001. Manipulations to regenerate aspen ecosystems. p. 355-365. *Sustaining Aspen in Western Landscapes Symposium Proceedings*. Grand Junction, CO, June 2000:355-365: USDA Forest Service Proceedings RMRS-P-18.
- Shepperd, W.D., D.L. Bartos, and S.A. Mata. 2001. Above-and below-ground effects of aspen clonal regeneration and succession to conifers. *Canadian Journal of Forest Research* 31:739-745.
- Shirley, D.M., and V. Erickson. 2001. Aspen restoration in the Blue Mountains of northeast Oregon. *Sustaining Aspen in Western Landscapes Symposium Proceedings*. Grand Junction, CO, June 2000: 101-115: USDA Forest Service Proceedings RMRS-P-18.
- Shive, J. and C. Peterson, 2001. Herpetological Inventory of the City of Rocks National Reserve. Idaho State University, Pocatello, ID 64 pp.
- Smith, A.E., and F.W. Smith. 2005. Twenty-year change in aspen dominance in pure aspen and mixed aspen/conifer stands on the Uncompahgre Plateau, CO. *Forest Ecology and Management* 213: 338-348.
- Strand, E.K. 2007. Landscape dynamics in aspen and western juniper woodlands on the Owyhee Plateau, ID. Dissertation. University of Idaho, Moscow, ID.
- Strand, E. K., and S. C. Bunting. 2009. Monitoring aspen in the Upper Columbia Basin Network: 2008 monitoring report for City of Rocks National Reserve and Craters of the Moon National Monument and Preserve. Natural Resource Technical Report NPS/UCBN/NRTR—2009/196. National Park Service, Fort Collins, CO.

- Suzuki, K., H. Suzuki, D. Binkley, and T. J. Stohlgren. 1999. Aspen regeneration in the Colorado front range: differences at local and landscape scales. *Landscape Ecology* 14: 231–237.
- van Mantgem, P. J., and N.L. Stephenson. 2007. Apparent climatically-induced increase of mortality rates in a temperate forest. *Ecology Letters* 10:909–916.
- van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, L.D. Daniels, J.F. Franklin, P.Z. Fulé, M.E. Harmon, A.J. Larson, J.M. Smith, A.H. Taylor, and others. 2009. Widespread increase of tree mortality rates in the western United States. *Science* 323: 521-524.
- Wall, T.G., R.F. Miller, and T.J. Svejcar. 2001. Juniper encroachment into aspen in the northwest Great Basin. *Journal of Range Management* 54(6):691-698.
- Wilson, E.O. 1992. *The diversity of life*. New York: W.W. Norton and Company.
- Winternitz, B.L. 1980. Birds in aspen: management of western forests and grasslands for nongame birds. USDA Forest Service General Technical Report INT-86. Intermountain Forest and Range Experiment Station, Ogden, UT.
- Woodley, S.J. 1993. *In* Kay, J. and G. Francis, *editors*. *Ecological integrity and the management of ecosystems*. St. Lucie Press, Del Ray Beach, FL.
- Worrall, J.J., L. Egeland, T. Eager, R.A. Mask, E.W. Johnson, P.A. Kemp, and W.D. Shepperd. 2008. Rapid mortality of *Populus tremuloides* in southwestern Colorado. *Forest Ecology and Management* 255:686-696.

Glossary of Terms Used by the UCBN I&M Program

ANOVA: In statistics, **analysis of variance (ANOVA)** is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different explanatory variables.

Azimuth: Azimuth is the horizontal component of a compass direction. It is usually expressed in degrees.

Dead aspen stems: Here defined as dead stems that are rooted within the plot and still standing or leaning. A stem that is lying on the ground is not included in the count of dead stems.

Density: The number of individuals or observations within a given area or volume.

Permanent plot: A plot that is revisited at the same exact location in consecutive years as opposed to temporary plots which may be located at different locations each sampling period (although within the same stand).

Power analysis: The **power** of a statistical test is the probability that the test will reject a false null hypothesis, or in other words that it will not make a Type II error. As power increases, the chances of a Type II error decrease, and vice versa. The probability of a Type II error is referred to as β . Therefore power is equal to $1 - \beta$. Power is a function of effect size or minimum detectable change, variance of the parameter (e.g. standard error of the mean), and sample size. A power analysis determines the probability of correctly rejecting a false null hypothesis given fixed values of effect size, variance, and sample size.

Simple random sample: In statistics, a **simple random sample** is a group of subjects (a sample) chosen from a larger group (a population). Each subject from the population is chosen randomly and entirely by chance, such that each subject has the same probability of being chosen at any stage during the sampling process.

Stratified random sample: In statistics, **stratified sampling** is a method of sampling from a population. When sub-populations vary considerably, it is advantageous to sample each subpopulation (stratum) independently. **Stratification** is the process of grouping members of the population into relatively homogeneous subgroups before sampling.

Status: Status is a measure of a current attribute, condition, or state, and is typically measured with population means.

Sucker: Aspen in the semi-arid West commonly reproduce via vegetative sprouting. These sprouts are commonly referred to as suckers.

Temporal variation: Variation in a population parameter, such as a mean, over time. For our purposes this typically refers to variation seasonally or annually.

Threshold: A threshold is a point "...in space and time at which one or more of the primary ecological processes responsible for maintaining the sustained equilibrium of the state degrades beyond the point of repair. These processes must be actively restored before the return to the previous state is possible. In the absence of active restoration a new state is formed (Stringham et al. 2001).

Trend: Trend is a measure of directional change over time and can occur in some population parameter, such as a mean (**net trend**), or in an individual member or unit of a population (**gross trend**).

Vital Signs: A subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

Without Replacement: In statistics, one deliberately avoids choosing any member of the population more than once. By contrast, replacement, used, for example, in bootstrapping, permits drawing any particular member of a population more than once.

Appendix A. Index of Standard Operating Procedures

(Bound as a separate document)

- SOP 1: Preparation for the Field Season
- SOP 2: Training Observers
- SOP 3: Finding GPS Waypoints
- SOP 4: Locating and Establishing Sampling Transects
- SOP 5: Measuring Vegetation along Transects
- SOP 6: Data Management
- SOP 7: Data Summary, Analysis, and Reporting
- SOP 8: Protocol Revision
- SOP 9: Field Safety

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 963/100295, September 2009

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