



Protocol Implementation Plan for Aspen Monitoring in Great Basin National Park and Grand Canyon-Parashant National Monument

Narrative Version 1.0

Natural Resource Report NPS/MOJN/NRR—2018/1758



ON THE COVER

Aspen (*Populus tremuloides*) and conifer woodlands near Bald Mountain, Great Basin National Park (left)

Aspen stand on Mount Logan, Grand Canyon – Parashant National Monument (right)

NPS Photograph courtesy of Eva Strand

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Executive Summary

The mission of the National Park Service (NPS) 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 Mojave Desert Inventory & Monitoring Network (MOJN) is one of 32 monitoring networks in the NPS. These networks were established to collect and analyze data about park natural resource conditions, take inventory of park species and natural features such as springs and streams, and monitor changes in these valuable resources over time. MOJN is comprised of nine national park units located within the Mojave and Great Basin deserts of Nevada, Arizona, and California. The MOJN parks encompass over 3.3 million hectares in the lower 48 states.

Quaking aspen (*Populus tremuloides*, Michx.) is a species of interest for two MOJN parks, Great Basin National Park (GRBA) and the Grand Canyon-Parashant National Monument (PARA). Aspen is a focal resource in 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). Aspen stands provide forage for wildlife and domestic livestock in western landscapes, and declining aspen habitats has been shown to result in losses of vertebrate species and vascular plants as well as invertebrates and nonvascular organisms (Campbell and Bartos 2001). Aspen is also an important attraction for campers, naturalists, and recreationists in the otherwise semi-arid landscapes of GRBA and PARA.

This document is a Protocol Implementation Plan (PIP) which, like a protocol, specifies a long-term monitoring program; however, unlike a protocol, a PIP is based on an already existing protocol. This PIP adapts objectives, sampling design, standard operating procedures (SOPs), and other components from the Upper Columbia Basin Network (UCBN) Aspen Monitoring Protocol Narrative and SOPs (Strand et al. 2009) to MOJN parks. The methods outlined in this document have been tested and utilized in two parks in the UCBN (City of Rocks National Reserve and Craters of the Moon National Monument) since 2007 (Strand et al. 2009). However, climate conditions in GRBA and PARA are different than in the UCBN parks, as are the spatial distribution and accessibility of aspen stands. The Strand et al. (2009) protocol has been modified here to account for those differences. Together, the UCBN and MOJN datasets can contribute information over a large region which will be important for understanding consequences of climate change for aspen across the semi-arid regions of the United States.

This PIP provides background information, a conceptual framework for monitoring, specific monitoring objectives, a plan for implementing monitoring plots, and proposed analysis procedures for monitoring the aspen woodlands in two MOJN parks, GRBA and PARA. As recommended by Oakley et al. (2003), the document consists of a narrative and a set of standard operating procedures which detail the steps required to collect, manage, and disseminate the data representing the status and trend of aspen regeneration and density within the selected parks.

Acknowledgments

Funding for this project was provided through the National Park Service Natural Resource Challenge and the Service-wide Inventory and Monitoring Program. This PIP was created in close collaboration with other NPS programs and personnel. Great Basin National Park staff Ben Roberts, Meg Horner, and Gretchen Baker invested time discussing research interests, explaining the natural and cultural history of their aspen forests, and supporting initial field visits. In Grand Canyon-Parashant National Monument, Jennifer Fox and others provided detailed information on specific aspen locations, park accessibility, aspen and fire management, overall logistics, and supported field work. In addition to the authors, MOJN staff were essential in development of this PIP, principally Alex Whalen and Carolyn Mills. The authors would like to acknowledge the Upper Columbia Basin Network staff who shared ideas, contributed advice, and assisted in the development of this PIP from start to finish. We look forward to implementing this protocol in MOJN parks and extending aspen long-term monitoring to additional national park sites.

Glossary of Terms and Acronyms

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: Defined here 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.

GRBA: Great Basin National Park

GRTS: Generalized Random Tessellation Stratification. GRTS is an algorithm developed by Stevens and Olsen (2004) used to select random locations with an unstructured, equal-probability, spatially balanced approach. This method is commonly used because of its flexible, efficient, and statistically robust approach that accommodates many of the difficulties commonly encountered in field sampling; it allows sites to be rejected or replaced if needed.

I&M: The National Park Service Inventory and Monitoring Program

IRMA: The National Park Service Integrated Resource Management Application System

MOJN: The National Park Service Mojave Desert Inventory and Monitoring Network

NPS: National Park Service

PARA: Grand Canyon–Parashant National Monument

PIP: Protocol Implementation Plan; technically defined here as a long-term monitoring program that builds on an already existing protocol. Like a protocol, a PIP details how and why to monitor a specific resource long-term. A PIP utilizes much of the background, objectives, and sample design of the protocol on which it's based.

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.

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

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.

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. 2003).

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*).

UCBN: The National Park Service Upper Columbia Basin Inventory and Monitoring Network.

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).

Background and Objectives

This document presents a Protocol Implementation Plan (PIP) for monitoring the status and trends of indicators of aspen ecological condition in two Mojave Desert Network (MOJN) parks: Great Basin National Park (GRBA) and Grand Canyon - Parashant National Monument (PARA). The document uses elements of Upper Columbia Basin (UCBN) aspen protocol (Strand et al. 2009), including the objectives, sampling design, and plot layouts, for implementation in MOJN parks. This PIP also provides rationale for why aspen monitoring in MOJN is similar to that of UCBN in most cases and explains where and why there are some differences.

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 3,700 m altitude (Mitton and Grant 1996). Although the geographic range is large, aspen's high evapotranspirative demands limit 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 western US is unique. The primary means of aspen reproduction in the West is thought to be via vegetative root suckering (Bartos 2001). 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). Recent research indicates that genetic variability within aspen stands is common, suggesting that sexual reproduction in xeric aspen occurs more frequently than previously thought (Mock et al. 2008). 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). Genetic analysis has also shown that the southwestern portion of aspen's range in the US has low within-population genetic diversity, structuring within geographical populations, and limited evidence of expansion towards the north (Callahan et al. 2013). Callahan et al. (2013) suggest that these southwestern populations may be disproportionately valuable in terms of conservation value because of their evolutionary potential.

Aspen in the Great Basin has been described occurring in seven different stand types (Shinneman et al. 2015) including meadow fringe, riparian, upland aspen/conifer, lithic, snowpocket, upland pure, and krumholtz aspen. In the upland, aspen/conifer type, aspen has been reported to 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), subalpine fir (*Abies lasiocarpa*; Smith and Smith 2005), white fir (*Abies concolor*), Engelmann spruce (*Picea engelmannii*), limber pine (*Pinus flexilis*), or ponderosa pine (*Pinus ponderosa*). Aspen stands have also been observed to occur as uneven-aged 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 in GRBA and PARA generally occur in conjunction with conifer species, although some stands in GRBA are mapped as stable aspen stands without a conifer component (Horner et al. 2014). One stand in PARA can be classified as lithic aspen, where the aspen is occurring in a recent lava flow.

Aspen stands are preferred habitats for native ungulates such as deer (*Odocoileus spp.*) and elk (*Cervus elaphus*) 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).

Park Descriptions

Great Basin National Park

Great Basin National Park (GRBA) is located in east central Nevada near Baker and less than 18 kilometers from the Nevada-Utah state border. The Park's history goes back to 1922, when Lehman Caves National Monument was established by Presidential Proclamation (No. 1618; 42 Stat. 2260) signed by President Warren G. Harding. Lehman Caves is the longest limestone cave in Nevada, and the National Monument was a 240 ha (593 ac) parcel surrounding the entrance to Lehman Caves, carved out from the then Nevada National Forest. Lehman Caves National Monument was initially administered by the Forest Service (Department of Agriculture) and transferred to the NPS in 1933, during a major federal government reorganization effort. Lehman Caves National Monument and much of the surrounding South Snake Range were designated as Great Basin National Park in 1986, the nation's 49th national park, when President Ronald W. Reagan signed Public Law 99-565 (100 Stat. 3181), or the "Great Basin National Park Act of 1986" (Unrau 1990). The purpose of the park was "to preserve for the benefit and inspiration of the people a representative segment of the Great Basin of the Western United States possessing outstanding resources and significant geological and scenic values." Park visitation in 2016 was 144,846 people (highest year on record; data sourced from the NPS Integrated Resource Management Applications [IRMA] system as of November 2017).

Unlike other MOJN parks, GRBA lies wholly in the Great Basin Desert region (Figure 1). It is a mountainous park as its 31,161 ha (77,000 ac) encompass the rugged South Snake Range, an elongated north-south trending range bounded on the west by Spring Valley and on the east by Snake Valley. The boundaries of GRBA are contiguous with Bureau of Land Management (BLM) lands managed by the Ely, Nevada district office and private lands. Besides Lehman Caves, another major feature of GRBA is Wheeler Peak (3,982 m), the highest point in the Snake Range and second

highest peak in Nevada, where the only glacier in Nevada is found. Elevations in GRBA range from 1,615 m in the sagebrush foothills to 3,982 m at the top of Wheeler Peak.

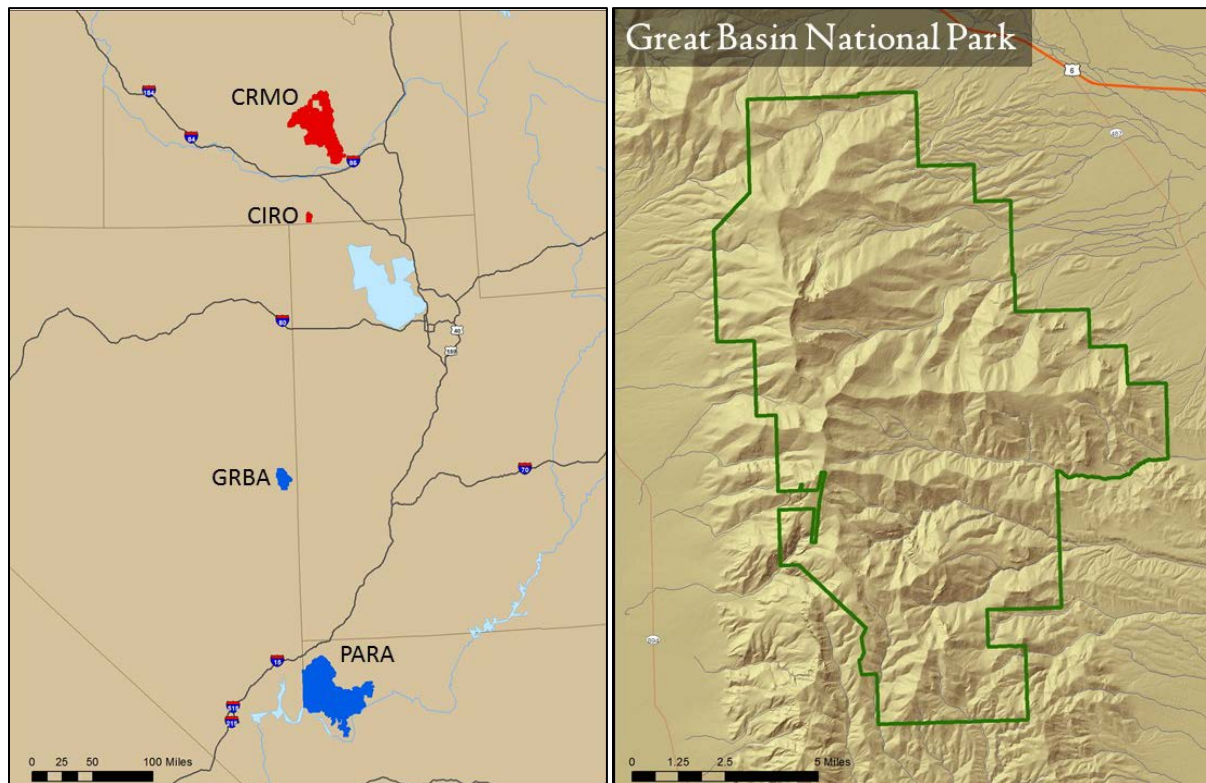


Figure 1. The UCBN parks that monitor aspen, CIRO and CRMO, are located in southern Idaho, and the MOJN parks that monitor aspen are, PARA and GRBA, in Arizona and Nevada (left). Great Basin National Park is located in eastern Nevada near the Utah border (right).

The extreme elevational gradient in GRBA leads to a variety of different habitats, ranging from sagebrush communities at lower elevations to alpine/subalpine communities at high elevations. GRBA has a variety of habitats including sagebrush steppe (*Artemisia* spp.), grasslands, aspen/conifer woodlands, ponderosa pine woodlands, limber pine-bristlecone pine forests, pinyon/juniper forests, mountain mahogany woodlands (*Cercocarpus ledifolius*), riparian shrubs, and wet meadows. Aspen in GRBA are found in many geographic locations and in multiple vegetation alliances. Primarily it occurs in riparian areas, as pure or mixed upland aspen/conifer stands, and as short shrubby snow-bank aspen near ridges. Conifer species such as white fir, Douglas-fir, limber pine, Engelmann spruce, Utah juniper (*Juniperus osteosperma*) and occasionally Rocky Mountain juniper (*Juniperus scopulorum*) occur in varying amounts in many aspen stands. Although livestock are not currently permitted in GRBA, past impacts by livestock and current browsing by wildlife is apparent. Large herbivores in GRBA include bighorn sheep (*Ovis canadensis*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), and elk, with occasional trespass cattle and domestic sheep.

Grand Canyon-Parashant National Monument

Grand Canyon-Parashant National Monument(PARA) was established in 2000 through Presidential Proclamation 7265 by President William J. Clinton. It was established to protect “a vast, biologically diverse, impressive landscape encompassing an array of scientific and historic objects.”

Approximately 424,240 ha (1.048 million ac) of land were set aside for PARA to be cooperatively managed by the BLM and NPS. A majority of the lands for PARA came from land that was managed by BLM (327,287 ha or 808,744 ac) that were part of the Arizona Strip and NPS (84,175 ha or 208,000 ac), generally referred to as the Shivwits Plateau, that were part of Lake Mead National Recreation Area (LAKE). Each agency retains the primary management authority over their respective sections. There are also a number of Arizona state (9,391 ha; 23,205 acres) and private lands (3,205 ha; 7,920 acres) that are within the Monument boundary. The entire designated wilderness in PARA, 76,130 ha (188,121 ac), is located on the BLM portion of the Monument (NPS 2008a).

PARA is located in northwestern Arizona in the drainage of the Colorado River (Figure 2). It is bordered by Grand Canyon National Park to the south and east, LAKE and the state of Nevada to the west, and surrounded by the southern portion of the Colorado Plateau called the Arizona Strip on the north. PARA is isolated from the rest of the Colorado Plateau by the Grand Canyon, and even though it borders Grand Canyon National Park, there is no direct access to the canyon from PARA.

However, PARA does provide spectacular overviews of the Grand Canyon and major features such as the Shivwits Plateau, Grand Wash Cliffs, and the volcanic Uinkaret Mountains, which include Mount Logan and Mount Trumbull and are known as “sky islands” because their high elevation provides distinctive habitats from the surrounding areas. The Monument ranges in elevation from 366 m to 2,447 m.

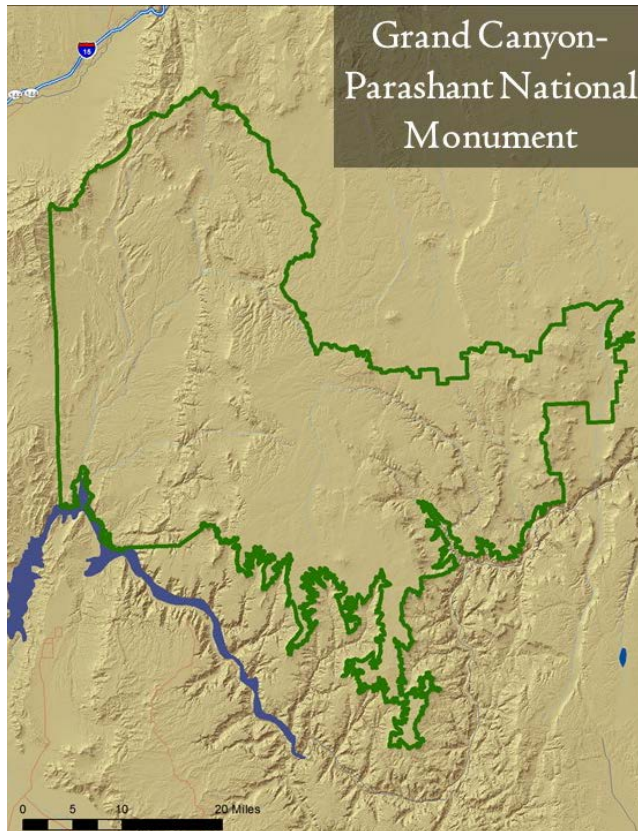


Figure 2. Grand Canyon-Parashant National Monument is located in northwestern Arizona, south of St. George, Utah.

The Monument spans three ecoregions, the Mojave Desert, the Great Basin, and the Colorado Plateau, and plants typical of specific regions can be found together along the transition zones. PARA lies at the northeast edge of the Mojave Desert, and this region is found at the lower elevations on the west side of the Monument, where Joshua tree woodlands occur. The Great Basin region is the largest region of the Monument, covering most of the central and eastern parts of the Monument and is characterized by sagebrush shrublands and pinyon-juniper (*Pinus* spp. – *Juniperus* spp.) woodlands. The smallest region is the Colorado Plateau, which tends to be found at the highest elevation areas in the Monument; tree communities, like ponderosa pine forests, are representative of the Colorado Plateau region.

This diverse Monument contains conifer species such as single leaf pinyon pine (*Pinus monophylla*), Utah juniper, and ponderosa pine. PARA also has large deciduous forests comprised of oak scrublands (*Quercus* spp.) and maple (*Acer* spp). New Mexican locust (*Robinia neomexicana*), mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), and gray rabbitbrush (*Ericameria nauseosa*). Aspen forests are found near both coniferous and deciduous forests. Understory species characteristic of upland aspen stands in sagewort (*Artemisia ludovisiana*), common dandelion (*Taraxacum officinale*), common mullein (*Verbascum thapsus*), and green rabbitbrush (*Chrysothamnus viscidiflorus*).

These habitats support a large number of wildlife species including mountain lion (*Puma concolor*), mule deer, and elk. 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 in the Mojave Desert Network

Aspen is an important resource to GRBA and PARA because of its biological, cultural, and aesthetic significance. Approximately 27% of the area within GRBA is mapped as stable or seral aspen woodland (Provencher et al 2013), and many of the stands are dominated by conifer species. Although aspen comprise only a small percentage of the land cover in PARA, the community type contributes significantly to species diversity and richness. Aspen brings visitors to the western mountains and parks, improves local economies, inspires poets and artists, and is portrayed in modern stories and tribal myths (McCool 2001). Aspen is an important attraction for campers, naturalists, and recreationists in the otherwise semi-arid landscapes. Additionally, aspen in GRBA hold interesting park history and serve as a living cultural resource of arborglyphs (also called dendroglyphs or aspen art). The practice was started by Basque sheepherders in the late 1800s. Basque sheepherders were replaced by Peruvian sheepherders in the late 1900s (Mallea-Olaetxe 2008). GRBA staff began documenting aspen carvings in the summer of 2006 and are interested in knowing more about their aspen stands from a cultural as well as biological standpoint.

Quaking aspen is currently declining across the western United States. Aspen decline compared to historical distribution ranged from 49% in Colorado to 96% in Arizona (Bartos 2001) within the past century. Data presented by DeByle et al. (1987) imply that rates and extents of wildfire rejuvenation of aspen stands have been reduced during the last 100 years in the western states, and that fire management has generally been very effective at suppressing fire in aspen, among other forest types, in the late 1900s. 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 prevent conifer expansion into aspen and would sustain healthy aspen stands. Conifer expansion into areas previously dominated by aspen is occurring in GRBA. Monitoring aspen and conifer species in GRBA is therefore of high importance for understanding the forest composition changes and aspen management in the Park. Fire activity, however, has increased in the past two decades; in particular, an increase in fire size has been observed (Westerling et al. 2006). For example, in 2016 the Strawberry wildfire burned 1,900 ha (4,656 ac) in the northeastern part of GRBA (NPS: 2,790 acres; BLM: 1,769 acres, and Private: 97 acres (Rasmussen et al. 2016)). Aspen monitoring in GRBA will inform MOJN and the Park about impacts of conifer encroachment and wildfire on aspen resources.

Browsing poses another potential risk since native ungulates and domestic livestock utilize aspen for preferred forage (Barnett and Stohlgren 2001, Shirley and Erickson 2001, Beck 2003). 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), where elk winter and are not hunted.

Native ungulates in GRBA include bighorn sheep, mule deer, pronghorn, and elk; livestock grazing is not permitted in the park but trespasses do occur. Mule deer and elk inhabit PARA, and livestock grazing is permitted in some areas. Aspen monitoring in the parks is designed to detect regeneration rates but would not specifically identify if low regeneration rates are caused by browsing. However, if stands with low regeneration are identified, further investigation into the reason for the lack of regeneration could be researched.

Another phenomenon affecting quaking aspen is referred to as Sudden Aspen Decline (SAD) and is different from the slow decline in aspen populations that has been occurring over the past century due to changes in fire regimes. In cases of SAD, mature aspen stems die with no apparent regeneration in the form of suckering (Morelli and Carr 2011, Worrall et al. 2008). SAD has not been specifically reported in GRBA or PARA; however, long-term monitoring would detect if SAD is occurring now or in the future.

Conditions identifying aspen stands at-risk of loss 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/ha, conifer canopy cover is >25%, total aspen canopy cover is <40%, or where the majority of the stems are >100 years in age. The desired future condition for aspen stands within GRBA and PARA is defined as stands that do not exhibit the at-risk traits 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 GRBA and PARA may yield thresholds that are different and specific to these parks and to specific stands within the parks. We will attempt to determine park-specific management thresholds for at risk aspen stands in a future version of this protocol.

Initial signs of aspen decline manifest as reduced regeneration within the clone, decreasing number of aspen stems, and increasing counts of conifer stems and/or 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 and conifers is important for determining when active management could be considered for restoration and the long-term maintenance of aspen stands in GRBA and PARA. Data provided by this 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 techniques. Important questions include (1) what is the desired future condition? (2) What factors are affecting proper ecological function? (3) What is the current state of the site? (4) 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 treated area 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 stands. Mueggler (1989) provides a decision support diagram for selecting an appropriate management strategy for aspen stands; we edited the figure to more directly apply to the objectives of this PIP (Figure 3). A long-term monitoring program for detecting status and trends in aspen regeneration and population density at GRBA and PARA 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.

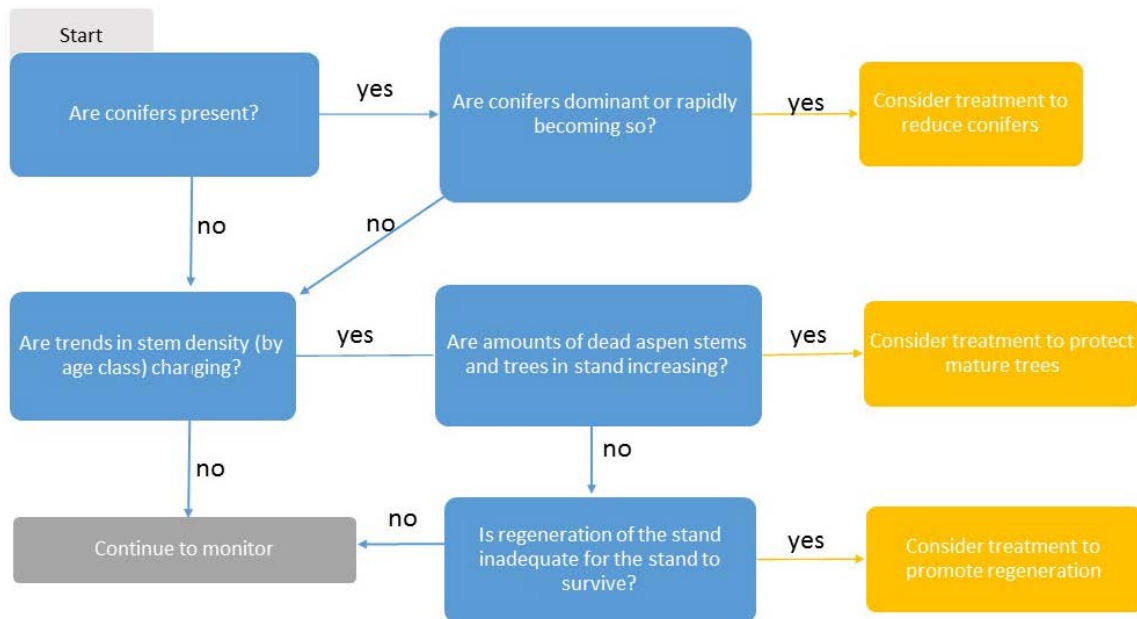


Figure 3. Management decision support chart for upland aspen in GRBA and PARA. This conceptual diagram is adapted from Mueggler (1989) to include monitoring elements specific to this protocol and shows how the data collected in this monitoring program will be used to inform management when needed.

Objectives

The goal of the MOJN aspen vital signs monitoring matches the goal developed for aspen monitoring in UCBN parks (Strand et al. 2009); the primary goal is to obtain information that will inform management decisions pertaining to the perpetuation of the aspen populations in the parks. Currently, there is little information available about aspen regeneration and stem density in GRBA and PARA. Given the current region-wide aspen decline and aspen die-off, it is essential to assess the status of the aspen populations in these parks. Identifying at-risk aspen stands is the first step towards selecting management strategies that may help to prevent loss of this biologically and culturally important resource. These objectives also pursue broader ecological questions about the population ecology of 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) within the context of predicted climate change. Long-term monitoring data in GRBA and

PARA will be able to more broadly address the following fundamental questions that continue to drive inquiry of aspen population age structure and ecology in semi-arid ecosystems:

- Are the aspen populations stable, declining, or increasing?
- Are aspen clones regenerating and at what level? What is the long-term trend in regeneration of park aspen populations and in individual stands?
- What is the 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?

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

- Estimate status and long-term trend in regeneration of park aspen populations as well as selected individual stands within GRBA and PARA.
- Estimate status and trend in aspen abundance, as measured by stem density (in size classes) of size classed live and dead trees, within selected aspen stands.
- Estimate the status and trend in density of dead standing aspen stems by size class within selected aspen stands.
- Estimate the status and trend in conifer density by size class within selected aspen stands.

This PIP will use the same statistical sampling objectives that were developed for UCBN parks (Strand et al. 2009):

- 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 aspen live or dead mean stem density estimates with a 0.10 acceptable false-change (α) error rate.

Sampling Design

Sampling Design Rationale

This PIP utilizes many methods currently used by UCBN but has altered some elements to meet the specific needs of MOJN parks (Strand et al. 2009). For similarities, MOJN and UCBN implement the same nested response design (i.e., the sampling unit is a stand, within a stand plots are located along transects) and revisit design (plots re-measured every five years). The most notable difference is in the sampling frames; the sampling frames had to be determined using different methods due to the nature of the aspen populations in each park. GRBA has notably more aspen forest, and the stands are less discreet, than either CIRO or CRMO in UCBN, and PARA in MOJN (described in detail below).

The sampling design was developed by considering existing NPS vegetation maps, reviewing existing LANDFIRE vegetation data layers (www.landfire.gov), site reconnaissance, and thoughtful consideration of park and network information requirements. The protocol implementation team consisted of UCBN staff (protocol authors and data managers), MOJN staff (program manager, ecologist, and data management team), Eva Strand (author and collaborator at University of Idaho), and GRBA and PARA staff. Members of the implementation team visited GRBA and PARA in June and October of 2017 for field reconnaissance and to evaluate existing vegetation maps and Geographic Information System (GIS) layers.

Target Populations, Sampling Frames, & Sample Size

Great Basin National Park

The target population in GRBA is the aspen population comprised of purely aspen trees as well as aspen-conifer mix stands, including aspen-Englemann spruce, aspen-Great Basin bristlecone pine, and aspen-white fir. We constructed sampling frames using the NPS Vegetation Inventory Program map for GRBA (Cogan et al. 2012); all mapped alliances which contained aspen were included in the sampling frame. Four applicable vegetation classes were identified in the vegetation map: Engelmann-Spruce-Quaking Aspen Forest, White Fir-Quaking Aspen Forest Complex, Quaking Aspen-Great Basin Limber Pine Forest, and Rocky Mountain Quaking Aspen Forest & Woodland Alliance. These alliances were placed in two groups (Figure 4) from which sample locations are drawn: the Conifer/Aspen Group (Engelmann-Spruce-Quaking Aspen Forest and White Fir-Quaking Aspen Forest Complex) and the Aspen Group (Quaking Aspen-Great Basin Limber Pine Forest and Rocky Mountain Quaking Aspen Forest & Woodland Alliance).

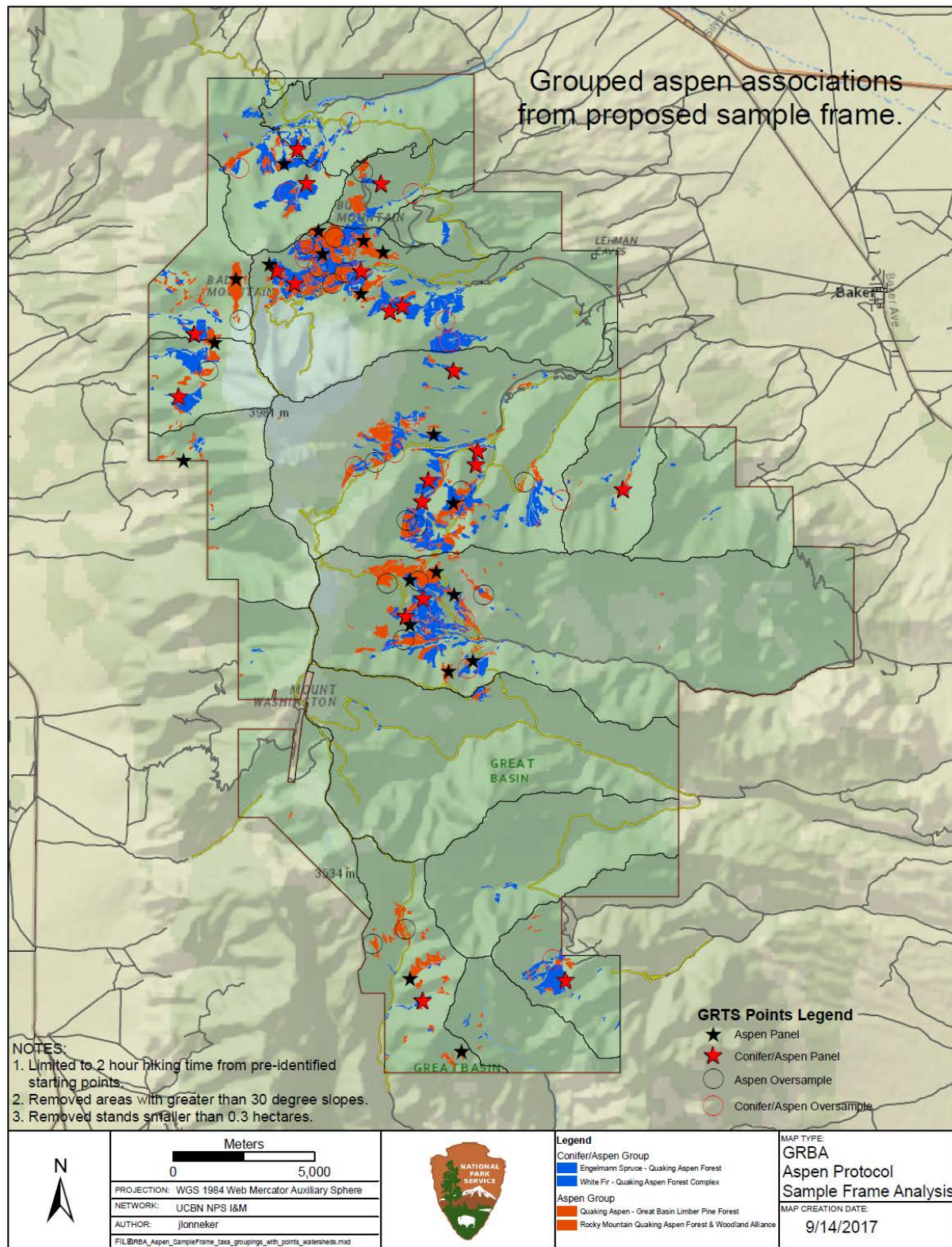


Figure 4. Map of aspen associations and a GRTS draw of aspen stands stratified by the two association groups (Conifer/Aspen and Aspen) in Great Basin National Park.

We further restricted the sampling frame to stands within approximately 2 hours hiking time using a Time Travel Cost Simulation Model (TTCSM, Frakes et al. 2015). The TTCSM is a model which considers the steepness of slopes, terrain types, and other factors to estimate how much time it would take to hike to locations from predetermined starting points, often camp sites, trail heads, or field offices. If the TTCSM determined accessing a plot would take greater than two hours, the location was withheld from the sampling frame. Additionally, stands smaller than 0.3 ha were excluded from the sample frame. Our scope of inference to the target population is therefore restricted somewhat towards the larger stands that are also accessible.

Within this sampling frame, aspen stands are measured along transects (described below in the Response Design section). The starting point of those transects were selected via a Generalized Random Tessellation Stratified (GRTS) procedure designed for drawing spatially distributed sampling points within the target population (Stevens and Olsen 2004). The target sample size for GRBA is 40 transects (see power analysis for rationale). Replicate plots within stands will be used to capture within-stand heterogeneity. In other words, larger stands will have more plots than smaller stands. Twenty points in each of the groups, Conifer/Aspen Group and Aspen Group, were drawn. These locations will be visited by the MOJN field crew. In instances where aspen is absent at the starting point assigned via the GRTS process, the start location can be moved up to 100 m in any direction from the assigned location. If no aspen is present within 100 m from the starting point, the crew will discard the point and move to the next location in the GRTS draw.

Target Population and Sampling Frame in Grand Canyon-Parashant National Monument

Unlike GRBA, PARA is not dominated by aspen; the aspen stands in PARA are small and discrete. Additionally, locating these stands required a different process than the one used in GRBA because there is not a complete NPS Vegetation Inventory Program map for PARA. Therefore, the sampling frame was created by viewing aerial images, Google Earth, other sources of remotely sensed data, and expert opinion provided by PARA staff. During field reconnaissance in PARA in October 2017, eight stands were located within the park boundaries (Table 1, Figure 5). Because of the small number of stands, the target population for monitoring in PARA is all detectable upland aspen stands located within the Park boundaries. The sampling frame is matched to this target population, as all stands are mapped, and effectively a census of these few stands will be included in monitoring.

Table 1. Site code, size, and number of transects of PARA aspen stands.

Site Code	Description	Area (sq. m)	Num Transects
PARAACOY	Trumbull - Coyote Springs Stand	4,163	1
PARAATR1	Trumbull - Mature Tree Stand	546	1
PARAATR2	Trumbull - Main Stand	11,437	1
PARAATR3	Trumbull - Lower Paired Stand	4,004	1
PARAATR4	Trumbull - Upper Paired Stand	1,185	1
PARAAEXC	Logan - Exclosure Stand	38,632	2
PARAALOG	Logan - Trailhead Stand	4,411	1
PARAABAS	Basalt Escarpment Stand	88,855	0*
Total	8 Sites	149,486	8

*The basalt escarpment stand at PARA will have photo point locations but no transects. Due to the young age and very low density of this stand it is not suitable for monitoring with transects.

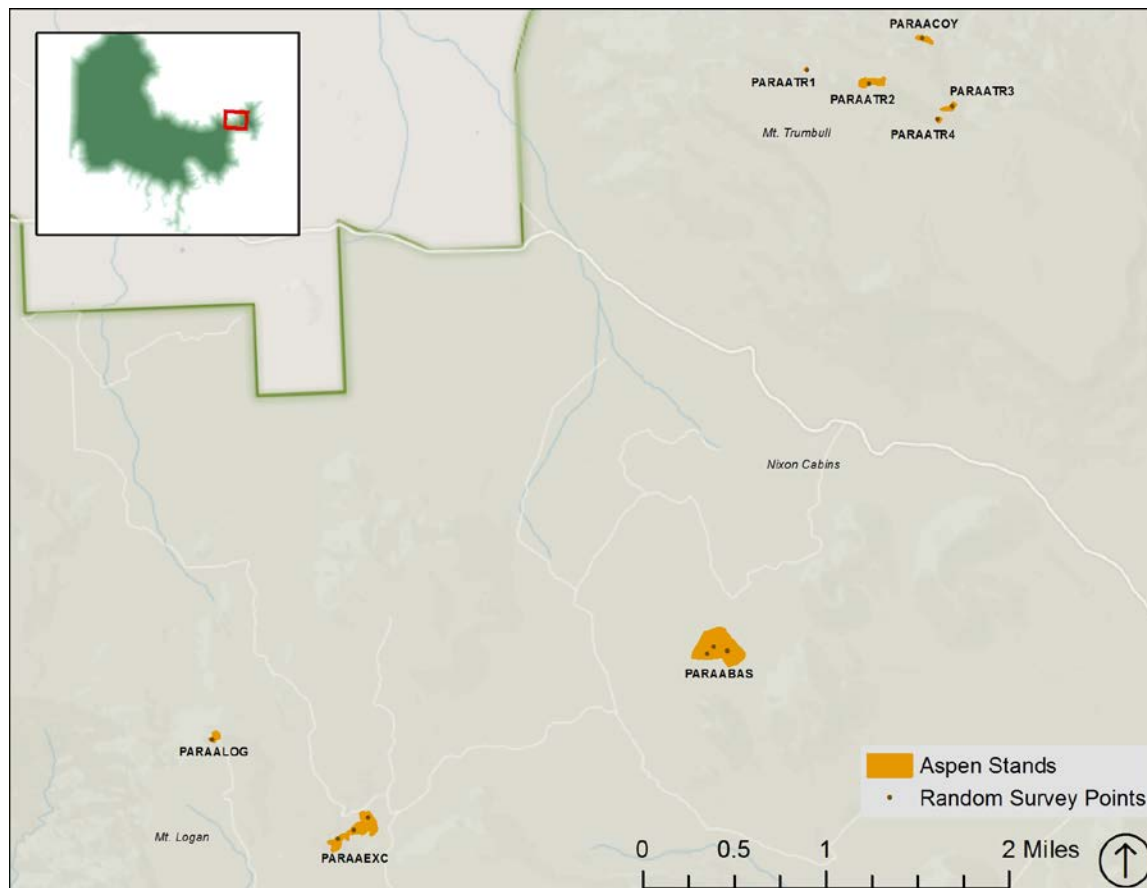


Figure 5. Map of the eight PARA aspen stands that are monitored in this PIP. All stands are located in Arizona in the easternmost region of the monument.

Each aspen stand will serve as the observational unit and will be monitored with transects or photo points (Table 1). Final adjustments to the number of stands included in the sampling frame will likely occur during the establishment of the permanent transects in both GRBA and PARA. For example if resources allow, additional points beyond the current sample may be added in the Strawberry Creek fire region of GRBA since this area is of particular interest to the park.

Revisit Design

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 (Table 2). We may later decide to change the sampling frequency once we begin to understand the nature of variation in GRBA and PARA aspen stands. A convenient schedule for arranging field crews is to alternate visits to the GRBA and PARA populations (Table 2). MOJN staff will also seek to integrate with other monitoring efforts in these parks to conserve resources and travel time. 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.

Table 2. Proposed revisit design [1-4] in which one panel is located in GRBA and one in PARA.

Panel	Sampling Occasion (Year)											
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
GRBA	–	X	–	–	–	–	X	–	–	–	–	X
PARA	X	–	–	–	–	X	–	–	–	–	X	–

The time of year at which sampling occurs is quite flexible because aspen stems within size classes remain recognizable over a long period. Sampling is not recommended before leaf-out in the spring or after leaves have begun to fall in autumn. The sampling period is therefore limited to May 10 to September 15. High elevation areas may not be accessible until approximately June 1.

Response Design

Field sampling in GRBA and PARA will follow the design outlined in UCBN's aspen monitoring protocol (Strand et al. 2009). Following Strand et al. (2009), 4-m radius circular plots will be used at each sampling point (Figure 6). Within plots, aspen stems in five size classes and dead aspen (Table 3) stems are counted, and the counts are converted to stems per hectare. 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.

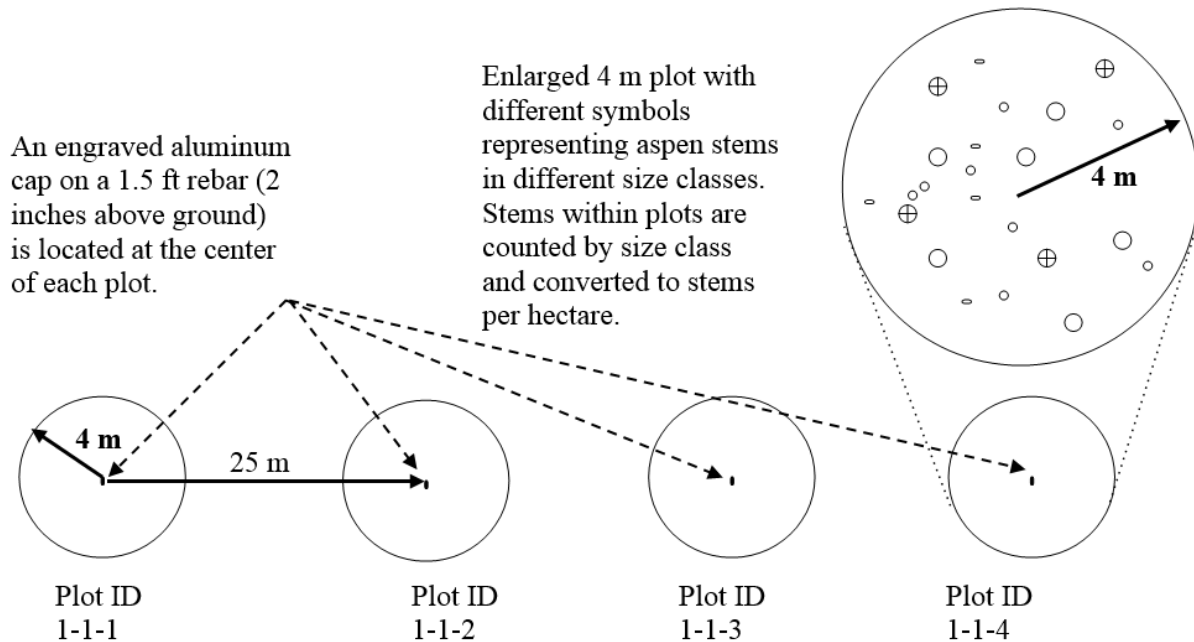


Figure 6. Placement of circular plots along a transect. This figure shows how circular plots, with a 4m radius, are spaced every 25m along a transect; the transect start location is also the center of the first plot. Each plot along the transect is located 25 m apart, center to center. The direction of a transect is determined by the pre-defined azimuth (true north). Trees in different size classes are counted within each plot. 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.

Size Class	Characteristic
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 in) in dbh and shorter than 75% of the stand height.
Class V	Greater than 2.5 cm (1 in) in dbh and taller than 75% of the stand height.
Class VI	Dead stems >2.5 cm (1 in) in dbh.

The distance between each plot is 25 m to minimize the risk that two adjacent plots are spatially dependent. This distance is based on analysis of variograms (Strand et al. 2009; 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 four plots 25 m apart in each transect (Figure 6). If possible, transects are oriented north-south or east-west, otherwise transects are oriented along the longest axis of the stand.

At each plot, observers count the number of aspen and conifer stems within pre-determined size classes (Table 3); in order to be counted, the stem must have 50% or more of the stem basal area at the soil level, within the 4-m radius plot. For example, if one stem has 60% of its basal area within the 4-m radius plot it is counted. However, if 40% of its basal area is within the 4-m radius plot, the stem is not counted. Conifers shorter than 15 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 if 50% or more of the stem basal area at soil level is 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.

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 dividing by 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 per hectare. 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).

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. Aspen stems that are beyond the reach of browsing animals (~1.7 m) but are not yet mature trees reaching the forest canopy (1.7 – 5 m tall) are considered new regeneration into the aspen population (Bartos and Campbell 1998).

Power Analysis

Power analyses were conducted by UCBN 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% increase and decline over 5 years within each park. The UCBN stand level and park level power analyses are described in detail in Strand et al. (2009).

The stand level power analysis (Strand et al. 2009) helped guide MOJN to select permanent rather than temporary sampling locations to maximize the statistical power and confidence while minimizing the sampling effort. To determine a change in mean of 25% with a confidence of 0.9 and a power of 0.8, 14-15 plots are required in stands of the size 2-3 ha. In other words, a stand of 2-3 ha would need or 3-4 transects (comprised of 4 plots each), in order to meet our desired levels of power and confidence. In the case of temporary plots, number of plots required for the same confidence and power is 60-70, which is unreasonable given cost and time constraints.

Table 4 lists the results of the park level power analysis for the regeneration and mature tree classes based on preliminary sampling (Strand et al. 2009). These results clearly exceed the original goal of detecting a 25% increase or decline over 5 years within each park at a power of 0.8.

Table 4. The power analysis conducted by UCBN in Strand et al. (2009) 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.

Percent Change	Regeneration Class Power	Mature Tree Class Power
-25%	1	1
+25%	1	0.994
-10%	0.816	0.627
+10%	0.745	0.555

We selected the number of plots in each park according to the results of this power analysis. The PARA sample area is comprised of less than 6 ha and will be monitored with 32 plots (8 transects). The GRBA sample area is approximately 31 ha which will be monitored with 160 plots (40 transects). After the implementation years, the number of plots will be revisited to ensure the sampling effort is large enough to adequately address the objectives of this PIP.

Thresholds and Management Support

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 to develop site-specific guidelines for stem density in the sampled size classes in both MOJN parks. Populated with park-specific field data and results from trend analysis, the decision support chart (Figure 3) may act as a guideline for management in the future.

Summary of the Benefits of the Selected Design

- The design follows an NPS aspen monitoring protocol developed and implemented in UCBN parks since 2007. In the future, UCBN and MOJN datasets can be directly compared to broaden the understanding of dynamics within aspen stands in different geographic and climatic regions.
- The design directly reflects the study objectives.
- Simple random placement of transects permits valid inference to the target populations.
- Using 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 minimizes the chance of spatial dependence between plots verified via semivariogram analysis.

- Having a nested sampling design, with plots nested within stands, we can maximize replication within stands; this replication can reduce variance within the sampling unit and help to better understand the population of aspen stands.
- Placement of plots along transects reduces the time it takes to relocate each plot.
- 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

Before starting a field season, the Protocol Lead must complete administrative tasks well before the field season begins. The first preparation is to review procedures of the previous sampling year and revise the protocol if needed based on the experiences and results from the previous sampling period. The Protocol Lead also needs to fulfil permitting and compliance requirements. Both study sites are NPS units, and the Protocol Lead must obtain a permit through the NPS research permit and reporting system (<https://irma.nps.gov/rprs/>). Depending on the MOJN staffing structure, it is likely that this protocol will require hiring seasonal employees for field work. Scheduling with partners should begin as early as possible, but no later than February preceding a spring sampling occasion. The Protocol Lead should maintain frequent, clear coordination with GRBA and PARA staff as well.

The Field Crew and the Protocol Lead will work together to gather necessary field gear and replace any items before the field season starts. SOPs should be thoroughly reviewed by directing staff well in advance of training and field work. GPS devices will be loaded with all permanent plot locations before the start of sampling, and digital data collection devices (if used) will be loaded with the appropriate field forms. Batteries and spare batteries must be charged for all GPS units and electronic devices, including backup units. Paper data entry sheets will also be updated and photocopied. Equipment needs are relatively modest, and once sufficient amounts are purchased, replacement will be infrequent. An equipment list is included in SOP 1.

Locating and Establishing Sampling Transects

Driving directions and procedures for locating transects in PARA and GRBA are included in SOP 3. Maps locating each sampling unit in GRBA and stand in PARA are found in Appendices C (for PARA) and D (for GRBA) of the Aspen Monitoring SOP document (Strand et al. 2018). Spring weather extremes can cause challenging conditions, so all field crew members are required to have warm clothes and rain gear, sun hats, and plenty of water. Summer monsoon rains in GRBA extend from June to August and pose significant risks to data collection; the work days and sampling season will be adjusted accordingly. In both GRBA and PARA, spring conditions in the high country often restrict access to the park by covering passes in snow, therefore the start and end dates of the monitoring season will be variable. 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 crews available. These routes will be illustrated on hard copy maps provided to each crew. The precise location of each plot will 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 MOJN typically allow navigation accuracies of 1-3 m.

Transect starting points will be located using GPS, following procedures outlined in SOP 3. When the crew 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 by placing rebar with an engraved aluminum cap in the ground at the center of

each plot along the transect. The exact location of the permanent marker is recorded with a high accuracy GPS unit (<1 m accuracy), and the location data are differentially corrected (in the office) to maximize accuracy of the coordinates that are stored in the MOJN database; see detailed data management procedures in SOP 5.

The azimuth 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 at different bearings in different stands. GPS is used to locate the plot center of each consecutive plot, 25 m apart from center to center, along the transects. Each plot along the transect is monumented (marked with rebar) and the location coordinates are recorded with high accuracy GPS.

Measuring Vegetation

Vegetation measurement procedures follow those implemented in UCBN parks (Strand et al. 2009). 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 records 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 4. All stems that enter the soil within the plot, 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 as two if the stems are split below ground. Conifer seedlings shorter than 15 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 are recorded during the establishment of the permanent plot, and that same location is used for taking 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 crew during each sampling occasion following recommended procedures outlined by Irwin (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 crew 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 4.

Data Entry and Management

MOJN aspen data are collected on paper data sheets and entered into the MOJN aspen database as soon after data collection as is practical. An example field data sheet is provided in Appendix B of

the Aspen Monitoring SOP document. When MOJN eventually transitions to digital data entry, paper data sheets may still be preferred in cases where volunteers are participating in data collection and project logistics do not allow adequate time to fully train volunteers on use of the mobile field computer and database. Both forms of data collection are relatively straightforward, since the appearance of data entry forms in the electronic 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 crew prior to entry into the field, with crew numbers, transect and plot ID's, azimuths, and UTM coordinates already in place.

The recommended 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 onto paper data sheet
4. Locate the next plot along the transect by moving in the bearing 25 m ahead (details on how to determine bearing are specified in SOP 1).
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.

Paper data sheets (or digital field forms) will be inspected by crew 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 MOJN aspen database, a Microsoft Access application, as soon after data collection as is practical, and will 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 locally by MOJN for at least four years, which will allow sufficient time for all possible QA/QC problems to be resolved.

After the Field Season

Following the field season, equipment will be stored in the MOJN headquarters. Non-electrical equipment, including wire ropes, stakes, rulers, and compasses will be stored in well-marked plastic bins. Some of this equipment may be used by other MOJN protocols, so thorough organization and documentation of equipment is important. Electronic equipment, including GPS units, will be stored in the MOJN headquarters. Batteries will 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 Management

Effective data management is critical to ensuring the quality, interpretability, security, longevity, and discoverability of the data produced by our monitoring efforts. The principles of sound data management as they apply to I&M networks are defined in the national data management guidelines document (NPS 2008b). This narrative will describe in general terms how these principles will be applied to the aspen monitoring effort at MOJN. A detailed set of procedures for all data management tasks can be found in SOPs 5 and 6.

Database Design

The MOJN aspen data will be stored in a MOJN-hosted copy of the Microsoft Access database that is used by UCBN to store their aspen data. The database structure consists of a user interface or “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). Network-specific components of the database such as equipment lookup tables will be populated with information relevant to MOJN. SOP 5 provides additional details about the database, including a model of table relationships and a data dictionary. The database tracks the quality control and quality assurance processes (data processing level) that have been applied to each site visit activity, and will store a “line of sight” to the full package of protocol materials that were in place at the time that the data were collected.

Data Entry, Verification, and Validation

Data Entry

The primary goal of data entry is to transfer the data from paper into the database with 100% accuracy. Ideally, this should be undertaken during the field season in order to provide the best opportunity to correct data omissions or ambiguities. When this is not practical, it should occur as soon after the field season as possible. Data entry should be completed by someone who participated in data collection, or is familiar with the project and data. Database backups will occur regularly to maximize the ability to recover from any irreversible errors or problems that occur during the data entry session.

Data Verification

The aspen database application will incorporate quality assurance/quality control (QA/QC) strategies to ensure data quality. The database design and the allowable value ranges assigned to individual fields within the data tables help to minimize the potential for data entry errors and/or the transcription of erroneously recorded data.

SOP 5 describes the steps that the Protocol Lead and data management staff will take to ensure that the data records within a given season’s dataset are verified (i.e., database values are compared against hard-copy data sheets). The goal is to check 100% of records, and correct and track any errors discovered. Errors and inconsistencies that cannot be corrected will be documented and included in the metadata and certification report. The completion of data verification and other QA processes will be tracked in the database.

The Protocol Lead or Data Manager will verify the geospatial component of the aspen database each field season.

When data verification is complete, the dataset has reached the “provisional” data processing level. The data processing levels referred to in this document are more fully described in *Certification Guidelines for Inventory and Monitoring Data Products* (National Park Service 2016).

Data Validation

The Protocol Lead and data management staff collaboratively validate a given season’s dataset (i.e., ensure that the data make sense). Some validation methods that check for outliers, missing values, and illogical values have been incorporated into the database. Other, more specific, validation routines are developed in collaboration with the Protocol Lead and will be incorporated into the database as appropriate. Data management staff will work closely with the Protocol Lead to provide any needed database queries, reports, graphs, or export file formats to assist with the overall validation.

Data Certification and Documentation

Once the data are validated, the Data Manager and Protocol Lead will complete the necessary accompanying metadata. Metadata is defined as structured information about the content, quality, condition, and other characteristics of a given dataset. Additionally, metadata provide the means to catalog and search among datasets, thus making them available to a broad range of potential data users. Any records that did not meet the documented quality standards in the validation process must be clearly identified in the metadata.

When this process is complete, the dataset has reached the “accepted” data processing level and is suitable for reporting and distribution.

Data Distribution

Prior to publication of any reports or data, MOJN I&M staff will work with a staff member from each park represented in the dataset to complete a data sensitivity assessment form. The results of this assessment will dictate the appropriate audience for the data: Park only, NPS only, or Public. Redacted datasets and reports may be created when it is deemed that sensitive information should be obscured for one or more of these audiences. The sensitivity or “protected status” of species and location data will be tracked in the database following the guidance in the IMD document *Minimum Standards for Network Projects* (Frakes and Kingston 2017).

As part of the reporting cycle, summary reports and derived data products will be made available on the IRMA Data Store (<https://irma.nps.gov/DataStore/>). Additionally, pertinent species data will be uploaded to the National Invasive Species Information Management System and NPSpecies.

Data Maintenance and Archiving

Secure data archiving is essential for protecting data files from loss or corruption. Once the master project dataset and metadata are considered final for a field season, the Data Manager will place a copy of the dataset and the metadata record into the appropriate folder within the archive directory on the MOJN M drive (a shared network server), which is backed up to a remote location. These

archived files will be stored in read-only format. Any subsequent changes made to this database must be documented in an edit log and in the metadata. In addition to the database copy in its native format, all tables will be archived in a comma-delimited ASCII format that is platform-independent. A full copy of the project master dataset will be uploaded to the IRMA Data Store on an annual basis.

Additional digital files to be archived include all digital photos associated with that field season and any digital files associated with data analysis products and project reporting. Hard-copy materials (e.g., data sheets, field notebooks) are currently stored in the Network office but will eventually be moved to an NPS-approved repository for permanent storage.

Any changes made to archived data must be documented in an edit log. Edit log entries must include the original value, the updated value, and a detailed description of why the change was made. This ensures that there are no unexplained discrepancies between the original data sheets and the archived data, or between different versions of archived datasets.

Data Analysis and Reporting

Data Analysis

This section provides an overview of the data analysis and reporting procedures for this protocol. Greater detail on all of these procedures is provided in SOP 6.

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 ($n = N$) for PARA. 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 four plots per transect 25 m apart—this makes the transect 75 m long. A detailed description of the data summary can be found in Strand et al. (2009).

Status results will be summarized after each year of data collection. Standard summary statistics 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 5) and conifer density (Table 6) 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 5. Example of summary table for aspen stem density. Aspen stem counts by stand and the average number of stems/ha 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

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

Stand #	Suckers (stems/ha)	Regeneration (stems/ha)	Mature (stems/ha)	Dead (stems/ha)
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	2,644	1,837	493	212

Table 6. 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 2024 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 become available (i.e., after three sampling periods), the trend analysis will be conducted using a linear regression design to evaluate trajectories.

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 will:

- 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 2024) 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 methods that affect data quality and interpretability.
- Evaluate and identify suggested or required changes to the protocol.
- If requested by the MOJN program manager or parks, a 1-2 page resource brief will be prepared from the annual report that will be provided to superintendents, resource managers, and park interpretive staff. The MOJN Science Communications Lead will provide the current resource brief template.

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 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:

<https://www.nps.gov/im/publication-series.htm>.

Current versions of the protocol, resource briefs, and annual and 5-year technical reports will be made available on the MOJN website (<https://www.nps.gov/im/mojn/index.htm>). The protocol and reports will also be available from the national Natural Resource Publications Management website (<https://www.nps.gov/im/reports-nrr.htm>).

Protocol Testing and Revision

This protocol was tested in UCBN parks in 2006, and long-term monitoring was implemented in those parks in 2007. Revisions and updates will be implemented as this protocol is implemented in MOJN parks. These field experiences and the analysis of data collected at MOJN parks will be instrumental in forming recommendations for training, plot location, database design, measurement calibration, sample sizes, power analysis, and trends analysis in the future. Protocol testing will occur during each field season, and evaluation of existing procedures and recommended revisions will be documented in annual reports and during season close-out. It is desirable to maintain compatibility

between the UCBN and MOJN sampling and analysis procedures, and proposed changes should be communicated between the two NPS networks.

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, other remote sensing methods, or field reconnaissance. The stand boundary will be adjusted for stands that have expanded into adjacent vegetation. 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 to this protocol will be carefully documented using the procedures outlined in SOP 5. In addition, revisions to the SOPs will be documented using the revision history log found at the beginning of each SOP.

Personnel Requirements and Training

Personnel Requirements

This monitoring project requires, at a minimum, participation and leadership from the Project Leader (currently the MOJN Ecologist) and the MOJN Data Manager, as well as a skilled field crew leader who 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 (Roles and Responsibilities). Additional assistance from park and Network technical staff and summer volunteers will ease the annual workload generated by this effort and ensure a high quality information product.

Field crews will consist of groups of two to three individuals, a crew leader, and one or two assistants. Field assistants must be able to work outdoors, learn GPS and data entry, and identify plants. Crew leaders must have these skills, as well as an understanding of project objectives and prior experience with field work and GPS. Field assistants can be MOJN staff, park staff, or 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 long-term monitoring of aspen requires careful counting of stems in pre-determined size classes. During field data collection in UCBN parks (2007-2017), UCBN staff 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 Project Leader 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. Volunteers or high school groups working only a day or two are not recommended for counting aspen stems as part of the sampling; however they can be very helpful in navigating to permanent plot markers. It is important to provide field assistants or volunteers with preliminary exposure to the program objectives, ecological and cultural background, and some opportunity to practice field methods before arriving on site.

During monitoring in UCBN parks, UCBN staff observed that counting stems within one plot is usually completed within 15 minutes; in plots with dense aspen or in difficult terrain, counting may take longer. In GRBA, we plan to implement approximately 30 transects, 15 in each vegetation alliance group (Figure 4). Each transect contains four plots, leading to 120 plots total, amounting to 30 hours of sampling. Maximum travel time to the start of each transect is 2 hours, amounting to a maximum 60 hours travel time. Travel time between plots in a transect and searching for permanent markers is estimated at 20 hours. These estimates result in 80-110 hours total sampling time in GRBA in a field season, i.e. 2-3 weeks depending on the travel time and weather. During the first sampling event in GRBA, the number of transects can be adjusted to reflect the time that MOJN plans to allocate to aspen monitoring. If additional transects are desired, additional sampling time could be allocated to aspen monitoring in GRBA, or the sampling could be divided into two data frames that are sampled in different years. As a comparison, in the UCBN parks, 2 weeks of field sampling time is allocated for each field season.

In PARA, eight aspen stands have been identified. We plan to implement one transect (a transect is comprised of four plots) in six stands and two transects in one stand (the largest stand), resulting in eight transects with 32 plots (refer to Table 1). Therefore, we estimate approximately 8 hours of stem counting and 14-20 hours of travel time to the transects and 8 hours of travel time between plots along transects, resulting in a total time allocation of 30-36 hours. Including the travel time to PARA from the MOJN headquarters, one week of sampling will likely be sufficient in PARA.

Roles and Responsibilities

Table 7 describes all roles and responsibilities required to implement this PIP.

Table7. Roles and responsibilities for implementing the aspen monitoring program in the MOJN. Current or anticipated staff and volunteers for 2018 are named here.

Role (Name/Position)	Responsibilities
Project Leader (MOJN Ecologist)	• 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
Field Leader (MOJN Ecologist or staff)	• Train and ensure safety of field crews • 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
Technicians (Seasonal crews, volunteers, MOJN or park interns)	• Collect, record, enter and verify data
Data Manager (MOJN 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

Table 7 (continued). Roles and responsibilities for implementing the aspen monitoring program in the MOJN. Current or anticipated staff and volunteers for 2018 are named here.

Role (Name/Position)	Responsibilities
GIS Specialist (MOJN Data Manager and Project Leader)	• 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
Network Coordinator (MOJN Program Manager)	• Project Leader oversight • Administration and budget • Consultant on all phases of protocol review and implementation • Review of annual reports for formatting and completeness
Park Resource Managers (GRBA and PARA resource management staff)	• Consultant on all phases of protocol review and implementation • Facilitate logistics planning and coordination • Communicate management and restoration plans and associated information to Project Leader • Review reports, data and other project deliverables

Training and Calibration

All field crew staff 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 crew leader, the crew will be split into two groups to practice locating and setting up transects and plots and taking measurements. Each group will measure the other groups' plots to ensure measurements are consistent. Calibration will continue until both groups are consistently counting within 5% of the "true" value (or 1 stem in plots with very low stem count), as established by precision within successive counts, or, if necessary, as established by the Project Leader. Experience from implementation of aspen monitoring in UCBN parks 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 observed that precision and reproducibility in data collection is not reached until all crew members have collected data under the supervision of the Project Leader or an experienced field lead for 1-2 days. Each aspen plot is different, and crews must master the classification of stems into the five live stem classes and dead stem class before reproducibility is reached. Consistency in field crew 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 round for aspen monitoring begins with the recruitment of field staff each January/February. By this time, final reporting, review, and close-out activities should be concluding for the previous year's monitoring efforts. 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-September. 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. Table 8 provides a summary of the annual schedule.

Table 8. Annual schedule of major tasks and events for the MOJN aspen monitoring protocol.

Month	Administrative	Field	Data Management
January	MOJN annual report and work plan complete, Begin recruiting and hiring MOJN seasonal personnel	Hire seasonal staff and schedule field visits, housing, and vehicles	–
February	Administrate and modify existing agreements, if necessary	–	–
March	–	–	–
April	–	Prepare maps and field data sheets (or digital field forms)	–
May	–	Prepare field and GPS equipment	–
June	–	Begin training and field work (will vary slightly due to weather)	–
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	Complete field season report	Preliminary analysis of current year's results Annual resource brief prepared for MOJN Science Advisory Committee meeting
October	MOJN annual report and work plan drafted	–	Data certification complete Data archival and posting

Table 8 (continued). Annual schedule of major tasks and events for the MOJN aspen monitoring protocol.

Month	Administrative	Field	Data Management
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 Complete close-out

Equipment Needs

Equipment needs are modest for this protocol. The list of equipment is included in Table 9, and instructions for preparing and organizing field equipment are included in SOP 1. All hardware materials have been purchased and are stored at the MOJN headquarters. 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 in GRBA both in the backcountry and at established campgrounds. To use established campgrounds, prior arrangements with the Park must be made to ensure that camp sites are available during the weeks of field sampling. In PARA, camping is dispersed. However, alternative housing may also be arranged. For example, the Nixon cabins at PARA can be reserved via the BLM office in St. George. MOJN might provide some camping gear (tents, sleeping bags, sleeping pad, and stove), and field staff is expected to provide additional necessary personal camping gear.

Table 9. Equipment list for monitoring aspen populations in the MOJN.

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 sheets	–
Orienteering compass	Backup copies of data sheets	–
Clinometer or laser range finder	Mechanical pencils and clipboards	–
Plant ID books	Mobile field computer with MOJN Aspen database loaded	–
Hard copies of SOPs	Metal detector	–

Budget

The budget in Table 10 demonstrates that adequate resources have been allocated to data management, analysis, and reporting activities.

Table 10. The approximate annual budget for aspen monitoring in the MOJN. This budget does not include equipment costs because existing equipment will be used.

Personnel Type	Position or Expense Type	Time Allotted (Cost in Dollars)
Permanent NPS Personnel	Network Program Manager (GS13)	1 week report review, hiring, and training (\$2,360)
	Data Manager (GS11)	1 week database maintenance and preparing field data collection device (\$1,600) 1 week field season prep (\$1,600) 1 week QA/QC, data archiving and close-out (\$1,600)
	Ecologist (GS11)	1 week hiring and training (\$1,600) 1 week sampling (\$1,600) 1 week analyzing data and report writing (\$1,600)
	Crew Lead and Logistics Coordinator (GS07)	1 week preparing and training (\$1,120) 3 weeks field work (\$3,360) 1 week season closure (\$1,120)
Seasonal Personnel	Field Technician 1 (GS05)	3 week sampling (\$2,400) 1 week data input and QA/QC (\$800)
	Field Technician 2 (GS05)	3 week sampling (\$2,400) 1 week data input and QA/QC (\$800)
Total Cost		\$23,960

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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.

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