



Grassland Monitoring Protocol for the Southern Plains I&M Network and Fire Group

Narrative Version 1.00

Natural Resource Report NPS/SOPN/NRR—2017/1568



ON THE COVER

Blue grama grass (*Bouteloua gracilis*). Photograph by: Dawnelle Malone

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1. Background and Objectives

1.1. Issues Being Addressed and Rationale

The parks of the Southern Plains Network (SOPN) are dominated by mid- and shortgrass prairies that have been impacted by grazing, fire suppression and rowcrop agriculture. Individual restoration efforts of varying techniques and duration have been employed in the past in most of these parks with mixed results. Monitoring of these efforts has been minimal. This grassland vegetation monitoring protocol has been developed to inform park management of the status and trends of the overall health of their grasslands and to provide some information on the effectiveness of restoration efforts. Collaboration with the Southern Plains Fire Group (SPFG) fire effects monitoring program has been developed to address broader issues of vegetation health and to achieve economic efficiencies in both programs. This protocol reflects this collaboration.

North American prairie once extended across the mid-continent region from Canada to Texas and from the Rocky Mountains to the Appalachian forest. The vast landscape was nearly continuous grassland, transitioning gradually from shortgrass steppe in the west to tallgrass prairie and savanna in the east. During the last century, large portions of grassland landscapes were plowed for cropland or converted to livestock pasture. Today, Great Plains grasslands are fundamentally altered by the conversion of prairie to cropland and pasture, the removal or disappearance of native ungulates, drainage of wetlands, and an increase in woody vegetation through plantings and fire suppression. Scientists estimate that the loss of native prairie ranges from 80 to 99.9%, with the greatest losses occurring in the tallgrass prairie and oak savanna communities. Further, only 71% of shortgrass prairie and 59% of mixedgrass prairie remain (Knopf and Samson 1997). Fragmentation and isolation continues today at an alarming rate.

The nature of the above-ground plant community (e.g., the diversity of species and

functional guilds) plays an important role in determining the stability or resistance to disturbance of a prairie system (Wardle et al. 2000). Prairies are dominated by a few matrix-forming grass species that effectively control community structure. A large number of less abundant species, referred to as satellite species, contribute to the diversity of prairie systems (Collins 1987, Collins and Glenn 1988, Collins and Glenn 1990). Distribution patterns of these satellite species are inherently bimodal, varying within and between growing seasons (Collins and Glenn 1988, Collins and Gibson 1990).

Ecological driving forces such as fire and the presence of native faunal species including bison (*Bos bison*), elk (*Cervus elaphus*), and wolves (*Canis lupus*), remain largely absent from prairie systems, having been eliminated or placed under human control. Domesticated animals have replaced only some of the services once supplied by these drivers and most parks in the southern Plains do not currently allow grazing. This change in grazing regime can lead to changes in plant community structure and nutrient cycling.

Fire frequency and seasonality plays a large role in the ecology of the Great Plains. Frequent fire is essential to maintaining native species diversity, and it affects other components, including nutrient cycling and productivity (Collins and Wallace 1990). Historically, lightning and Native Americans were the principal causes of fire. SOPN parks generally average between 40 and 50 days with thunderstorms per year (Bryson and Hare 1974) and fire ignited by summer storms occurred May through September (75% of these between July and August) when storms are most common (Bryson and Hare 1974). In the southern mixedgrass prairie, Native Americans appeared to use fire most frequently in July and August (Moore 1972). The southern mixedgrass prairie has slow litter accumulation and fires probably occurred every 3 to 10 years (Umbanhowar 1996) due to slow litter accumulation. In shortgrass, fires were less frequent, although they were reported from early travelers and were still an ecological driver of the system

(Brockway et al. 2002). The majority of SOPN parks have developed fire management plans and implemented prescribed burns over the past decade, although during extended droughts, many parks employ an alternative (mechanical) control of fuel load.

Long-term ecological monitoring, while contributing to our empirical understanding of prairie communities, is integral to the proper management and protection of the lands entrusted to the National Park Service (NPS). Park resource managers require an effective plant community monitoring protocol to assess their management strategies in maintaining and/or restoring prairie plant community composition, structure, and diversity. Our monitoring strategy attempts to balance the immediate needs of managers for current information and the need for insight into the changes occurring in vegetation communities over time.

1.2. Measurable Objectives for the Grassland Monitoring Protocol

SOPN has developed the following objectives for grassland vegetation monitoring:

1. Determine status and trends in plant species composition (richness and diversity) and community structure (relative abundance, frequency, distribution, ground cover) of remnant, disturbed and/or restored grasslands

Justification: In the Great Plains, grasslands have been converted to agricultural land and urban areas, their hydrology has been altered, and they have been degraded due to overgrazing, increased land fragmentation, fire suppression, and exotic species invasion. Changes in the vegetation communities can lead to subsequent changes in the faunal communities and natural processes. Land fragmentation, exotic species, and altered fire regimes with subsequent invasion by native woody species are major threats to SOPN grasslands. Land fragmentation can increase the chances of exotic plant species invasion and alters landscape-scale processes including species immigration and emigration in SOPN grasslands. Exotic plants can greatly alter ecosystem processes and displace native communities. Moreover,

even native woody species such as Eastern red cedar, mesquite, Ashe juniper, piñon pine and juniper represent a threat to SOPN parks as they invade/encroach and convert native grasslands to wood- and shrublands.

2. Determine relationship between status and trends of species composition and community structure and environmental variables including such things as long-term management actions, climate, and atmospheric deposition.

Justification: The structure of the vegetation is a primary identifying characteristic of the ecosystem; changes in structure may be rapid or gradual and are indicative of ecologically important trends. In addition, grassland vegetation structure can be used to evaluate the effectiveness of management practices (prairie restoration, grazing, and fire).

1.3. Overview of Vegetation and Monitoring at Southern Plains Parks

The Southern Plains Inventory and Monitoring Network (SOPN) is composed of 11 National Park Service (NPS) units: Bent's Old Fort National Historic Site (BEOL) and Sand Creek Massacre National Historic Site (SAND), Colorado; Fort Larned National Historic Site (FOLS), Kansas; Capulin Volcano National Monument (CAVO), Fort Union National Monument (FOUN), and Pecos National Historical Park (PECO), New Mexico; Chickasaw National Recreation Area (CHIC) and Washita Battlefield National Historic Site (WABA), Oklahoma; and Alibates Flint Quarries National Monument (ALFL), Lake Meredith National Recreation Area (LAMR), and Lyndon B. Johnson National Historical Park (LYJO), Texas (Figure 1-1). Park units within the SOPN are located in shortgrass and mixedgrass ecosystems, and range in size from 326 acres (WABA) to 46,349 acres (LAMR).

The Southern Plains Fire Group (SPFG) is responsible for the majority of these same parks and is headquartered at LAMR. Four parks of the SOPN are overseen by other fire groups: FOUN and PECO are under the Bandelier Fire Group, LYJO under the Big Thicket Fire Group, and FOLS under the Midwest Region.

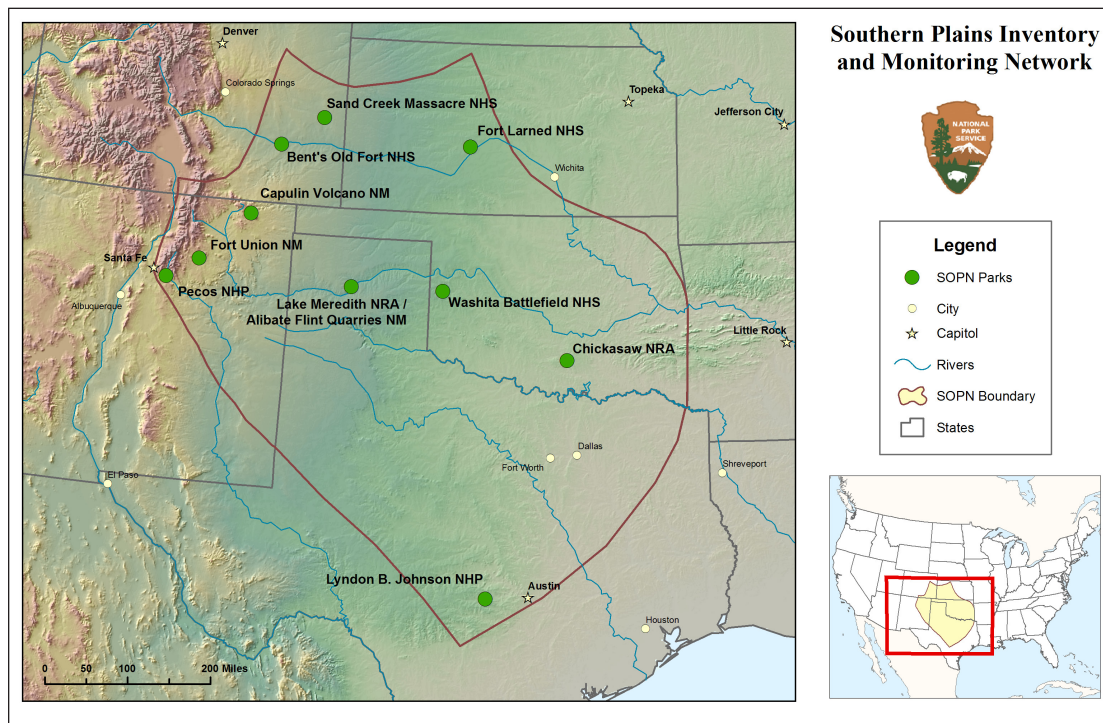


Figure 1-1. The Southern Plains Inventory and Monitoring Network.

CHIC, FOLS, LYJO, and WABA are in mixedgrass prairie or savannah. ALFL, BEOL, CAVO, FOUN, LAMR, and SAND are located in shortgrass prairie, and PECO is in the ecotone between shortgrass prairie and piñon-juniper forest. At a finer scale, the SOPN parks can be placed in six different vegetative zones or biomes (Küchler 1986, Omernik 1987, Bailey 1995). The SOPN has a wide range of soil orders present, including dry mollisols through central Texas, central Oklahoma, and central Kansas; wet mollisols in the vicinity of CHIC; entisols and aridisols in southeastern Colorado; and aridisols and alfisols in northeastern New Mexico.

Alibates Flint Quarries NM

Alibates Flint Quarries National Monument (1,371 acres [555 ha] in size and adjacent to LAMR) was created in 1965, to preserve the extensive flint quarries that were once used by prehistoric humans as a source of raw material for weapons and tools. ALFL also protects the ruins of several village sites of the Plains Village Indians, who inhabited the area circa 1200–1450 A.D. The land surface at ALFL is nearly flat and slopes to the southeast at approximately 8 to 10 feet (2.4 – 3 m) per mile. In the vicinity of Lake Meredith, this flat surface has been downcut by the Canadian River and its tributaries, causing canyons or “breaks”, some of which are now filled

by Lake Meredith. The Alibates Dolomite is Permian in age and contains an abundance of flint, which was used by some of the earliest humans to make tools and points. The flint can often be found in alternating beds of gray and red. The Canadian River Basin climate is characterized as semi-arid with an average annual rainfall of 20 inches (51 cm) per year. Seventy percent of the precipitation falls between April and September, which is the primary growing season. This area has hot summers and cold winters with strong winds that work to increase evaporation rates, which have been estimated to average 60-65% of the total precipitation. Elevation is approximately 3,200 feet (975 m).

A total of 486 species have been documented and supported by vouchers from ALFL and LAMR (Wright and Meador 1981, Nesom et al. 2005). Vegetation at ALFL is dominated by yucca grassland (36%), vegetated cliffs (34%), mixedgrassland (18%), mesquite grassland (8%), and mixed forest (3%) (Lake Meredith National Recreation Area 2002). Bell et al. (2000) also provides a list of plant species from ALFL but it is un-vouchered. Bell and Coffman (2000) identified a number of major introduced plant species at ALFL. There are no known endangered or threatened plants within the boundaries of the parks. Prescribed burning has not yet

been applied to the grassland at ALFL and no vegetation monitoring has taken place.

Bent's Old Fort NHS

Bent's Old Fort National Historic Site covers 799 acres (323 ha) along the Arkansas River in southeastern Colorado. The original adobe fort was constructed in 1833, to serve as a trade center on the Santa Fe Trail and became a staging area for the U.S. Army during the U.S.–Mexican War in 1846. The fort was abandoned in 1849, and established as a national historic site in 1960. BEOL is situated on a series of low terraces along three miles of the Arkansas River, within the Great Plains-Palouse Steppe ecological province and the short-grass prairie ecoregion Ladyman (2003). This part of the Central Short-grass physiographic region is dominated by Buffalo grass (*Buchloe dactyloides*) and blue grama grass (*Bouteloua gracilis*). Temperature and rainfall reflect seasonal patterns at BEOL. The average maximum temperature from June to August is 91°F (32°C), while the average minimum temperature from December to February is 15°F (-9.5°C). Annual precipitation averages between 11 and 15 inches (28 to 38 cm). Approximately 70 percent of the precipitation falls in April through August and only about 10 percent falls in November through February.

In a 1986 assessment of prairie, James Stubbendieck estimated that approximately 638 acres of Bent's Old Fort National Historic Site was in various successional stages leading to short-grass prairie (Stubbendieck and Wilson 1986). A 2003 restoration management plan (Ladyman 2003) determined that approximately 124 acres (50 ha) were upland prairie, 271 acres (110 ha) were riparian grassland and 300 acres (121 ha) were riparian shrub- and grasslands recovering from tamarisk invasion. Grazing by livestock used in cultural interpretation still occurs (Ladyman 2003). Prairie restoration efforts continue at BEOL. Ladyman's (2003) restoration plan states that all grasslands had varying amounts of the exotic plants, including several listed on Colorado's noxious plant list. Prescribed fire has been used at BEOL since 2002, while vegetation monitoring has been sporadic.

Capulin Volcano

Capulin Volcano National Monument was established to preserve a volcanic cinder cone that formed more than 60,000 years ago. The park includes 793 acres (321 ha) in northeastern New Mexico. CAVO receives 16–20 inches (41 - 51 cm) of rain annually. The average annual temperatures range from 35°F to 62°F (2–17°C). Average maximum temperatures for June to August is 78°F (25.5°C), while average minimum temperatures for December to February is 19°F (-7°C). Reaching an elevation up to 8,182 feet (2,494 m), Capulin Volcano is a cinder cone primarily covered with piñon-juniper woodland and surrounded by shortgrass prairie. CAVO is located in the Arkansas Tablelands section of the Great Plains-Palouse Dry Steppe ecoregion.

Six communities are identified by Natural Heritage New Mexico's (NHNM) Vegetation Community Classification system are crater grassland, disturbed grassland, piñon-juniper, lowland grassland, gamble oak and ponderosa (Johnson et al. 2003). No threatened or endangered plants were located during the field survey conducted by NHNM in 2002. Two hundred and fortythree species (92%) of the 255 potential species were documented, including twenty-two introduced plant species (Johnson et al. 2003). An assessment of the condition of the prairie and recommendations given for management were completed by Stubbendieck and Wilson (1986). A newly instituted Fire Management Plan has introduced prescribed burning to the park. Fire effects monitoring has taken place since 2005, but no other vegetation monitoring has occurred.

Chickasaw NRA

Chickasaw National Recreation Area comprises 9,889 acres (4,002 ha) in south-central Oklahoma. In the late 1800s, the Chickasaw and Choctaw Native American tribal units recognized threats to the freshwater and mineral springs in this area and, consequently, requested that the federal government establish sustainable management practices (Wikle et al. 1998). The juncture of the southern Osage Plains and the Arbuckle Mountains in south-

central Oklahoma is a transitional ecotone of Eastern deciduous forest and the Western prairies. Although much of Chickasaw National Recreation Area is in the Arbuckle Mountains physiographic province, the northwestern portion of CHIC is a transitional area to the low rolling hills of the redbed plains (Hoagland and Johnson 1999). The topography of the park is moderately rolling with several steep bluffs in the northern portion and level terrain on the upland areas in the southern portion. Elevations range from 872 feet (266 m) at Lake Arbuckle to 1,082 feet (330 m) at Mount Airy (Chickasaw National Recreation Area 1999). The park is located in the Subtropical Humid climate zone (Hoagland & Johnson 2001), resulting in a warm continental climate. Summers are hot and humid, with an average maximum temperature June–August of (91°F [33°C]) and prevailing winds from the southwest. Winters are mild with an average minimum temperature December–February of (28°F [-2°C]). Snowfall is light and lasts only a few days, resulting in a relatively dry season. Average annual precipitation is 38 inches (97 cm), with 70% falling during the warm months predominately from thunderstorms. Damaging hail is common and tornados not unusual (Chickasaw National Recreation Area 1997).

Mixed grasslands (primarily *Schizachyrium scoparium*–*Sorghastrum nutans*) and oak forests cover a large portion of the upland areas, while riparian vegetation dominates the lowlands. There are no federally threatened or endangered plant species known to exist in the recreation area (Chickasaw National Recreation Area 1999). Oklahoma Biological Survey documented 582 taxa during an inventory in 2000 and noted there was a floristic affinity with the Edwards Plateau. Ten species are tracked by the Oklahoma Natural Heritage Inventory. Grazing was allowed throughout much of the park until 1986 (Chickasaw National Recreation Area 1997) but continues today only within a fenced pasture containing reintroduced bison (Chickasaw National Recreation Area 1999). Vegetation management using prescribed fire began in 1998 in an effort to restore habitat health (Chickasaw National Recreation Area

1999) and is the only vegetation monitoring that has taken place.

Fort Larned NHS

Fort Larned National Historical Site encompasses 718 acres (291 ha) along the banks of the Pawnee River, most of which falls within the Pawnee River floodplain. Fort Larned, originally established to protect traffic along the Santa Fe Trail, became a key U.S. military base during the Indian Wars. FOLS is located in the South-central Great Plains section of the Great Plains Steppe Ecological Province at an elevation of approximately 2000 feet (610 m). FOLS has a semi-arid continental climate, generally west of the flow of Gulf moisture and east of the Rocky Mountain rain shadow (Becker et al. 1986), with changeable temperatures and precipitation. The average maximum temperature of 89°F (31.5°C) June through August is made more bearable by a constant breeze and low humidity. The dry season of winter brings average minimum temperatures of 19°F (-7°C) December through February. Snowfall averages 20 inches (51 cm) annually and seldom persists longer than three days after a snow event (Becker et al. 1986). The average annual precipitation nears 23 inches (58 cm), with most of the moisture falling from intense thunder storms August through October. Winds are constant with only rare periods of calm (National Park Service 1979). The detached Trail Ruts unit is found on gently rolling uplands 4.5 miles (7.2 km) southwest of the Fort unit.

It is estimated that at least 400 acres (162 ha) (60%) of FOLS is considered grassland habitat (Becker et al. 1986). Both units lie on the western edge of the mixed grass prairie region of Kansas, characterized by grama grasses (*Bouteloua* spp.), buffalograss (*Buchloe dactyloides*), big bluestem (*Andropogon gerardii*), indian grass (*Sorghastrum nutans*) and associated species (Choate et al. 1998). The Trail Ruts unit, while never plowed, has had its original prairie vegetation heavily impacted by grazing and prairie dogs. It is estimated that 76% of FOLS is formerly cropped grassland that has undergone continuing prairie restoration since 1964 (Delisle and Busby 2004). There are no known federally threatened or endangered plant or animal

species at Fort Larned. Prairie restoration at FOLS began in 1968. The management tool of mowing was augmented in 1983 by the onset of prescribed burning (Stubbendieck and Willson 1986). FOLS falls outside of the Southern Plains Fire Group, requiring that SOPN monitor grasslands independently or form a collaboration with the Midwest Region Fire Group.

Fort Union NM

Fort Union National Monument (721 acres [292 ha]) was established in 1956, to preserve and protect the mid-19th century fort situated on the Santa Fe Trail in New Mexico. The monument, at an elevation of 6,800 feet (2,073 m), is located in a wide valley of Wolf Creek, on the southwestern fringe of the Great Plains. Annual precipitation is 16-20 inches (41 - 51 cm), with the majority of rain falling from May to September, results in a semi-arid climate with notable periods of wind (Muldavin et al. 2004). Fort Union is in a region of the heaviest thunder and lightning regions in the nation (Fort Union National Monument 2000). Temperatures range from an average high of 80°F (27°C) from June to August to an average low of 14°F (-10°C) for December to February, with daily temperature fluctuations of 30°F (16.8°C) or more.

FOUN is located in the southern parks and ranges section of the Southern Rocky Mountain Steppe ecoregion. An assessment of prairie carried out by Stubbendieck and Willson (1986) classified the majority of the monument as native prairie “in excellent condition,” with blue grama as the dominant grass, thought to be similar to conditions of 1884. A more recent survey of vegetation by Natural Heritage New Mexico in 2004 described the plant life at FOUN as relatively diverse, with the shortgrass prairie still dominant yet reflecting the impacts of historic use. Drought was prevalent during the three summer seasons of this survey, resulting in the identification of 142 taxa, 16 plant associations and 11 alliances. The vegetation survey carried out by Natural Heritage New Mexico found only twelve species they considered “non-native alien introductions,” with none posing significant threats to native species (Muldavin et al.

2004). Lack of grazing on these prairies, while initially beneficial, may now limit range improvement. FOUN continues to be surrounded by a 96,000-acre (38,850 ha) cattle ranch that pre-dates the 1891 closure of the fort (Johnson et al. 2003a). The reintroduction of fire into this grassland is not feasible at this time. No vegetation monitoring has been carried out at FOUN in the past.

Lake Meredith NRA

Lake Meredith was formed in the 1962, when the U.S. Bureau of Reclamation constructed the Sanford Dam on the Canadian River. LAMR was designated as a national recreation area in 1990, at which time its management was transferred from the U.S. Bureau of Land Management to the NPS. LAMR, covering 46,349 acres (18,757 ha), is located on the High Plains of the Llano Estacado, specifically along the Breaks created by the Canadian River as it meanders west-east across the Texas Panhandle. Much of LAMR is in the category “Rough Broken Land” that can be divided into Mesa Top, Gravelly Slope, Steep Slope, and Bottomland. This area of Texas is comprised of gently rolling to moderately rough topography. Narrow, intermittent stream valleys flowing east to southeast dissect it. The Canadian River Basin climate is characterized as semi-arid with an average annual rainfall of 20 inches (51 cm) per year. Seventy percent of the precipitation falls between April and September, which is the primary growing season. This area has hot summers and cold winters with strong winds that work to increase evaporation rates, which have been estimated to average 60-65% of the total precipitation. The elevation ranges from 2800 to 3320 feet (853-1,012 m).

A total of 486 species have been documented and supported by vouchers from the park (Wright and Meador 1981, Nesom et al. 2005). An earlier plant list by Phillips (1997) lists 516 species but there are no voucher specimens to support the list, and Nesom et al. (2005) estimated that 59 of these species were unlikely to occur at LAMR. Much of the terrain surrounding the parks consists of flat grasslands. The predominant vegetative cover is comprised of blue grama (*Bouteloua*

gracilis), little bluestem (*Schizachyrium scoparium*), and buffalo grasses. Nesom et al. (2005) detected 47 exotic species, from the park based on vouchered specimens. There are no known endangered or threatened plants within the boundaries of the parks. Prescribed fire has been used at LAMR since 1998.

Lyndon B. Johnson NHP

Lyndon B. Johnson National Historical Park preserves the birthplace, boyhood home, ranch, and final resting place of the 36th president of the United States. The two districts of LYJO, one consisting of the LBJ Ranch and the other of properties in Johnson City, Texas, total 674 acres (273 ha). The park is classified as southwest plateau and plains dry steppe and shrub according to Bailey (1994). Elevations range from 1190 to 1565 feet (363-477 m). The subtropical, subhumid character of the Edwards Plateau results in a sunny, mild climate, except for summer's high humidity and 100°F (38°C) temperatures. Winter temperatures are usually in the 50s°F (10°C); snow and ice are rare. Annual precipitation averages about 32 inches (81 cm), with May and September the wetter months and November, December and January the driest months. LYJO lies in the Hill Country of south-central Texas, and has a landscape of forested hills and grasslands.

The majority of the Ranch District is managed as improved range with exotic plant species. The Johnson City District has approximately 39 acres that can be classified as prairie or semi-natural prairie (Stubbendieck and Willson 1986), however these areas also contain a large number of exotic species. Two floristic inventories have documented 609 native and cultivated species (including distinct varieties, cultivars, and hybrids) occurring (Sanders and Gallyoun 2004, Sanders 2005). The first intensive inventory was conducted in 2002 and was completed at the end of a drought. An additional 2005 inventory was done in a year with normal or slightly above normal precipitation and documented 51 additional species. Sanders (2005) documented two new introduced naturalized species that had not been reported from Texas. Prescribed

burning at LYJO has been determined to be inappropriate at this time. LYJO falls within the Big Thicket Fire Group, requiring that SOPN monitor grasslands independently.

Pecos NHP

Pecos National Historical Park (6,670 acres [2,699 ha]) was designated in 1965, to preserve an exceptional cultural and natural area with a long human history. Paleo-Indians, archaic people, basket makers, and Puebloan peoples all left evidence of early use in the valley, followed by Spanish and Anglo settlement. Most of PECO lies in the upper Pecos River valley. This narrow valley is bordered by the 13,000-foot (3,962 m) Sangre de Cristo Mountains to the north, the rugged hills of the Tecolote Range to the east, and the steep Glorieta Mesa to the west. The 8,200-foot (2,499 m) Glorieta Mesa escarpment is the most prominent geologic feature in the area, rising abruptly above the 7,000-foot (2,134 m) valley floor. Annual precipitation varies from 16 to 20 inches (41-51 cm) per year, with the majority falling during the summer season. Temperatures range from an average high of 80°F (27°C) June to August to an average low of 15°F (-9°C) December through February. The spring season tends to be windy. The southern Rocky Mountain Steppe geographic province, southern parks and ranges ecoregion gives way to the Mexican Highlands in this area, producing a climate and vegetation unique for this elevation.

Major habitats found within PECO include riparian corridors, grasslands of old pastures, and predominant piñon/juniper woodland (Parmenter and Lightfoot 1996). Approximately 40 acres (of the original monument) is classified as Grama-Galleta Steppe prairie. A vegetation survey conducted by PECO between 1992 and 1994 resulted in 354 species of vascular plants, 57 of which were exotics (Reed et al. 1999). There are no threatened or endangered plants or animals documented at PECO. Grazing generally ceased in June 1967 when the boundary fence was completed. The 64-acre core of the monument has been closed to grazing since the 1940s, while the newest acreage was protected from grazing in 1978 (Stubbendieck and Willson 1986). Naturally occurring fire

has been suppressed for at least 50 years but a prescribed burn program is now in place. PECO falls outside of the Southern Plains Fire Group, however a collaboration with the Bandelier Fire Group for monitoring at this one park is underway.

Sand Creek Massacre NHS

The recently formed Sand Creek Massacre National Historic Site (2,400 acres [971 ha]) lies along a 5.5-mile (8.85 km) stretch of Big Sandy Creek in southeastern Colorado. Established in 2007, SAND commemorates the Sand Creek Massacre of November 1864. SAND is located within the High Plains section of the Great Plains-Palouse Dry Steppe Province ecoregion, at an elevation of approximately 4,000 feet (1,219 m). The climate at SAND is fairly typical of the eastern Colorado Plains – predominately clear and dry with moderate winds out of the southeast. Average annual precipitation is 13-14 inches (33-36 cm), falling fairly evenly throughout the year. Summer thunderstorms can bring heavy rains and hail, while winter snowfalls average 27 inches (69 cm) annually (Anderson et al. 1981). Temperatures range from an average of 87°F (31°C) from June through August, to an average minimum of 14°F (-10°C) December through February.

There are three types of habitat identified: riparian cottonwood along sections of the creek, short-grass prairie north of Big Sandy Creek; and the sand sage (*Artemisia filifolia*) community to the south. Within these grassland communities there are pockets of grasslands with tall-grass species due to the sandy soils. The blue grama (*Bouteloua gracilis*) and buffalo grasses (*Buchloe dactyloides*) of the short-grass prairie dominate at SAND. Sand sage has gained a foothold on drier slopes and where grazing has been excessive (National Park Service 2000). As a newly-formed park, a Fire Management Plan will be developed, with a goal of introducing prescribed fire.

Washita Battlefield NHS

Washita Battlefield National Historic Site (326 acres [132-ha]), located on the banks of the Washita River, protects and interprets the site where the 7th U.S. Cavalry, led by George Armstrong Custer, attacked the

Southern Cheyenne village of Chief Black Kettle in November 1868. WABA is in the Rolling Plains, near the western limit of the Redbed Plains physiographic region of the Great Plains Steppe and Shrub Province. The Washita River winds west to northeast for 1.25 miles (2 km) across the park, dividing WABA into a floodplain bounded to the north and south by wooded “benches” at an approximate 2000 foot (610 m) elevation. The climate at Washita Battlefield is sub humid, temperate and continental. It is characterized by hot summers, mild winters, relatively high wind velocities and wide fluctuations in rainfall. Average maximum temperature June through August is 91°F (33°C), while average minimum temperatures December through February is 23°F (-5°C). Average annual precipitation is 25 inches (64 cm) with most of this falling between April and August. Severe thunderstorms are common and can produce tornados (National Park Service 2001). The surrounding landscape is classified as dry plains, steppe with moderate valley slopes (2–20%), and a gently rolling topography (Bergey 2003).

The area was once continuous mixed and shortgrass prairie amid red sandstone and gypsum outcroppings. It is estimated that historically, riparian areas covered 19 acres (8 ha) of park, while grassland dominated 316 acres (128 ha) (Hoagland et al. 2005). Baseline vegetation data was collected under drought conditions by Stotts and DuBey (1998). Their analysis suggested that the southern riparian area was the most “pristine,” the upland prairie in the southeast sector was the most ecologically healthy, and that the wooded “bench” to the north, although heavily grazed, had never been plowed (Stotts and DuBey 1998; Milner 2003). The Oklahoma Biological Survey conducted a vascular flora inventory in 2002, collecting over eight months. They documented 272 species of vascular plants, 32 of which were trees, shrubs or vines. Five species tracked by the Oklahoma Natural Heritage Inventory were found (Hoagland et al. 2005). Thirty-two exotic species were documented, representing 11.8% of the flora collected at Washita Battlefield (Hoagland et al. 2005), several of which are listed by the State of Oklahoma as noxious weeds. There

are no endangered or threatened species found at WABA. Prescribed fire has been in use at the park since 2003 with the only plant monitoring being conducted through fire effects monitoring.

2. Sampling Design

The Inventory and Monitoring Program and the Fire Program both monitor grassland ecosystems; however, the emphasis has differed among the two programs. The fire program has historically had a greater emphasis on monitoring immediately before, during and after fire events, with a goal of understanding the response of grasslands to fire. These effects, sometimes referred to as first order fire effects (Key and Benson 2006) relate to the change in living biomass, energy, etc. as a direct result of the fire (Figure 2-1). In contrast, the emphasis of the Inventory and Monitoring Program has been on long-term ecosystem health; thus, tends to focus more on the cumulative effects of a fire regime, including secondary effects from fire events that manifest themselves over a more extended period time. From the perspective of both fire management and ecological health, it is important to understand the effects of fire as a process that shapes our grassland communities, and given the high overlap in our respective programmatic goals in monitoring these ecosystems, it only makes sense for a collaborative effort between the Fire Effects Monitoring Program and the Inventory and Monitoring Program. The design we have developed reflects both areas of emphasis with an intent to gain mutual benefit of a more comprehensive and coherent collaborative program.

2.1. Target Population, Sample Frame, and Sample Units

Target Population

The target population of this effort is the grassland communities of each park

within the Southern Plains Network. For the purposes of this project, grasslands are defined as areas with > 60% graminoid cover, or areas that are targeted for habitat management with the intention of achieving 60% graminoid cover.

Sample Frame

Using vegetation types alone as a basis for defining the sample frame can be problematic if the intended scope of inference is broader than the vegetation classes themselves. In such cases, the dynamic nature of vegetation can result in a shifting population for which inference becomes nebulous. However, for the purposes of this protocol, we are interested in changes in grassland which include both the current and potential state. As such, our sample frame is somewhat analogous to an ecotype based on a combination of habitat types, soils, and general land form such that it includes existing grassland or riparian habitat types as well as areas that have a reasonable potential for such types either through management or natural processes. For example some pinyon-juniper savannahs (CAVO) or honey mesquite shrublands (LAMR, ALFL) are included in the sample frame, even though the current habitat type may not be strictly considered a grassland, these could under certain future scenarios become grass dominated.

Thus, the sampling frame for this protocol is defined in terms of mapped habitat types derived from existing vegetation maps for each park using the criteria described above. A few areas are excluded from the sample

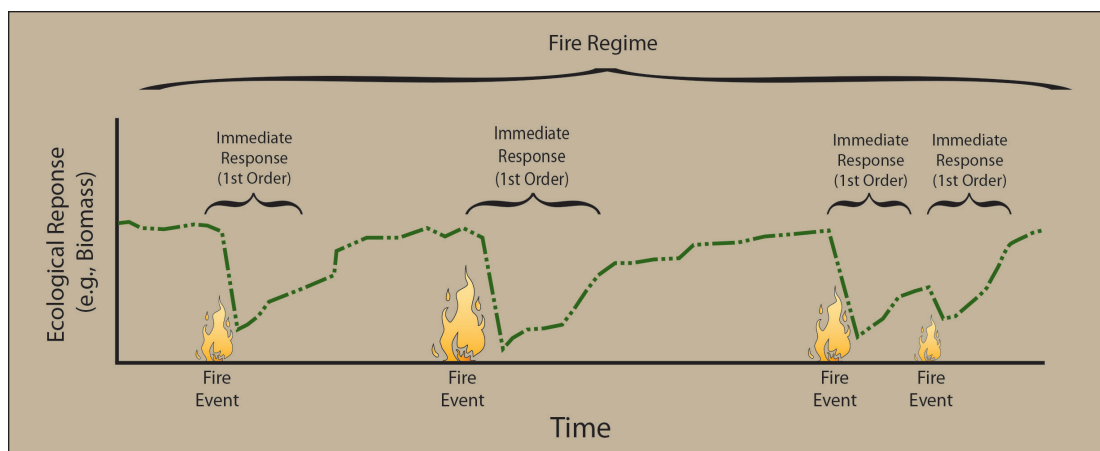


Figure 2-1. The Southern Plains Inventory and Monitoring Network and Fire Group have historically emphasized different components of a comprehensive assessment of fire effects and ecosystem health.

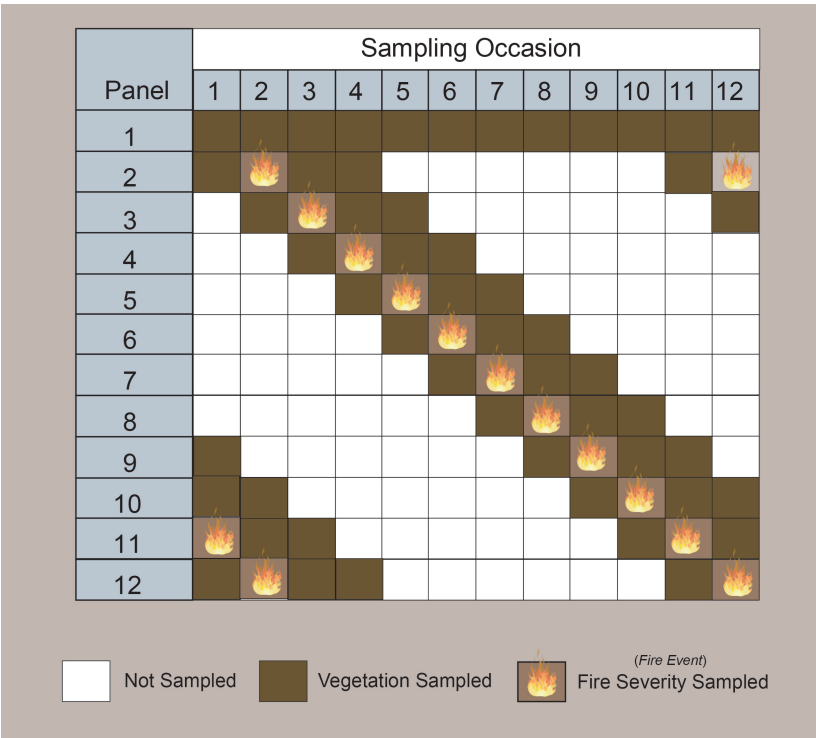


Figure 2-2. Temporal revisit design. Panel 1 are the transects sampled annually.

frame due to high disturbance areas that will continue to undergo disturbance and slopes >30%.

Sample Units

The sample units consist of 50 m permanent transects within which 5 divided quadrats (2 x 1 m) are located every 10 m (beginning at 0 m) (see Figure 3-1). Sample size varies between parks depending on park size and habitat variability. ArcMap was used to generate the sample units needed for each park.

2.2. Spatial Design

The overall spatial design for this protocol is a stratified random sample with unequal inclusion probabilities to ensure samples in particular habitat types of interest (grasslands, riparian areas, and areas slated for type conversion to grasslands). In most cases, fire plots already existed from previous efforts. These plots were initially selected using a stratified random sample based on burn units. However, these plots were selected and sampled for the purpose of monitoring fire effects; thus were sampled in conjunction (before and after) with burns. The intention of our design was to

compliment this sampling with plots intended to monitor long-term changes in these communities. As such, we augmented the existing plots through the selection (building upon the original stratified random sample) of additional plots where the temporal revisit design (see below) was not restricted to burn events or original burn units. In cases where no fire plots existed in a habitat of interest, we increased the inclusion probability to 1, for that habitat to ensure some samples fell in that area.

2.3. Temporal Revisit Design

The temporal revisit design, like the rest of this protocol, is intended to reflect our two programs and their corresponding objectives in such a way that the sum is greater than its parts. The fire plots focus on the immediate response of the vegetation to fire and are sampled pre-burn, post-burn, and years 1, 2 and 5. The SOPN plots emphasize the long-term changes in the vegetation and are sampled annually. The overall approach is a split panel design where the fire plot panels are a rotating panel based on burn frequencies (Figure 2-2). It is important to note however, that in those parks which use prescribed fire (currently all but FOUN and SAND), all areas are burned over time unless excluded for archeological resource protection. Therefore, no areas can be considered a “control” with respect to fire as an unburned treatment. Rather, any inference derived between burned and unburned areas are based on what is burned within a given year.

It is important to note that the panel of samples that are visited every year does not constitute a “control” in the sense that these sites do not experience fire events. Virtually all of the sites experience fire events. Rather, these units are sampled every year regardless of whether or not a fire event has occurred. These units help to ensure that we have samples from all successional stages relative to fire (or other treatment) events and help to interpret the potential confounding effects of year (e.g., environmental effects) and fire events. The time since the previous fire event will typically always be considered as an explanatory variable in our analyses.

3. Field Methods

SOPN Grassland Monitoring has been integrated into SPFG fire effects monitoring efforts and takes advantage of many of the field methods used by this group. This enables one crew to collect data required of both programs. The divided frequency quadrat method of vegetation measurement has been added to the existing SPFG suite of field methods to meet SOPN needs. For the immediate future, vegetation methods using the point-line intercept currently employed by the fire effects monitoring program will continue along the same transect used for collecting divided frequency, so that we can compare methods to determine the most robust method for detecting species richness and to provide a cross-walk for historic vegetation data. Once this determination has been made, a single best method will be chosen for use in future monitoring.

3.1. Field Season Preparation, Schedule and Equipment

Prior to the field season each year, the field crew will review this protocol, including all SOPs. It is important that each member of the field crew is thoroughly familiar with the elements of the design and standard operating procedures for this program. There are numerous tasks that must be performed to ensure a smooth and efficient field season, including generating and copying sufficient data sheets for the year, making appropriate logistical plans, and purchasing necessary equipment and supplies to provision the field effort. These procedures are described in SOP #1.

Due to the number of procedures performed as part of the vegetation monitoring field sampling effort, considerable preparations are necessary in order to effectively accomplish this suite of tasks. All materials

and equipment must be brought on sampling trips with the crew. The suite of tasks involved in preparing for a field sampling bout include:

- Acquisition of a list of plots to be monitored and any supporting field data from past visits;
- Review of park species lists from previous monitoring efforts;
- Scheduling of sampling dates, communication with park regarding dates, and organization of logistics;
- Acquisition of collection permit;
- Equipment organized and prepared for field season.

3.2. Establishing and Marking Permanent Monitoring Sites

Transects are established after they have met certain criteria for safety and have been confirmed to fall within the target monitoring type (refer to SOP #3). Transects are permanently marked using stakes at the ends and are marked with GPS points. In addition two photographs document the site and serve as repeat photo points on subsequent visits

3.3. Field Sampling Methods

Grassland sampling consists of a variety of measurements collected on or adjacent to each established 50 m transect. Vegetation data will be collected using two methods – a series of divided quadrats and point-line. Additional measurements can be taken to meet the needs of a monitoring program. Detailed information used to collect data can be found in SOPs 5 - 12.

Divided plots for cover and frequency

Frequency and cover data are collected in five divided quadrats located along each transect, spaced 10 meters apart (Figure 3-1).

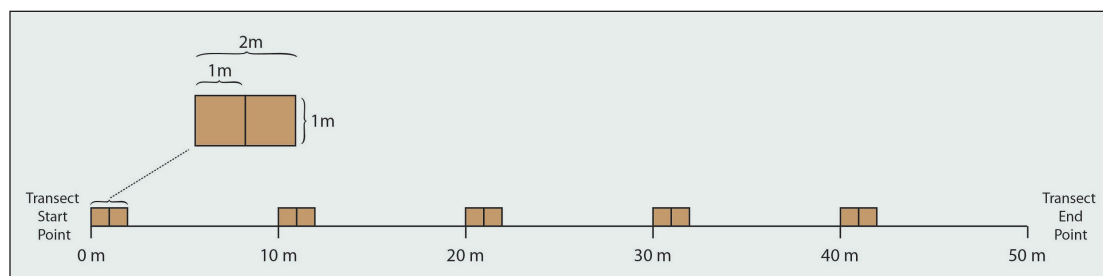


Figure 3-1. General plot layout for sampling grasslands.

Table 3-1. Definitions of soil surface features for quadrat sampling.

Soil surface type	Definition
Bare soil, no overhead vegetation	Loose soil particles (0-2 mm diameter) exposed to erosion
Bare soil, under vegetation	Loose soil particles (0-2 mm diameter) protected by vegetation overhead
Litter	Embedded litter that is less than 2.5 cm in diameter, where removal of the litter would leave an indentation in the soil surface or would disturb the soil surface
Woody debris	Detached woody plant material that is greater than 2.5 cm in diameter and in direct contact with soil
Small rock	Rock fragments 2-20 mm in diameter
Large rock	Rock fragments >20 mm in diameter
Lichen	Lichen crust on soil (lichen on rock is recorded as the appropriate rock type)
Moss	Moss on soil (moss on rock is recorded as the appropriate rock type)
Crust, undifferentiated	Anything from physical crust to weak biological crust but NOT including lichen, or moss
Scat, livestock	Any type of livestock scat

The variable scale plot design is effective for assessing changes in frequency when sampling multiple species simultaneously. Plot size determines frequency values and frequency values between 30% and 70% allow the greatest potential for detecting increases or declines in species frequency (Elzinga et al. 1998). The various sized plots are useful for detecting changes in frequency of dominant prairie grasses and some ubiquitous forb species.

Within each quadrat foliar cover of each species present is recorded using ocular cover estimates. Ocular cover was chosen as the most efficient technique for measuring herbaceous dominated vegetation and has the added benefit of allowing grouping of cover estimates into classes when needed. Well trained observers will lessen subjectivity and rounding error. (Wilson 2007)

After collecting foliar cover in a given plot, the ground-level cover of bare soil, litter and other attributes (Table 3-1) is estimated using the same ocular estimation techniques (SOP #5) in only the 1x2 m plot. Two measures of bare soil are estimated: bare soil exposed to wind and rain erosion and bare soil below standing live vegetation that receives some protection from erosion. When percentages are combined the cover value for a plot may not be greater than 100%. These attributes

are measured in plots to describe changes in ground cover, and allow for exploration of the correlative relationships between compositional changes and environmental attributes. For example, changes in bare ground and litter cover are directly affected by fire spread and intensity (Knapp and Seastedt 1986). These changes have been correlated with changes in species composition and the dominance of certain guilds of species following a fire (Collins et al. 1998).

Point-Line Intercept Sampling

Data will be collected using the Point-Line Intercept method historically employed by the SPFG fire effects monitoring program. This data will be collected along the first 30 m of the 50 m transect used to collect divided frequency data. This method of data collection requires that a vertical pole be placed at every 0.3 m point along the transect, starting at 0 m, and the following data collected at each point:

- Height and species identification of tallest vegetation touching the pole;
- Species identification of additional lower-growing vegetation in decreasing height order;
- Ground layer condition (bare ground, litter, bedrock, etc.).

Detailed instructions on collection of this data can be found in SOP #6.

Fine Fuel Load (Biomass) Collection

The fine fuel load and biomass of grassland will be collected using the established protocol of the SPFG monitoring program. Detailed instructions for this sampling can be found in SOP #8. In brief, this sampling will be done by clipping all above ground vegetation found within five 0.25m² quadrats located systematically within 10 m of the established vegetation transect. Clipped vegetation from each of the quadrats will be placed in separate bags, weighed, dried, and weighed again to extrapolate the biomass and moisture content of the grassland area.

Fuels Data

Fire fuels data will be collected at each transect using the standard protocol of the SPFG monitoring program. Detailed instructions for this sampling can be found in SOP #9. This data is collected using the Browns Transect method.

3.4. Ancillary Data Collection

Shrub Transect Sampling

When the sampling transect falls within areas containing shrubs and other woody vegetation, it will be necessary to collect data on the plant species present and the number of living stems contained within a 10 meter radius from the 25 m point on the transect. This sampling method follows the standard sampling methods employed by the SPFG fire effects monitoring program. Detailed instructions for the collection of this data can be found in SOP #7.

Site Impact Assessment

Should a disturbance be observed either on the transect or surrounding area that could potentially impact the site, use the following guidelines to record disturbances on the Site Impact Assessment data sheet. Conditions that would be classified as a disturbance include: social roads or trails, campsites, livestock grazing, wildfire, burrowing and wind or water erosion.

A. On-site disturbances

The purpose of this section is to document the occurrence of on-site factors which

Table 3-2. Definitions of soil-surface disturbances.

Disturbance type	Definition
Ant mound	Holes and mounds created by ants
Bicycle	Disturbances caused by non-motorized bicycles
Human track/trail	Tracks or trails created by humans
Livestock track/trail	Tracks, marks, or trails created by livestock
Motor vehicle	Disturbances caused by any motorized vehicle
Wildlife excavation	Holes and mounds created by wildlife
Wildlife track/trail	Tracks, marks, or trails created by wildlife
Other anthropogenic	Any human disturbance other than tracks and trails
Undifferentiated	Any disturbance not classified as one of the other categories

may affect ecological processes within the transect. Examples include land uses or natural or anthropogenic landscape alterations which alter hillslope hydrological processes or wind- or water-driven erosional processes. Such alterations may affect runoff patterns or sediment deposition within the transect. Common types of disturbances are listed on the bottom of the data sheet (Table 3-2). Include any other type of disturbance that appears significant at a site.

B. Off-site disturbances

Upslope - The purpose of this section is to document the occurrence of off-site (i.e. outside the transect), upslope (gravitational) factors which may affect ecological processes within the transect. Concepts and examples are the same as for on-site influences. Observe the area to the hilltop or 500 m upslope of and perpendicular to the transect for any sign of disturbance. For each disturbance encountered, describe the type of disturbance, the size of the area affected in m², the distance upslope from the transect, and the severity of the impact. Answer the questions on the data sheet to assess potential effects of the disturbance and provide additional information to help describe the disturbance. Use additional data sheets as necessary.

C. Off-site disturbances

Other than Upslope - Assessment of disturbances at orientations other than upslope is more general and is conducted without leaving the transect area. Looking

down slope and across slope, record noticeable disturbances, the approximate direction and distance from the transect edge, and the approximate aerial extent of the disturbance.

Unknown Plant Species

It may be difficult or impossible to determine the specific identify of individual plants encountered during sampling. When this situation occurs, a “grab sample” of the unknown plant is collected from the surrounding area. This sample is comprised of leaves, stem, flowers and/or fruit – anything that will aid in proper species identification at a later time. Once collected, an identifier is assigned to the sample and is used as a place-holder on the data sheets. Additional information is recorded on the appropriate data sheets (SOP 10) to track the specimen throughout the data entry and species identification process.

Unknown plant material is examined and identified rapidly due to the temporary nature of the sample collected; an un-pressed specimen will deteriorate rapidly, making identification more difficult. It is recommended that a high-resolution (600 dpi) scan of the specimen be done immediately upon return from the field each day. This ensures that minute detail are preserved that are needed for proper identification.

Vouchers are collected only at the request of the Principal Investigator. There are specific directions to follow in the collection of a voucher specimen, outlined in SOP #11. Collected material is mounted on acid-free herbarium paper, kept in insect proof containers, and becomes reference specimens. Rare, threatened, and endangered species are not collected. Voucher specimens are housed in the appropriate herbarium for

each park. Kartez/ITIS is used as the first system for standardizing taxonomy.

3.5. End-of-Season Procedures

Equipment maintenance

Make certain that all equipment is in good working order, or repair or replace if necessary.

Supplies inventory.

To ensure that adequate supplies are on hand for the next field season, order supplies if needed.

Complete ID of unknowns.

The field-crew leader is responsible to ensure complete resolution of all unknown plants. Plants are identified to species, genus or family. Should the crew leader encounter difficulty with identification, the Project Manager will assign a botanist to handle identification.

Data management

The field crew leader is responsible to ensure that all data sheets are completed properly, and that all digital photos are labeled and stored (SOP 13).

New Species

The crew leader is responsible to ensure that any observed plant species that is not on the current park list are submitted to the Project Manager to update NPSpecies. This requires a voucher specimen which the crew leader is responsible to acquire.

Protocol review procedures

Prior to the departure of the field crew, the Project Manager will implement the annual Protocol Review procedures, which queries the field crew for problems, issues, and recommendations regarding the extant grassland protocol.

4. Data Management

The grassland monitoring staff annually makes thousands of observations about plant communities and their environments. Taken together, these observations can form a statistical representation of our sampling universe. To ensure that an accurate and complete record is maintained in perpetuity a coordinated data management plan must be in place early in the monitoring process. Specific data management objectives relate to three themes: database design, data entry, and long-term data integrity and security.

4.1. Collaboration with Fire Effects Monitoring

It was determined during the development of this protocol that SOPN would work to integrate SOPN grassland monitoring with the regional fire effects vegetation monitoring program. This is mainly due to the overlap of the objectives of both programs and that they both collect similar data. Fire is a natural process in all of the vegetated area within SOPN's parks, although frequencies differ among vegetation types. Based on this, the combined resources of the two programs would produce a much stronger vegetation monitoring program for the NPS Southern Plains parks than would two separate programs.

4.2. Database Overview

As part of the collaboration with the fire program, data will be entered into both FFI, a SQL database that has been developed as an integration of FEAT and FIREMON fire monitoring databases, and SOPN Grassland Monitoring database (SOPN Grass), an MS Access database developed using the standard Inventory and Monitoring database template. Collected data that is explicitly needed for fire effects monitoring will be entered at the end of season by the fire effects crew lead. Efforts have been made to 1) modify the FFI database to contain SOPN data and 2) export from the SOPN Grass to import into FFI. Both of these efforts failed. Therefore, two databases are currently maintained to house data.

4.3. Data Entry, Verification and Editing

Data entry is the initial set of operations in which raw data from paper field forms or field notebooks are transcribed into a computerized form (i.e., within a database). Data entry is best performed by a person who is familiar with the data and ideally takes place as soon as data collection is complete. Inevitably, the process of transcribing data from field forms to a digital format introduces error. FFI and SOPN Grass use data entry forms with quality assurance and quality control (QA/QC) features in order to minimize such errors. Data entry forms reduce transcription errors through pick lists and value limits. Standardized identifiers (e.g. sample period or location) are selected from a list generated from a look-up table. Look-up tables contain project specific data and prohibit entry of data into a field if a corresponding value is not included in the look-up table. Consequently, only valid names or measures may be entered and spelling mistakes are eliminated.

If a species name does not appear in the FFI dropdown pick list, a series of quality control measures will prevent the entry of an erroneous species name into the database. Without a species name or habitat measure listed in the pick list, it cannot be typed in. Sequential procedures within the database structure determine if it is the result of a name change or a new species or habitat measure. Synonymous names (i.e. two or more different names referring to the same taxon), common for plant species, are searched for prior to entering a new species name, thereby preventing the duplicate entry of synonyms. To check the current nomenclature for a taxon in the FFI database, a nomenclature update form is attached to the data entry form via a button. If the species or habitat measure name has changed, the form will indicate the current accepted name. If the species name is valid, but not currently in the database, a form is provided to update the species table with the new species name and attribute data. A similar system of managing

species nomenclature is under development for the SOPN Grass database.

Data verification is the process of checking the accuracy of the digital data against copies of the original paper data sheets, and it should immediately follow data entry. To minimize transcription errors in the final dataset, personnel familiar with the project's field and data collection methods should verify 100% of the records to the source documents. After any required corrections have been made, the project manager will review 10% of the records a second time. The results of that comparison will be reported in the metadata. If the project manager finds any errors, the entire dataset will be verified again. The paper data sheets will be archived after the project manager verifies that the digital data accurately reflects the original field data.

Data validation is the process of reviewing digital data for range and logic errors. Even when data are correctly transcribed from field-data sheets, some values may not be logical or accurate. Although some validation features, such as range limits, are built into the database itself via data-entry forms (see above) and queries, the project manager or another person familiar with the data will further review the dataset for these types of range and logic errors.

Data certification is the process of ensuring that the dataset (i.e., portion of the database related to all of the records for that year) has been verified and validated for accuracy, is complete, and that metadata/documentation for the dataset is finalized. Data certification will be completed annually for all tabular and spatial project data sets. The project manager will complete the certification form (in development) and notify the data manager that the data are ready for archiving and storage. Once the dataset is certified, it can be used in analyses and reports.

Validation of spatial data is accomplished using ArcGIS 10.x (ESRI, Inc.). FFI includes a GIS module capable of directly connecting to ArcGIS via a toolbar. As such, data can directly be imported into ArcGIS to create a shapefile. The UTM coordinate values stored

in the database for point locations will then be compared to the original GPS coordinates. The process of verifying, editing, validating, and certifying spatial data will follow the same process as for other electronic data.

4.4. Data Archival Procedures

Secure data storage and archiving is essential for protecting data files from corruption. A copy of the FFI database and the SOPN Grass database is maintained on the SOPN server. Backup copies of all data will be maintained at SOPN. A complete copy of the database also will be archived prior to any database version changes.

Data sets are rarely static. Changes, improvements, or updates to the data may be made following the archival of a data set. There are three main caveats to this process: 1) data integrity must be maintained; 2) once archived, all changes to the data set must be documented; and 3) mistakes made during editing must be recoverable. Any editing of archived data is accomplished jointly by the project manager and data manager. Every change must be documented in an edit log and accompanied by an explanation that includes pre- and post-edit data descriptions.

Prior to any major changes in an archived data set, a copy is exported with the appropriate version number, which allows for the tracking of changes over time. With proper controls and communication, versioning ensures that only the most current version is used in any analysis. Versioning of archived data sets is handled by adding floating-point number to the file name, with the first version being numbered 1.00. Each major version is assigned a sequentially higher whole number. Each minor version is assigned a sequentially higher 0.1 number. Frequent users of the data are notified of the updates and provided with a copy of the most recent archived version. Once the data are archived, any changes made to the data must be documented in an edit and original field forms are not altered. Field forms can be reconciled to the database through the use of the edit log.

Certified and archived non-sensitive data will be posted to the NPS Data Store and SOPN website where they may be downloaded

for research and management applications. Other datasets, including those containing sensitive data, may be requested in writing from the SOPN data manager. Sensitive data will be released only with a signed confidentiality agreement.

4.5. Metadata Procedures

All tabular datasets in FFI, and SOPN Grass including all database objects (e.g., tables, fields) will be defined and documented using

the database's built-in metadata functionality. FGDC-compliant metadata (including the NPS profile) for all spatial data will be created using the Metadata Tools and Editor. Both spatial and non-spatial metadata records for non-sensitive data will be uploaded to the NPS Data Store where they will be available to the public. All metadata records will be updated as needed whenever additional data are collected and added to the database.

5. Analysis

5.1. Routine Data Summaries and Analyses

Biotic Integrity is the foundation upon which analysis is conducted. The proportion of annual, biennial and perennial species provides an indication of the stability of the site, and it is generally expected that the proportion of annual species at a given site would be higher immediately following a disturbance, but would shift toward an increased proportion of perennials as time passes since a disturbance. One of the major threats to grasslands and other plant communities is invasive species. Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), and changes in water availability (D'Antonio and Mahall 1991). Fire frequency and seasonality plays a large role in the ecology of the Great Plains. Fire, and the lack thereof, has important effects on native species diversity, nutrient cycling and productivity (Collins and Wallace 1990).

Routine descriptive data summary reports are available through the Reports and Analysis section of both the SOPN Grass and FFI ecological monitoring utilities version 1.02 and are described below. Additional analysis for trend will be determined when enough data has been acquired to offer a synthesis report.

5.2. Species Cover

The Cover summary displays the average percent cover for a transect. To calculate the percent cover for each species sampled on a transect, the mid-point of the estimate range for the species' cover in each 2x1 quadrat is summed by transect. The transect sums are divided by the number of quadrats to give an average percent cover for the species on that particular transect.

Output from this measure is also used to determine the extent of exotic invasion within the transect by looking at the proportion of

natives vs. exotic species. This assessment is based primarily on percent foliar cover, rather than the number of individual species because most species are quite rare and cover provides a more realistic assessment of the impact of native species and exotic invasion. However, we do present the proportion of individual species as an ancillary reference.

There are occasions when the Fire program needs to determine dominant species cover. The Cover - Points by Transect summary displays the average cover and average height of each species or substrate item by point-line transect and monitoring status (dead, live, immature, resprout). This summary report uses the only the summary of total hits for each species or substrate item. Percent cover for each transect is calculated by dividing the total number of hits for a species/substrate by the total number of points sampled on the transect. Average cover for the transect is computed by summing all percent covers by species or substrate and dividing by the number of transect lines.

5.3. Proportion of Groups

The response of annual species (grass and forb) to disturbance is monitored to determine progress of succession. It is generally expected that the number of annual species at a given site would be higher immediately following a disturbance, and would shift toward an increasing number of perennials as time passes since a disturbance. The persistence of large quantities of annuals after a disturbance could indicate some basis for concern. This is accomplished by grouping species found within a transect by duration (annual, perennial, etc.) and dividing by the total number of species per transect.

The composition of functional groups can have a dramatic effect on grassland ecosystems and their associated processes (Tilman et al. 1997, Pellant et al. 2005). Tilman et al. (1997) found that functional composition and functional diversity were principal factors explaining plant productivity, plant percent nitrogen, plant total nitrogen, and light penetration. They further conclude

that habitat modifications and management practices that change functional diversity and functional composition would likely have a dramatic effect on ecosystem processes. Plant species within a transect are grouped by lifeform and divided by the number of species found.

5.4. Ground Strata Cover

The amount of exposed soil, protected soil, litter, crust, rock and moss contributes to the understanding of species composition, fire behavior, and soil stability. Strata cover is estimated for each component by averaging quadrat readings.

5.5. Additional Measures

The Fire program takes additional measures to inform their program. These measures are taken when needed at the same time main transect data is collected. In this case, additional transects may be added to the main one – these are referred to as macro-plots.

Density - Shrubs

The Density summary report in FFI displays a summary by transect for each species of shrub and sub-shrub and their status (live, dead, re-sprout, immature). The total counts are converted to an average per unit area (per ft² (m²) or per acre (hectare)) by dividing the count by the sample area and applying the appropriate conversion factors.

Post Burn Severity

The Post Burn Severity summary report in FFI gives separate assessments of burn effects for the substrate and vegetation strata. The severity rating for each assessment is an average obtained by adding all values and dividing by the number of points on a transect and by the total number of transects. The percent severity values are determined by counting the number of hits within each substrate category (i.e., how many hits in

substrate 1) and dividing each by the total number of points per transect. If more than one transect is taken at a macro plot, all subplot totals are averaged by the total number of points on the multiple transects.

Surface Fuels

The Surface Fuels summary in FFI report displays the average fuel loadings in tons per acre (or kg per m²) for each macro plot. The loadings are calculated from fuel counts and duff/litter estimates on the fuels transects along with average vegetation cover and heights. Down woody loadings are calculated for 1-hr, 10-hr, 100-hr, 1-100-hr, 1000-hr sound, 1000-hr rotten, and 1-1000-hr fuels. Biomass is calculated based on the equations presented in the Handbook for Inventorying Downed Woody Material (Brown, 1974).

Non-slash, composite values are used for quadratic mean diameter, non-horizontal correction and specific gravity of fine woody debris. Pieces of coarse woody debris in decay class 1, 2, and 3 are considered sound and assigned a specific gravity of 0.40. Decay class 4 and 5 pieces are considered rotten and assigned a specific gravity of 0.30. Loading of litter and duff is calculated using bulk densities of 2.75 lbs/ft³ and 5.5 lbs/ft³, respectively. Duff and litter depth summaries are provided. Averages for live shrub cover, dead shrub cover, live herbaceous cover, and dead herbaceous cover are also calculated. Average shrub height and herbaceous height are calculated in feet (m). Biomass of live and dead shrubs and biomass of live and dead herbaceous plants are calculated using the equation:

$$B = H * C * BD$$

where B = biomass (kg/m²), H = height (m), C = percent cover/100, and BD = bulk density (kg/m³).

6. Reporting

Reporting will be hierarchical and intended for multiple audiences and media. The primary delivery system will be the Internet, via the Southern Plains Network website, <https://science.nature.nps.gov/im/units/sopn/index.cfm> (Figure 6-1). Individual products listed on the web site will be in a format (pdf) that will facilitate easy printing or enable us to deliver a printed version to appropriate audiences. All website products link to the NPS Data Store, <https://irma.nps.gov/DataStore/>, where the actual product can be viewed online or downloaded

Information within the SOPN website is presented as a series of products organized by both resource and product type. Resource types are reflective of the initial selection of Vital Signs and report on the condition of the resource. This is the level that best synthesizes the available information regarding the status and trends of the resource. In contrast, products report the available information from a given park. Thus, someone looking for the most comprehensive information about status and trend of a resource would find it at the resource level, while someone looking for

the specific results from a given park would find it in the Reports & Publications section. I&M monitoring data will contribute to, and sometimes be the only source of information for resource-level products.

For this monitoring effort products are described below and summarized in (Table 6-1). We anticipate producing a project report and summary annually and a synthesis report approximately every five years.

6.1. Resource Brief

The resource brief is a one-page synthesis document that explains the importance of a resource, describes its status and trend, and discusses its stressors and drivers. Relevant photos, maps, and/or graphs complement the text. The resource brief page contains three parts:

- Importance. A one-paragraph description of why the resource is important that may include information on the ecological role or historical significance of the resource.

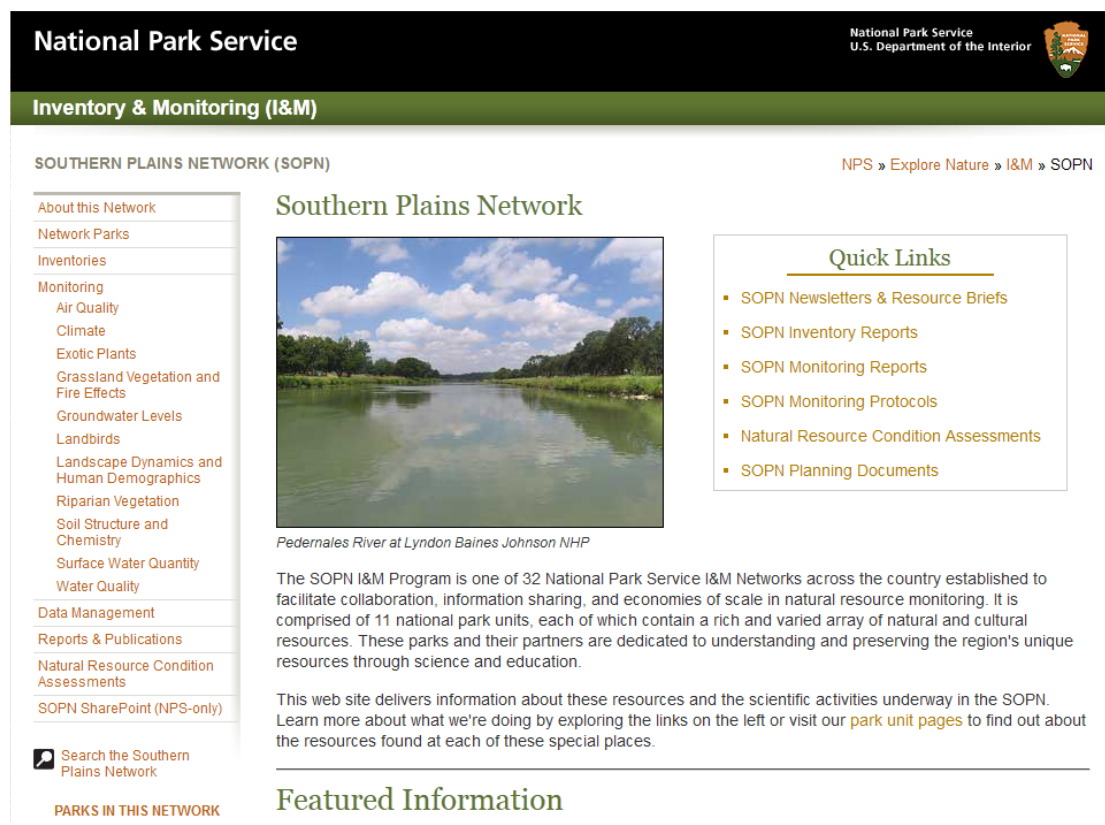


Figure 6-1. The home page of the Southern Plains I&M Network.

Table 6-1. Primary products produced for the Southern Plains I&M Network.

Product	Primary Purpose/Scope	Primary Target Audience(s)	Scale	Length	Frequency
Resource Brief	Status and Trend of Grassland Habitat	Superintendents/ Resource Managers	Park	1 Page	Annual
Project Summary	Summary of Project Accomplishments and Results for a given year. Extracted from Annual Report	Resource Managers	Park	2 Pages	Annual
Monitoring Reports	Project Accomplishments and Results for a given year.	Resource Managers	SOPN with individual Park Sections	5-20 Pages	Annual
Synthesis Report	In depth synthesis of data and supporting evidence. Primary focus on Trends and Influences on those trends.	Resource Managers/ Science Community	SOPN with individual Park Sections	Variable	Every 5 Years

- Status and Trends. A one-paragraph summary of the status of the resource and how the resource has changed over a specified period of time.
- Discussion. A one-paragraph discussion of the key drivers and stressors for a resource. If this is not applicable or unknown, describe the issues faced in managing this resource.

6.2. Project summary

The project summary is a two-page synthesis of the current status and results, if applicable, of a given project. The pdf provides the user with a summary of a project and includes an introduction as well as sections on methods, results, and project contacts. Relevant graphs, photos, and/ or maps complement the text.

6.3. Project report

Project reports will be produced annually or as appropriate, and will synthesize the results of a given period's effort for that project. It is more limited than the synthesis report (below) in that its emphasis is on a data summary and estimates of the primary parameters being assessed. The project report provides additional detail not included

within the project summary, and includes the following sections:

- Introduction. Explains the purpose and background of the project.
- Methods. A brief description of the methods with reference to the full monitoring protocol.
- Results. The results of the current period's effort and trend information where appropriate.
- Discussion. A short narrative putting the reporting period results into context, a discussion of patterns or trends, and a description of possible implications to management.

6.4. Synthesis Report

The synthesis report is a more in depth assessment of the status and trend of the resource. The annual report, while also synthesizing project results, is a generally limited to a data summary and estimates of the core parameters. In contrast, the synthesis report will provide a much more in depth assessment, including more comprehensive analyses and broader interpretation of the implications of the results to other resources.

7. Personnel and Training

7.1. Collaborative Model

The collaboration between the fire and monitoring programs is intended to gain efficiency from our respective strengths, programmatic goals, and legacy (Table 7-1). The Inventory and Monitoring Program approaches grassland monitoring with an emphasis on long-term ecosystem health. In contrast, but not mutually exclusive, the Fire Program approaches monitoring with an emphasis on understanding the effects of wildland or prescribed fire as a management or “natural” treatment on the ecosystem. Not surprising, the parameters that would be monitored from each of these perspectives overlap considerably. Furthermore, most of the park lands are subject to fire or other treatments at some point in time. Consequently, there is no inherent difference between lands being managed with fire or other treatments and the lands for which ecosystem health is being assessed. It also follows that there is considerable efficiency to be gained from a combined effort whereas complimentary types of sampling can add value to the sampling designs that might otherwise occur independently.

7.2. Roles and Responsibilities

The SOPN project manager and the Fire Ecologist for the Southern Plains Fire Group are the lead ecologists for implementing the vegetation community monitoring protocol, and are supervised by the network coordinator for the SOPN Program. Because of the need for a high level of consistency in implementing the protocol, the project manager will be responsible for training the seasonal and permanent personnel assisting with the monitoring efforts. The data management aspect of the monitoring effort is the shared responsibility of the project manager and the data manager. Typically, the project manager is responsible for data collection, data entry, data verification and validation, as well as data summary, analysis, and reporting. The data manager is responsible for data archiving, data security, dissemination, and database design. The data manager, in collaboration with the project manager, also develops data entry forms and other database features as part

of quality assurance and automates report generation. The data manager is ultimately responsible for ensuring that adequate QA/QC procedures are built into the database management system and that appropriate data handling procedures are followed. The Crew Leader will be responsible for, among other activities, day-to-day scheduling and field operations over the Crew Members. It is anticipated that there will be two to three Crew Members responsible for efficient data collection.

Table 7-1. Primary roles and contributions of the Fire and Inventory and Monitoring Programs toward the collaborative effort.

Contribution	Description	Lead Group
Field Crew	Oversight	Fire
Field Crew	Day to Day	Fire*
Data Analysis	As per Fire & I&M Needs	I & M
Data Management	Maintain Database with Shared	I & M

* I & M will contribute to the cost of one or two field technicians

7.3. Qualifications and Training

A competent, detail-oriented observer is essential for collecting credible, high-quality data in vegetation communities. Observer bias in the estimation of cover and misidentification of species will affect the ability to detect valid trends or changes in vegetation communities through time (Elzinga et al. 1998). Field observers must be proficient at accurately identifying plants and estimating plant coverage. Observers should also have good organizational skills, memory retention and an ability to work methodically and consistently under difficult conditions.

Training is essential for developing competent observers. Herbarium specimens and comparative notes on difficult or uncommon species should be provided for field observers. Observers should be tested frequently on their ability to identify plant species, tailoring the testing for the more problematic look-alike species. Time should also be invested in training personnel

on cover estimation. Estimating cover is best taught at the start of the season in the field with all crew members present and then reviewed periodically throughout the summer to reduce within-year observer differences in cover estimation. Refer to the following instructions for training observers in both plant identification and cover estimation.

Training Observers

Necessary skills to be acquired or honed before data collection begins each field season are reviewed below.

1. Knowledge of the use of a GPS is essential. GPS is used to navigate to transects, and in the future, may be employed to record key site information. SOP #2 (Use of a GPS) should be thoroughly reviewed. Training sessions described below will require field crew members to exercise the use of a GPS.
2. Plant identification skills are critical. Only field crew members with demonstrated plant ID skills should be hired. Even so, fine-tuning ID skills for SOPN plant species is still important. The SOPN Integrated Grassland Ecologist or designee (e.g., lead bio-tech) will provide training for all crew members. Training will consist of field-based identification of plants anticipated to be observed during the field season, with emphasis on difficult-to-ID species. Additionally, field crews will be instructed in the use of taxonomic keys and reference materials which will be available to all crew members.
3. Identifying Ecological Site types is critical during transect-establishment. Establishing new transects requires determining if the preselected transect corresponds to the targeted ecological site. Ecological site is an underlying strata in SOPN grassland monitoring, and it is important that the computer-selected transects actually represent the intended ecological-site stratum.
4. Transect Establishment and Marking procedures will be exercised prior to operational monitoring efforts. The PI or designee will provide several days of instruction covering the operational procedures of all field methods. Practice procedures will commence with using a GPS to locate a pre-determined point. Each crew member will need to find specified points using a GPS. Site Characterization procedures will be explained and demonstrated, which includes evaluation of Ecological Site conditions. Transect Establishment, on-site measurement methods, and site-impact procedures will be explained and demonstrated. For each of these categories of activities, field crew members will be paired, and required to exercise all procedures under the supervision of the PI. All procedures will be exercised to the full extent, including actual recording of observations on data sheets.

Table 7-2. Roles, responsibilities, and minimum qualifications of the primary positions of this project.

Position	Roles	Responsibilities	Minimum Qualifications
Project Managers (SOPN & SPFG)	•Serves as a liaison among project cooperators (cooperating agencies), other related projects (i.e., monitoring by other groups or in neighboring locales), and between other staff (crew leader and members) and the SOPN (and its cooperators)	•To hire other staff members (crew leader and members) •To coordinate field schedules and availability of supplies with the crew leader •To participate in the creation of (and possibly lead) training for crew leader and members •To inform SOPN & SPFG staff and cooperators of the progress of monitoring and any areas where adjustments may be needed •To act as a direct channel of communication between this project and others of this nature, thus building relationships and cooperation among this project and other similar projects •To be the party responsible for providing data from fieldwork to SOPN & SPFG staff for analysis in a quality checked format, along with copies of all original data, and to be available for any questions pertaining to the data	•Excellence in identifying (and explaining the identification of) native and exotic plant species found in SOPN parks. •Experience hiring personnel •Experience managing projects and communicating results in a clear and concise manner to all interested parties through a variety of media •Experience collecting and quality checking reliable data •Experience training crews and performing field work
Crew Leader	•Serves as the leader of the field crew members and is the primarily liaison between the project manager and the crew members	•To participate in field training •To act as the primary coordinator with respect to field schedules and supplies •To serve as the party who is primarily responsible for the safety of crew members and to conduct safety training for crew members •To accompany crew members in the field •To act as a direct liaison between the project manager and the crew members •To enter and quality check all data before submitting for analysis	•Experience performing field work •Experience training, leading and coordinating crews •Experience with data collection, entry and quality assurance •Experience communicating with a variety of audiences •Experience with teaching outdoor safety and route finding •Excellence in identifying (and explaining the identification of) native and exotic plant species found in SOPN parks. •Experience using a GPS unit •Must be able to hike long distances and carry a heavy backpack
Crew Members	•Serve as the back bone of the field operation by performing all field work related to the monitoring project	•To participate in field training •To alert crew leader of any scheduling conflicts or needed supplies •To account for safety of yourself and others at all times •To be responsible for all loaned equipment and use it properly •To collect reliable, accurate data and submit it to the crew leader in a timely manner	•Capability to learn to identify native and exotic plant species •Capability to learn safety and route finding •Capability to learn the use of a GPS unit and undergo training if necessary •Experience communicating and working with a variety of personalities in close settings under arduous conditions •Must be able to hike long distances to and carry a heavy backpack •Preferably have experience performing field work in vegetation measurements, have experience working with dichotomous keys and identifying species, and have extensive hiking/backpacking experience

8. Continual Improvement

Quality assurance extends beyond data management and must be an integral component of all aspects of the SOPN program. The USFS Forest Inventory and Analysis Program (FIA) identified three aspects of quality assurance (prevention, assessment and correction), which are referred to as the QA triangle (Figure 8-1). In the context of the overall SOPN program, prevention is addressed through sound development of sampling design, data management and analysis. Although prevention is extremely important, it is not sufficient by itself, due to changing programs, funding, environments, technologies, etc. Thus, this protocol includes the following section for assessment (i.e., the review process) and correction.

8.1. Review Process

Reviews may be periodic (planned at a predefined interval) or episodic (resulting from changing mandates, funding, priorities, etc). The review process should permeate through all phases of our monitoring. It also should permeate through all of our thematic elements (i.e., applicability, reliability and feasibility), although it may not be the same review process for each element. Rather, the details of a given review should reflect which element(s) is being targeted. For example, a review intended to assess the scientific reliability is likely to be conducted by qualified scientists. In contrast, a scientific review panel may have little insight if a review is intended to assess whether or not the monitoring meets the needs of managers. Consequently, the review strategy should also clearly specify the purpose of the review and, at least in general terms, who should conduct the review.

8.2. Process for Change

Determining the status and trends of selected indicators of the condition of park ecosystems is an essential and critical goal of the I&M Program. Understanding the spatial and temporal scales over which change occurs is paramount to achieving this goal. We have considered the spatial and temporal scale in several elements of this report, including sampling design and

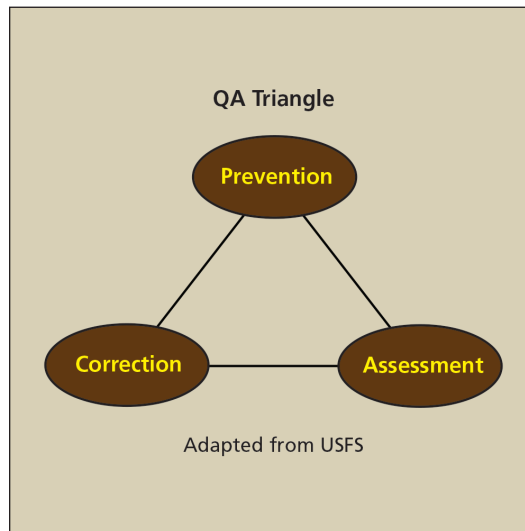


Figure 8-1. The quality assurance triangle. Adapted from the USFS.

implementation. However, many ecosystem attributes of interest operate at such long time scales that implementing a temporal sampling design requires a long-term commitment that enables teasing apart true change from environmental noise (i.e., variation). Thus, one of the key values of the I&M program is its long-term prospect. Frequent changes in monitoring protocols in the attributes being monitored and how they are being monitored would likely lead to an ever-weakening ability to meet the program goals, leading to erosion of support, further weakening the program, etc. Thus, at the outset the SOPN needs to be vigilant about disruptive change in our monitoring, while at the same time recognizing that changing resources and management regimes may require some degree of flexibility. The difficulty lies in finding the right balance between maintaining the necessary consistency to meet our program goals with enough flexibility to meet the challenges of changing natural and political environments. Thus, when making changes in protocols, the following questions should be addressed:

1. What are the criteria for determining whether or not a change is warranted? These should reflect the general themes identified above:
 - Reliability - The data are not reliable in their present form

- Applicability- The data are not applicable to managers, the public, etc. in their present form
- Feasibility- The data are not feasible to obtain in their present form (e.g., funding, logistics, priorities, etc).

If it is determined that a change is required, what programmatic element needs to be changed?

- Objectives?
- Design?
- Field Methods?
- Data Management?
- Analysis?
- Reporting?

Note: Changing a vital sign or an objective is far more drastic than changing a reporting method. Thus the criteria for making changes to different elements may reflect their relative degree of severity.

2. What is the procedure for making the change?

What precautions will be taken to ensure that the revised protocol will be acceptable?

- Pre-change reviews (based on planned changes)?
- Post-change reviews (based on results from implemented changes)?
- Testing concurrent with existing protocol?
- Post-change analyses

3. How will the transition to the revised protocol be accomplished?

- Will there be a period of overlap; if so, how?

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