PART I: VEGETATION OF
PETRIFIED FOREST NATIONAL PARK, ARIZONA

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Geography of Petrified Forest NP

Petrified Forest National Park (Petrified Forest NP) is located in the Lower Puerco River watershed in Navajo and Apache Counties, northeastern Arizona (Figure 1). Its surface area is more than 147 square miles (approximately 38,000 ha). Areas bordering the park include state owned lands, mostly used as cattle allotments, private cattle ranches and the Navajo Nation. The nearest town is Holbrook, Arizona, 22 mi (35 km) to the west.

Figure 1. Location of Petrified Forest NP.

The park's average elevation is 5500 ft (1680 m) and ranges between 5340 ft in the Puerco River corridor to 6230 ft at Pilot Rock (1620 m to 1890 m). Gently rolling hills characterize the terrain in the south and steeply eroded badlands in the north. The park is divided by the Puerco River into a northern section, added in 1932, to protect the natural resources of the Painted Desert region, and a southern section, set aside in 1906 to protect the petrified wood accumulations of Rainbow Forest, Crystal Forest and other major outcrops in the area.

Much of the parks' watershed drains into Puerco River; the main tributaries being Lithodendron, Dead, Ninemile and Dry Wash. In the southern part of the park Cottonwood and Jim Camp Wash drain directly into the Little Colorado River.

The park is known for its geologic features derived from the Triassic. Mudstone, siltstone, claystone and volcanic ash are prevalent in the surficial geology (Chronic 1988) and have been described in Bezy et al. (1975) and Colbert et al. (1985). However, only a draft geologic map exists for the park (Billingsly 1985). The Soil Conservation Service (Miller and Kermit 1975) mapped the soils of Petrified Forest NP and surrounding Apache County.

The park is bisected east/west by Interstate 40 (I-40) in the northern section and is accessible by the mainly north/south Park Road, which connects I-40 with Highway 180 south of the park. The Park Road serves approximately 700,000-900,000 people/year (US-DOI/NPS 1992). Former Route 66 in the northern section and old Highway 180 in the southern section also cross the park. Both are in deteriorating condition and are closed to the public. There are also a number of dirt roads of different age and purpose. Many of these are closed to public traffic and serve park-maintenance needs.

Climate

Two distinct precipitation periods provide moisture to the park, one during the winter months and the other during the summer months. Winter storms are primarily influenced by the Mogollon Rim, which stretches across the central part of Arizona. Petrified Forest NP is located on the rain shadow side of this mountain and canyon region. During the winter, precipitation originates from low-pressure systems that travel eastward from the east Pacific and is deposited as snow or rain as it encounters the Mogollon Rim. However, the Mogollon Rim acts as an orographic barrier reducing the amount snow and rain that actually reaches the park. When precipitation does occur from winter storms, gentle showers followed by strong winds characterize it.

Summer storms originate from monsoon-like activity arising in the Gulf of California and result in heavy isolated rain. These July, August and September monsoons create excessive run off that leads to most of the erosion activity within the park. Petrified Forest NP experiences very dry months with little or no rainfall in the late fall (October and November) and spring months (April, May and June, 8% of the annual precipitation, Western Regional Climate Center 2002). The total annual rainfall in the park is approximately 9.6 in (243.5 mm) per year (Western Regional Climate Center 2002).

Winter is a variable season at the park, ranging from warm winter temperatures in the sixties (F°) to extreme subzero temperatures. Mid-summer daily temperatures occasionally exceed one hundred degrees, but low humidity and clear skies generally tend to keep summer nights cool. On average, the maximum temperature for summer months is 90° F and the minimum temperature is 60° F (Western Regional Climate Center 2002).

The present day climate of the park is windy and semi-arid (Burton 1990). High winds are a feature of the Painted Desert Basin, which are caused by winds on the east side of the San Francisco Peaks (Smiley et al. 1984). The prevailing wind direction in Winslow, the closest recording station, is southeast to southwest. Peak wind speed can easily reach 50-60 mph, during any month of the year (Western Regional Climate Center 1999). Wind speeds of about 20 knots (about 23 mph) are common throughout spring (Smiley et al. 1984). During the summer monsoons, dust storms (haboobs) occur frequently (Smiley et al. 1984). These dust storms often exceed 12 knots (about 14 mph), the threshold wind speed for sand grain movement (Smiley et al. 1984)

Vegetation Alliances

Introduction

Vegetation ecologists usually describe assemblages of plants by a classification system, which assumes that there are characteristic and repeated groupings of species across the environment. Classification systems are a heuristic method to describe the patterns observed irrespective of the processes that underlie the patterns.

The Federal Geographic Data Committee (FGDC) recognized the need for a federal standard for vegetation classification and reporting of vegetation statistics (1997). To that end, they adopted the National Vegetation Classification (NVC) for inventory, mapping and reporting on vegetation resources. The standard derives from earlier work on vegetation classification such as the UNESCO (1973), Driscoll et al. (1984) and Grossman et al. (1998).

NVC is a hierarchical classification with the upper levels (system, class, subclass, group, subgroup and formation) describing physiognomic levels of the vegetation and the lower levels (alliance and association) based on floristic levels of the vegetation. The standards (FGDC 1997) describe the upper level categories, but do not yet describe alliances and associations.

An alliance is a ‘physiognomically uniform group of plant associations sharing one or more dominant or diagnostic species, which as a rule are found in the uppermost stratum of the vegetation’ (Grossman et al. 1998). An association is ‘characterized by diagnostic species that occur in all strata (overstory and understory) of the vegetation’ (FGDC 1997). The Nature Conservancy (TNC) developed an initial listing of alliances and associations in the United States. More recently, the Association for Biological Information (ABI), which originated in TNC, developed preliminary descriptions of alliances in the Western United States (Reid et al. 1999) as part of the Gap Analysis Program. These descriptions are from extensive literature review of existing vegetation descriptions.

NatureServe, formerly the ABI, now maintains a repository of occurrence descriptions of alliances and associations. This repository, the Biological Conservation Datasystem database, is part of NatureServe's International Classification of Ecological Communities (ICEC). ICEC is currently the only source for review and national documentation of NVC alliances and associations.

The FGDC is engaging upon development of standards for alliance and association description within the NVC. The Ecological Society of America's (ESA) Vegetation Classification Committee is developing proposed standards for alliance and association classification (Jennings et al. 2002) and developing a registry database (VegBank) for plot data (see http://www.vegbank.org/index.html). FGDC will consider the ESA proposed standards as well as proposed standards developed by the US Forest Service in further refinement of the NVC.

Method

We sampled, described and classified vegetation types throughout the park. This phase of the work included field sampling of 190 relevés and multivariate analysis of the resulting data to characterize vegetation alliances in the park. We measured field relevés in 1996 (85 relevés) and 1997 (105 relevés). NatureServe, a non-governmental organization, reviewed Alliance classifications.

Sampling design

In 1996 we measured vegetation in relevés along roadsides. We did this as part of the assessment of an existing 1:24,000 scale map (see Vegetation Distribution below). Relevés were measured at least 100 meters from roadsides and were placed adjacent to public land survey markers that are parallel to the road or where a different vegetation type was observed that would not be captured by placement next to the public land survey marker.

In 1997 sampling locations were determined using a sampling design based on identifying environmental types within the park. We identified digital maps (coverages) of environmental factors considered important in vegetation distribution such as geology, soils, and elevation. Using a geographic information system (GIS), we derived slope and aspect from the elevation coverage. A coverage of each environmental factor was recoded into discrete classes and then overlain with the other environmental factor coverages to stratify the park. We identified five sampling areas based on the criteria to maximize sampling of the environmental types and to minimize access time. Random points for 210 sampling locations were assigned within the 5 sites.

The pre-selected random relevé coordinates were located in the field using global positioning systems (GPS) and topographic maps. Differential correction was not used; therefore, geopositional accuracy is +/- 100 meters for all UTM coordinates.

Relevé measurements

The relevés consisted of a circular 500 sq. meter plot. To establish the plot, we used two measurement tapes. Each tape was laid to intersect and cross in the center of the plot at a radius of (12.2m). The tapes form four radii of the circular plot, which allows plot circumference to be interpolated from the marked ends of each of the four radii formed by the crossed tapes.

Trained observers used a standardized data sheet to collect data on the floristic and environmental features of each plot. Table 3 lists the categories of data collected and the features for each.

Table 1. Data items for field relevés.

Category	**Feature**
Site information	Relevé code Geographic position: GPS coordinates, datum, GPS error, UTM zone, Quad Name Relevé size Directions to relevé Survey date Surveyors Photo information
Environmental description	Elevation Slope Aspect Landform Substrate Surface cover Hydrology Soil Texture Disturbance on site
Vegetation	Leaf type Leaf phenology Strata (height class) Physiognomic class (lifeform) Plant species (perennial) Plant cover (calibrated ocular estimate)

Floristic analysis of relevé data

In order to classify the vegetation we conducted a multivariate floristic analysis using a matrix of all relevés by species cover estimate. All analyses were done using an Excel spreadsheet or with a vegetation classification and ordination software program, PC-Ord v4 (McClune and Mefford 1999).

We calculated the total cover of each relevé by adding the cover by lifeform, that is the forbs, grasses, shrubs and trees in each relevé. Relevés were separated into individual matrices based on vegetation cover and species cover within lifeform class. Unvegetated relevés were identified to be those with 2% or less cover. In order to divide the remaining relevés into formation classes, we calculated the relative proportion of grass, shrub and tree species to total cover. Relevés with shrubby species comprising at least 25% of the relative cover were separated in a matrix of shrub formation relevés. Herbaceous formation relevés had grass species comprising at least 25% relative cover and shrubs less than 25% of the relative cover. No relevés had 25% or more tree cover.

Each formation matrix was imported into PC-Ord for further analysis. Twinspan, a divisive cluster analysis method, was first used to examine the species and relevé separation using 10, 25 and 50% cut levels for species cover classes. Twinspan produces a table that classifies sites (relevés) and species. We identified initial species and relevé groupings and the species characteristic to the groupings with this step.

We applied group averaging to the matrices, a multivariate cluster analysis technique that defines groups of relevés based on their similarity, with the distance measure defined as by Sorensen's coefficient (also known as the Czekanowski or Jaccard coefficient). We then examined available descriptions of alliances to identify alliances that potentially described the relevé groups determined in the group averaging. Each relevé in the group averaging cluster was labeled with a preliminary alliance label. We labeled each relevé by iteratively examining the alliance descriptions, the matrix of cover values for each species, the Twinspan grouping of species by site and the group averaging clusters.

NatureServe reviewed the preliminary alliance assignments and provided descriptions of each (see Appendix A).

Results and discussion

Summary of all relevés

One hundred ninety relevés were measured (Figure 2). We classified one hundred eighty-six relevés to NVC alliances or provisional alliances. NVC descriptions of each alliance throughout their global range appear in Appendix A.

We could not assign an alliance type to four relevés because of unidentified grass species. We eliminated these relevés from further analysis for classification purposes. This may be due to the grasses at Petrified Forest NP being difficult to separate without floristic parts. The summer of 1996 was a particularly dry year and we had to identify many of the grasses using flowering parts (florets) that remained from the previous year. Where floristic parts did not exist, identification to species was problematic. In addition, errors were made in recording the location coordinates for thirteen relevés and, therefore, the relevés cannot be precisely relocated.

Of these relevés, the 15 most common species occurred in 20% or more of all relevés (Table 2). All 15 of these species had a low mean cover (less than 10%) on all of the relevés. Three species; galleta (*Pleuraphis jamesii*), snakeweed (*Gutierrezia sarothrae*), and alkali sacaton (*Sporobolus airoides*) occurred in greater than 70% the total relevés sampled.

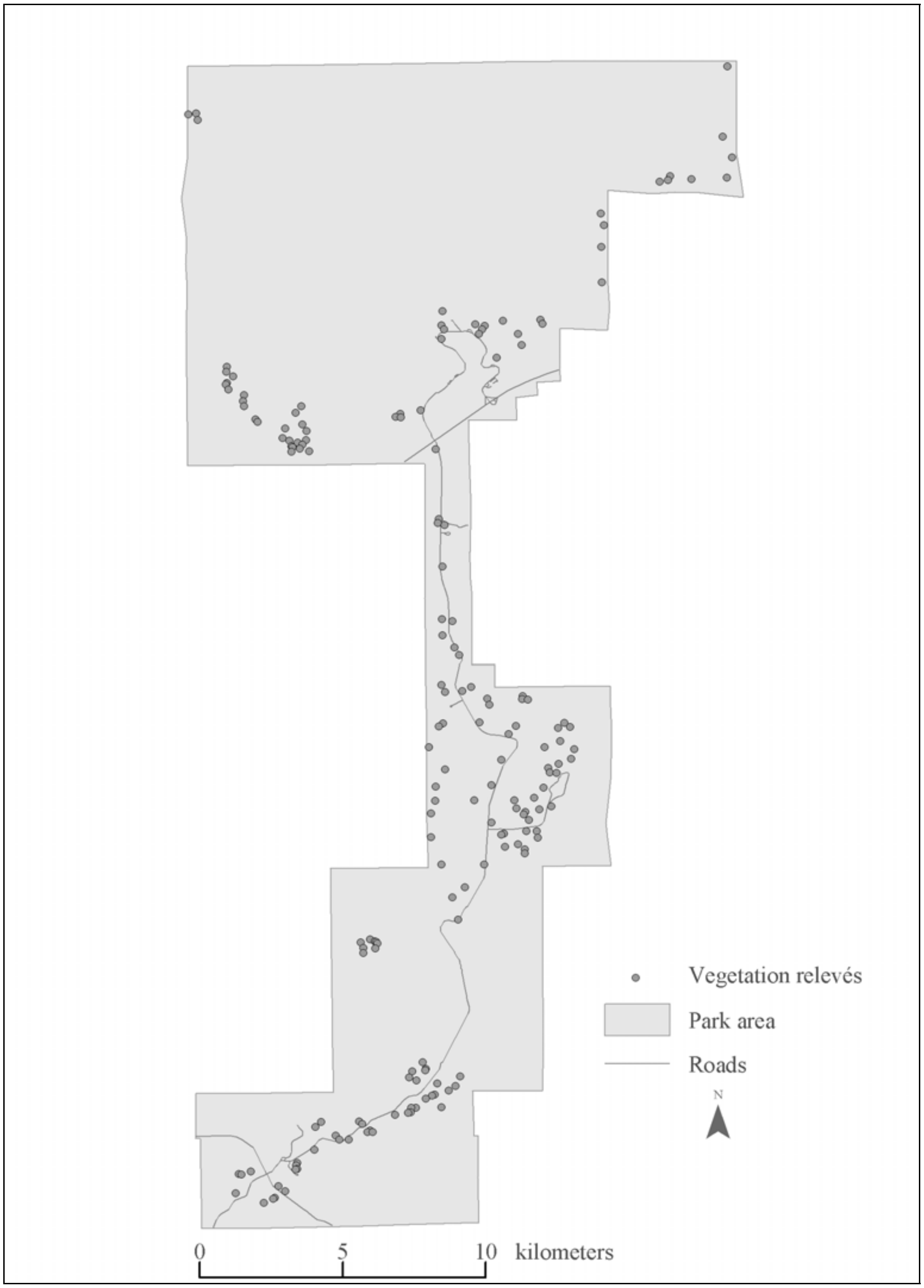

Figure 2. Location of relevés sampled at Petrified Forest.

Table 2. The fifteen most common species at Petrified Forest NP.

Species Name	Common Name	Mean [1]	SD[2]	Max[3]	#[4]	Freq[5]
Pleuraphis jamesii	galleta	5.2	8.2	51	138	74.2
Gutierrezia sarothrae	snakeweed	3.1	4.8	30	136	73.1
Sporobolus airoides	alkali sacaton	5.8	8.2	37	134	72.0
Achnatherum hymenoides	Indian ricegrass	1.4	3.3	27	92	49.5
Atriplex obovata	New Mexico saltbush	2.0	4.6	41	89	47.8
Bouteloua gracilis	blue grama	6.3	11.8	70	88	47.3
Opuntia sp.	prickly-pair	0.3	0.4	2	82	44.1
Yucca angustissima	narrow-leaved yucca	0.3	0.4	2	72	38.7
Atriplex confertifolia	shadscale	0.5	1.3	13	62	33.3
Atriplex canescens	four-winged saltbush	1.3	4.0	30	60	32.3
Ericameria nauseosa	rubber rabbitbrush	1.0	2.9	17	48	25.8
Parryella filifolia	dunebroom	1.0	2.8	23	46	24.7
Artemisia bigelovii	Bigelow's sagebrush	0.8	2.1	14	44	23.7
Ephedra torreyana	Torrey's jointfir	0.4	1.3	8	44	23.7
Isocoma drummondii	Drummond goldenweed	0.6	2.5	22	41	22.0

1 Mean cover on all relevés
2 Standard deviation of mean cover
3 Maximum cover on all relevés
4 Number of relevés on which it occurred
5 % of occurrence among all relevés

Shrubland alliances

We classified 20 relevés into six shrub alliances and 35 relevés were classified into four dwarf-shrub alliances. The NVC distinguishes between dwarf-shrub and shrub alliances by the height of the shrub. NVC defines dwarf-shrubs to be on average <0.5m and shrubs to be between 0.5-2m. However, these distinctions are currently in review and may be eliminated from the NVC formation hierarchy.

For our analyses we choose to combine both shrub and dwarf-shrub species in our total shrub cover, since many of the shrubs at Petrified Forest NP range between dwarf-shrub and shrub height. We also felt that by splitting the cover into dwarf-shrub and shrub formations that we were artificially dividing the total shrub cover, which could result in the appearance of a lower total shrub cover than we determined in the relevés. Therefore, we combined all shrubs into one single total cover value for our classification. However, we did retain the naming convention currently used by the NVC and have separate dwarf-shrub and shrub alliances.

Shrublands and dwarf-shrublands are generally classified by their total shrub cover greater than 25% and grass cover less than 25%. In some cases relevés had more than 25% herbaceous species, but were classified in the shrub formations due to the dominance of overstory shrubs.

Bigelow's Sagebrush Dwarf-Shrubland Alliance

We classified twelve relevés with 47 total species to Bigelow's Sagebrush (*Artemisia bigelovii*) Dwarf-Shrubland Alliance. The number of species in each relevé ranged from 12 to 26. Shrubs dominated these relevés (13 to 38% total cover) and had a total cover of 20 to 43%. Herbaceous cover was generally low (1-13%). Relevés often occurred on mesa rims and slopes.

These relevés are characterized by Bigelow's sagebrush (3-14% total cover), which is an indicator for the alliance. Other shrubs that could be present are cliffrose (*Purshia stansburiana*, 0-8% cover), crispleaf buckwheat (*Eriogonum corymbosum*, 0-10% cover), dunebroom (*Parryella filifolia,* 0-10% cover), shadscale (*Atriplex confertifolia*, 0-4% cover), snakeweed (*Gutierrezia sarothrae*, 0-13% cover), Torrey's joint-fir (*Ephedra torreyana*, 0-8% cover), Mormon tea (*Ephedra viridis*) and grassy rockgoldenrod (*Petradoria pumila*). Galleta (*Pleuraphis jamesii*) was the most prevalent grass (0-7% cover).

Bigelow's sagebrush commonly occurs in rimrock substrate in the southern Great Basin (Welsh et al. 1987) and in Apache, Navajo and Coconino counties of northern Arizona (Kearney et al. 1960). The alliance in Petrified Forest NP has a higher total cover and cover of Bigelow's sagebrush than the stands as previously described based on observations from SE Colorado. Descriptions of the alliance throughout its range are in Appendix A.

Drummond Goldenweed Shrubland Alliance (Provisional)

We classified two relevés with 17 total species to Drummond Goldenweed *(Isocoma drummondii)* Dwarf- Shrubland Alliance. These relevés were dominated by Drummond goldenweed (20 and 22% cover) and had a total cover of 51 and 61%. Shrub cover was 30 and 37%. Herbaceous cover was moderate in both relevés (20 and 24%). Relevés were often found on level or gently sloping sand soil.

In addition to Drummond goldenweed, alkali sacaton (*Sporobolus airoides,* 12-15% cover) and galleta (*Pleuraphis jamesii*, 5-8% cover) were present in both relevés. Other shrubs that could be present with less cover are greasewood (*Sarcobatus vermiculatus*), New Mexico saltbush (*Atriplex obovata*), shadscale *(Atriplex confertifolia*), and snakeweed (*Gutierrezia sarothrae*).

Drummond goldenweed was previously classified as *Haplopappus drummondii* (Welsh et al. 1987) or apparently as *Aplopappus drummondii* (Kearney et al. 1960). The species occurs in Apache, Navajo and Coconino counties in northern Arizona (Kearney et al. 1960) and in southeast Utah (Welsh et al. 1987). The alliance has not been recognized to-date in the NVC. Recognition requires at least five plot descriptions as well as review. The alliance is presented as provisional in this report and will require more field description before it can be considered for inclusion in the NVC.

Dunebroom Shrubland Alliance (Provisional)

We classified three relevés with 31 total species to Dunebroom (*Parryella filifolia*) Shrubland Alliance. Total cover was 30-58% and shrub cover was 14-36%. Grass cover ranged from 11 to 21%, forbs 1-4% and one relevé had 4% tree cover. Relevés occurred on a variety of landforms including terraces, washes and floodplains.

The relevés were characterized by dunebroom (7-23% total cover). All three relevés contained the grass alkali sacaton (*Sporobolus airoides*, 5-15% cover) and other grass included galleta (*Pleuraphis jamesii*, 0-7% cover) and giant sandreed (*Calamovilfa gigantea*, 0-6%). Other shrubs present were rubber rabbitbrush (*Ericameria nauseosa*) (0-8% cover) and snakeweed (*Gutierrezia sarothrae*) (0-5% cover). Dunebroom serves as an indicator species in this alliance, but only where *Artemisia bigelovii* (Bigelow's sagebrush) is not present or only present in trace amounts. If Bigelow's sagebrush and dunebroom are both present as indicators, the site is classified as Bigelow's Sagebrush Dwarf-Shrubland Alliance.

Dunebroom occurs from Apache, Navajo and Coconino counties in northern Arizona (Kearney et al. 1960) and in Grand and San Juan counties in Utah (Welsh et al. 1987). This alliance has not been recognized to-date in the NVC and we present it as provisional in this report. Additional observations will be required for inclusion into the NVC.

Four-wing Saltbush Shrubland Alliance

We classified four relevés with 18 total species to Four-wing Saltbush (*Atriplex canescens)* Shrubland Alliance. The number of species in each relevé ranged from 4 to 15. These relevés had shrub cover from 25% to 33% cover and a total vegetation cover of 72-85%. Herbaceous cover was fairly high (45-60%), hence the alliance has a 'steppe' like appearance at Petrified Forest NP. We measured little forb cover and no tree cover. The relevés occurred on sandy or clay loam soils with low slope (1-7%).

The relevés were characterized by the presence of at least 19% four-wing saltbush (19-30%). Galleta (*Pleuraphis jamesii)* and alkali sacaton (*Sporobolus airoides*) consistently occurred in the relevés with 5-28% and 5-37% cover, respectively. An unidentified needle-and-thread species (*Hesperostipa* spp.) and grama grass (*Bouteloua* ssp.) occurred in one relevé with 25% and 5% cover, respectively. Shrubs that were common include Bigelow's sagebrush (*Artemisia bigelovii*, 0-6% cover) and snakeweed (*Gutierrezia sarothrae,* 0-5% cover).

Four-wing saltbush occurs on saline soil and sandy soil but is not restricted to that substrate. It occurs throughout northern Arizona (Kearney et al. 1960) and southern Utah (Welsh et al. 1987).

New Mexico Saltbush Dwarf-Shrubland Alliance

We classified eight relevés with 22 total species to New Mexico saltbush *(Atriplex obovata)* Dwarf- Shrubland Alliance. Shrub cover was between 8 to 49% and total cover 10 to 62% Grass cover was between 1 and 26%, forb cover was slight (0-1%) and there was no tree cover. New Mexico saltbush total cover ranged from 3 to 41%. In all relevés New Mexico saltbush contributed to at least one-third, and often more, of the total cover. Alkali sacaton (*Sporobolus airoides*) ranges from 0-25% cover and galleta (*Pleuraphis jamesii*) from 0-6% cover.

New Mexico saltbush occurs generally in southern Arizona (Kearney et al. 1960) and in San Juan County in Utah (Welsh et al. 1987). While this alliance occurs in the NVC, it is not described in Arizona. Description of the alliance throughout its range is in Appendix A.

Rubber Rabbitbrush Shrubland Alliance

We classified six relevés with 32 total species to Rubber Rabbitbrush (*Ericameria nauseosa)* Shrubland Alliance. The number of species in each relevé ranged from 11 to 17. Total cover was 22-85%; shrub cover 12 to 37%. Herbaceous cover ranged from 6-48%. Forb cover was low (0-2%). There was no tree cover. The relevés occurred on low slopes (0-4%) on sand and sandy loam soils.

The relevés were characterized by the presence of at least 6% rubber rabbitbrush (6-17% cover). Other shrubs that can be present include buckwheat (*Eriogonum* spp., 0-12 cover), New Mexico saltbush (*Atriplex obovata,* 0-5%), sandsage (*Artemisia filifolia,* 0-5%) and snakeweed (*Gutierrezia sarothrae*, 1-10%). The grasses alkali sacaton (*Sporobolus airoides,* 2-20%), blue grama (*Bouteloua gracilis,* 0-10%), galleta (*Pleuraphis jamesii,* 0-15 %) and sandhill muhly (*Muhlenbergia pungens*, 0-7%) were common. All the relevés except one had grass cover less than 25% and shrub cover nearly equal to or greater than the grass cover. The one relevé with higher grass cover (47%) also had high shrub cover (37%). An alternate interpretation of this relevé is as an alkali sacaton dominated alliance; however, alkali sacaton alliances in the park are characterized solely by herbaceous species and not by a shrubby herbaceous component. Therefore, we classified this relevé as Rubber Rabbitbrush Shrubland Alliance due to the high cover of rubber rabbitbrush shrubs.

Rubber rabbitbrush can be an indicator of grassland deterioration (USDA 1988, Stubbendieck et al. 1997). It occurs throughout northern Arizona (Kearney et al. 1960) and southern Utah (Welsh et al. 1987). Descriptions of the alliance throughout its range are in Appendix A.

Sandsage Shrubland Alliance

We classified six relevés with 32 total species to Sandsage (*Artemisia filifolia)* Shrubland Alliance. The number of species in each relevé ranged from 8 to 15. These relevés had moderate shrub cover (24 to 45% shrub cover) and had a total cover of 44 to 70%. Grass cover could range from low to moderate (7-37%). The relevés were on low slopes (2-5%) in sand or sandy loam. We found little forb cover (0-2% cover) and no tree cover.

The relevés were characterized by the presence of at least 10% sandsage (10-31% cover). Other shrubs that can be present include buckwheat (*Eriogonum* spp., 0-10%), four-wing saltbush (*Atriplex canescens,* 0-3%), rubber rabbitbrush (*Ericameria nauseosa,* 0-10%) and snakeweed (*Gutierrezia sarothrae,* 0-8%). Grasses commonly present are blue grama (*Bouteloua gracilis,* 0-20%), Indian ricegrass (*Achnatherum hymenoides,* 0-15%) and sandhill muhly (*Muhlenbergia pungens,* 0-10%).

Sandsage commonly occurs on sandy soil throughout northern Arizona (Kearney et al. 1960) and southern Utah (Welsh et al. 1987). Additional information on the alliance throughout its range is in Appendix A.

Snakeweed Dwarf-Shrubland Alliance

We classified twelve relevés with 43 total species to Snakeweed (*Gutierrezia sarothrae)* Dwarf-Shrubland Alliance. Individual relevés had 8 to 15 species. Shrub cover ranged from 16-46% and total cover ranged between 20 and 80%. Herbaceous cover was low to moderate (4-42%).

These relevés are characterized by the presence of the dwarf-shrub snakeweed (7-30% cover). Generally this species constituted half of the shrub cover. Other shrub species were common such as dunebroom (*Parryella filifolia*, 0-8%), Bigelow's sagebrush (*Artemisia bigelovii*, 0-5%), four-wing saltbush (*Atriplex canescens,* 0-6%) and pricklypear (*Opuntia* sp., 0-1%). Grass species such as alkali sacaton (*Sporobolus airoides*, 0-10%), blue grama (*Bouteloua gracilis*, 0-40%), galleta (*Pleuraphis jamesii*, 0-10%), needle-and-thread (*Hesperostipa* spp., 0-20%) and Indian ricegrass (*Achnatherum hymenoides*, 0-10%) were common in the relevés.

Tamarisk Semi-natural Temporarily Flooded Shrubland Alliance

We identified one relevé as Tamarisk (*Tamarix* spp.) Semi-natural Temporarily Flooded Shrubland Alliance. This alliance had only 9 species, low cover, 10%, and half of that was the invasive exotic species of tamarisk. This alliance is non-native and often replaces native alliances. Tamarisk is noxious in New Mexico and Colorado (Southwest Exotics Plant Information Clearinghouse 2002). While only one relevé was measured, extensive areas dominated by tamarisk do occur along the Puerco River corridor. Description of the alliance throughout its range is in Appendix A.

Wild-privet Temporarily Flooded Shrubland Alliance

We classified one relevé, found along the Puerco River drainage, with seven total species to Wild-privet (*Forestiera pubescens)* Temporarily Flooded Shrubland Alliance. The relevé had 12% cover of wild-privet and a total cover of 56%. Total shrub cover was 37%

and grass cover was 19%. Other species present were alkali sacaton (*Sporobolus airoides*, 18% cover), four-wing saltbush (*Atriplex canescens*, 7%) and rubber rabbitbrush (*Ericameria nauseosa*, 14%).

Grassland alliances

Ninety six relevés were represented in the grassland formation. Eighty-one species collectively occurred in these relevés and ten alliances were identified (Appendix A). Distinction between the grass alliances and between the 'shrub' or 'dwarf-shrub' expressions of these types is a function of both the total cover of the grass and shrubs and the cover of the component species' in relationship to each other.

The NVC criteria for grasslands is at least 25% graminoid species and no woody species with greater than 25% cover. If the relevé showed less than 25% graminoid species and species in other lifeforms were also less than 25%, then the relevé had to have at least 10% graminoid species to be considered a grassland. If shrubby species were greater than 10% but less than 25%, and the graminoides were >25% then the relevé was considered to be a Shrub Herbaceous Alliance. Since the occurrence of shrubs in the grasslands is common in Petrified Forest NP, an alliance may have both a shrubby and non-shrubby form; if this were to occur, we present alliance descriptions sequentially.

Three grass species are widespread in the park: galleta (*Pleuraphis jamesii*), alkali sacaton (*Sporobolus airoides*) and blue grama (*Bouteloua gracilis*). These grasses occur in mosaics of nearly pure stands and in combination with each other. These grasses can co-occur and the alliances can intergrade. Distinction between the alliances depends on the proportion of each grass, and in the case of the shrub herbaceous alliances, the amount of shrubs in the alliance. We developed decision rules for Shrub Herbaceous and Herbaceous alliances in conjunction with discussion with NatureServe and are in Appendix B. These criteria are continuing to evolve with additional plot data in arid grasslands and the most recent criteria should be determined before application to vegetation types outside of Petrified Forest NP.

Alkali Sacaton Herbaceous Alliance

We classified thirteen relevés with 41 total species occurring in the Alkali Sacaton (*Sporobolus airoides*) Herbaceous Alliance. The number of species in each relevé ranged from 6 to 15. Total cover ranged between 18 and 79%, herbaceous cover between 11 and 63% and shrub cover between 1 and 24%.

Alkali sacaton was the dominant grass in these relevés (10-35%). Blue grama (*Bouteloua gracilis*) and galleta *(Pleuraphis jamesii)* could co-occur but always with lower cover (both 0-6%). Indian ricegrass (*Achnatherum hymenoides*) was an associate in some relevés (0-7%). Occasionally another grass species co-occurred such as hairy grama (*Bouteloua hirsuta*) in one relevé (15% cover), grama (*Bouteloua* sp.) in another (25% cover) or sandhill muhly (*Muhlenbergia pungens*) in another (20% cover). This alliance is determined by examining the relative abundance of alkali sacaton in relationship to galleta and blue grama (Appendix B). Unlike the shrub herbaceous expression of the alliances dominated by galleta and blue grama grasses, a shrub herbaceous expression has not been defined for alkali sacaton dominated grasslands. Shrubs, therefore, can be present up to 24% and can include species such as Drummond goldenweed (*Isocoma drummondii*, 0-10% cover), four-wing saltbush (*Atriplex canescens*, 0-5%), New Mexico saltbush (*Atriplex* obovata, 0-12%), shadscale (*Atriplex confertifolia*, 0-13%) or snakeweed (*Gutierrezia sarothrae*, 0-7%).

Alkali Sacaton Sod Herbaceous Alliance

We classified two relevés with ten total species to Alkali Sacaton (*Sporobolus airoides*) Sod Herbaceous Alliance. The number of species in each relevé ranged from 6 to 9. These relevés had high total cover (58-71% cover) with grass being the major strata (55-61%). Shrub cover was low (3-10%).

Relevés had high total cover (greater than 50%) and high cover of alkali sacaton (20% cover for both), hence forming a sod. Galleta (*Pleuraphis jamesii*) does occur in the relevés (1-5% cover); however, cover is never twice as much as alkali sacaton. Blue grama (*Bouteloua gracilis*) can occur with higher cover (30-40%) than alkali sacaton. These decision rules may be reevaluated with more data on vegetation types characterized with alkali sacaton on the Colorado Plateau.

Black Grama Herbaceous Alliance

Only one relevé was classified as Black Grama (*Bouteloua eriopoda*) Herbaceous Alliance. This relevé contained 18 total species with a low total cover of 24%. Grass species comprised 12% of the plot and was dominated by 5% black grama, with no other dominant grasses. Shrubs covered 10% of the total relevé; however, no particular shrub dominated the relevé.

Blue Grama Herbaceous Alliance

We classified 17 relevés with 43 total species to Blue Grama (*Bouteloua gracilis)* Herbaceous Alliance. The number of species in each relevé ranged from 7 to 17. These relevés had herbaceous cover ranging from 23 to 62% and shrub cover generally less than 10% (2-11%). Where shrub cover was greater than 10%, the grass cover was very high (22 and 45%). Total cover was 30-86%. We measured little forb cover and no tree cover.

Blue grama was always at least 30% (32-91%) of the grass cover. Galleta (*Pleuraphis jamesii*) and alkali sacaton (*Sporobolus airoides*) may co-occur with blue grama, and occassionally galleta may have up to two times the cover of blue grama and still be placed within the Blue Grama Herbaceous Alliance. If blue grama cover is less than 10%, galleta cover should be less than two times blue grama and alkali sacaton less than 10% total cover. Within the relevés measured blue grama cover ranged from 9-39%, galleta from 9-28% and alkali sacaton from 0-25%. Other grass species could co-occur with blue grama including hairy grama (*Bouteloua hirsuta*, 0-15% cover), Indian ricegrass

(*Achnatherum hymenoides*, 0-7%), needle-and-thread (*Hesperostipa comata*, 0-8%) and red three-awn (*Aristida purpurea*, 0-5%). Shrub species commonly present include four-wing saltbush (*Atriplex canescens,* 0-7%), New Mexico saltbush (*Atriplex obovata*, 0-10%) and snakeweed (*Gutierrezia sarothrae*, 0-5%). Pricklypear (*Opuntia* spp.) occurred with low cover (0-1%) in greater than 80% of the total number of relevés. Generally less than 10% or more shrubs distinguishes this type from Blue Grama Dwarf-Shrub Herbaceous Alliance. However, this percentage may be hard to accurately estimate in the field and these two types may not always be readily distinguishable.

Blue Grama Dwarf-Shrub Herbaceous Alliance

We classified fifteen relevés with 46 total species to Blue Grama (*Bouteloua gracilis*) Dwarf-Shrub Herbaceous Alliances. The number of species in each relevé ranged from 6 to 18. These relevés had grass cover generally greater than 25% (24 to 65% grass cover), shrub cover between 10 and 23% and total cover between 46 and 78%. We measured little forb cover and no tree cover.

Relevés were characterized by the presence of blue grama (9-50%). Other grass species could co-occur such as alkali sacaton (*Sporobolus airoides,* 0-7% cover), galleta (*Pleuraphis jamesii*, 0-7%), Indian ricegrass (*Achnatherum hymenoides*, 0-12%), needle-and-thread (*Hesperostipa comata,* 0-20%) and wildrye (*Elymus* spp., 0-10%). Some grass species periodically occurred in the relevés with a high percent cover including an unidentified needle-and-thread (*Hesperostipa* spp.) species that occurred in three relevés with up to 15% cover, sandhill muhly (*Muhlenbergia pungens*) in two relevés with up to 6% cover, an unidentified muhly (*Muhlenbergia* spp.) species also in two relevés with up to 8% cover, and one relevé containing sand dropseed (*Sporobolus cryptandrus*) with 25% cover. A suite of shrubs could be found in the shrubby component: four-wing saltbush (*Atriplex canescens*, 0-12% cover), Bigelow's sagebrush (*Artemisia bigelovii*, 0-8%), Mormon tea (*Ephedra viridis*, 0-6%), New Mexico saltbush (*Atriplex obovata*, 0-10%), sandsage (*Artemisia filifolia*, 0-13%), snakeweed (*Gutierrezia sarothrae*, 0-15%), Torrey's joint-fir (*Ephedra torreyana*, 0-6%) and winterfat (*Kraschenninikovia lanata*, 0-5%). Fineleaf yucca (*Yucca angustissima*) and pricklypear (*Opuntia* spp.) occurred with very low cover (0-2% cover) in greater than 60% of the total relevés.

Galleta Herbaceous Alliance

We classified twenty-three relevés with 54 total species to Galleta (*Pleuraphis jamesii*) Herbaceous Alliance. The number of species in each relevé ranged from 4 to 19. These relevés had grass cover ranging from 5 to 58% and had a total cover of 10 to 70%. Forty-three percent of the relevés had a total cover less than 25%. Shrub cover was almost always less than 10% (4-12%); however, in the relevés with less than 25% cover the shrub cover could be equal or even more than the grass cover. With the addition of observations on galleta grasslands elsewhere on the Colorado Plateau, the alliance designation of low cover grasslands with a high proportion of shrubs may be reevaluated.

Relevés were characterized by the presence of at least 2% galleta (2-50% range observed). Blue grama (*Bouteloua gracilis*) was usually present with 0-15% cover. Alkali sacaton (*Sporobolus airoides*) also commonly occurred in the relevés (0-35% cover observed), but with no more than twice the cover as galleta. Shrubs that were common include New Mexico saltbush (*Atriplex obovata*, 0-10% cover) and shadscale (*Atriplex confertifolia*, 0-4%).

Galleta Dwarf-Shrub Herbaceous Alliance

Twelve relevés were classified as Galleta (*Pleuraphis jamesii*) Dwarf-Shrub Herbaceous Alliance. These relevés contained a total of 34 species. Cover ranged in the relevés from 21-84%; with grass cover ranging from 14-71% and shrub cover generally greater than 10% (9-17%). Little forb (0-2%) and no tree cover were observed. Both a high grass and shrub cover characterize these relevés, thus this alliance has a 'steppe' like appearance at Petrified Forest NP. This alliance can be distinguished from the Galleta Shrub Herbaceous Alliances by dominant shrubs consisting of shrub heights of less than 0.5 meters with a "dwarf-shrub" appearance. However, the distinction between dwarf-shrub and shrubs is currently being reviewed in the NVC and these two alliances may be merged in the future.

The grass component of these relevés are characterized by galleta (*Pleuraphis jamesii*, 1-25%). Other common grasses include blue grama (*Bouteloua gracilis,* 0-20%) and alkali sacaton (*Sporobolus airoides*, 1-15%). Common dwarf-shrubs include Drummond's jimmyweed (Isocoma drummondii, 0-10%), New Mexico saltbush (*Atriplex obovata*, 1-12% cover), shadscale (*Atriplex confertifolia*, 0-12%), and snakeweed (*Gutierrezia sarothrae*, 0-7%).

Galleta Shrub Herbaceous Alliance

We classified seven relevés with 36 total species to Galleta (*Pleuraphis jamesii*) Shrub Herbaceous Alliances. The number of species in each relevé ranged from 8 to 19. These relevés had shrub cover between 15 and 59% and a total cover of 30-72%. Herbaceous cover ranged between 11 and 59%. Hence, the alliance has a 'steppe' like appearance at Petrified Forest NP. We measured little forb cover and no tree cover. This alliance can be distinguished from Galleta Dwarf-Shrub Herbaceous Alliance by many of the shrubs consisting of taller shrubs (>0.5m). However, these shrub size classes may be re-evaluated within the NVC.

The relevés were characterized by the presence of at least 2% galleta (2-51%), <10% blue grama (*Bouteloua gracilis*) and alkali sacaton (*Sporobolus airoides*) cover no more than twice the cover of galleta. An unidentified wildrye (*Elymus* spp.) with 0-5% cover occurred in three relevés. The relevés have more shrub cover than the Galleta Herbaceous Alliance and a wider assortment of shrubs including: Bigelow's sagebrush (*Artemisia bigelovii*, 0-4% cover), dunebroom (*Parryella filifolia*, 0-8%), New Mexico saltbush (*Atriplex obovata*, 0-12%), shadscale (*Atriplex confertifolia*, 0-5%), snakeweed (*Gutierrezia sarothrae*, 0-11%) and Torrey's jointfir (*Ephedra torreyana*, 0-2%).

Hairy Grama Herbaceous Alliance

We classified only one relevé as Hairy Grama (*Bouteloua hirsuta*) Herbaceous Alliance. Fourteen species occurred on the relevé; however, it was clearly dominated by hairy grama at 50% total cover. It had 62.5% grass cover, 11% shrub cover and 74% total cover.

Indian Ricegrass Shrub Herbaceous Alliance

We classified five relevés with 31 total species to Indian Ricegrass (*Achnatherum hymenoides*) Shrub Herbaceous Alliance. The number of species in each relevé ranged from 10 to 15. These relevés had grass cover greater than 25% (26 to 40% cover) and had a total cover of 52-62%. Shrub cover was fairly high (18-29%), hence the alliance appears as a shrubby grassland. Little forb (0-4%) and tree (0-3%) cover occurred in all relevés. The relevés often occurred on slopes with sandy or clay loam soils.

The relevés were characterized by the presence of at least 10% Indian ricegrass (10-27%). Other grasses that found are alkali sacaton (*Sporobolus airoides*, 0-8% cover), galleta (*Pleuraphis jamesii*, 0-10%) and sandhill muhly (*Muhlenbergia pungens*, 0-15%). Blue grama (*Bouteloua gracilis*) does not occur, other than possibly in trace amounts, in this alliance. One relevé had an unidentified grass at 20% cover and could possibly be classified elsewhere depending upon the grass species. Common shrubs are dunebroom (*Parryella filifolia*, 0-15%), fineleaf yucca (*Yucca* angustissima, 0.5-1%), fourwing saltbush (*Atriplex canescens*, 0-1%), rubber rabbitbrush (*Ericameria nauseosa*, 0-14%), snakeweed (*Gutierrezia sarothrae,* 1-10%) and Torrey's joint-fir (*Ephedra torreyana*, 0-6%).

Sparse vegetation alliances

We classified only one sparse vegetation type at Petrified Forest NP. Sparse vegetation typically has less than 10% total vegetation cover but more than 2%. It is difficult to distinguish floristic dominance characteristics of sparse vegetation as surficial geology of the site and low precipitation control species expression.

Painted Desert Sparse Vegetation (Proposed)

Twenty-six relevés with 42 total species were classified to the alliance Painted Desert Sparse Vegetation. The number of species in each relevé ranged from 2 to 17. Some relevés with slightly greater cover (up to 16%) are included in this class if the assemblage of species typically found in Painted Desert Sparse Vegetation characterizes them. Grass cover was 0-4% and shrub 0-10%.

Grasses typical of the Colorado Plateau occur in greater than 20% of the relevés in this alliance: alkali sacaton (*Sporobolus airoides*), galleta (*Pleuraphis jamesii*) and Indian ricegrass (*Achnatherum hymenoides*). Shrubs that commonly occurred in greater than

20% of the relevés include Arizona siltbush (*Zuckia brandegeei* var. *arizonica*), buckwheat (*Eriogonum* spp.), common dunebroom (*Parryella* filifolia), Drummond goldenweed (*Isocoma drummondii*), New Mexico saltbush (*Atriplex obovata*), shadscale (*Atriplex confertifolia*), slenderleaf buckwheat (*Eriogonum leptophyllum*), snakeweed (*Gutierrezia sarothrae*). While any of these species may occur, galleta and alkali sacaton had the most fidelity in the relevés of the grasses and New Mexico saltbush and Arizona siltbush had the most fidelity for the shrubs.

Barren

Barren relevés are those with less than 2% cover. We characterized nine relevés with less than 2% cover.

Vegetation Distribution

Introduction

One initial goal of the project was to develop vegetation map products with appropriate metadata. The USGS/NPS Park Mapping Program has the goals of mapping vegetation types on all parks using the NVC classification system. However, vegetation mapping at Petrified Forest NP was not scheduled in the near future.

Initially we believed that more current vegetation distribution data could be achieved through an update of an existing vegetation map. The Applied Remote Sensing Program, Office of Arid Lands Studies at the University of Arizona (Miller et al. 1977) developed this vegetation map in 1977. They mapped vegetation using color aerial photography (1:24,000). Vegetation types were identified in the field and then delineated on the aerial photography. The Miller team applied a vegetation classification system modified from Lowe and Brown (1973), Poulton (1970) and Kuchler (1964). This map, referred to here as the Miller map, was compiled in hardcopy and was later digitized. Another version of the Miller map, with aggregated vegetation types, was also found at the park (DePoy, pers. comm. 1998). No documentation has been found for this aggregated map with nominal display scale of 1:64K. This version of the Miller map was digitized at the Colorado Plateau Field Station in 1999.

Methods

We evaluated the registration of the Miller vegetation map by creating acetate overlays of the 1977 map scaled to 7.5' topographic quads of the park. During a field reconnaissance trip we compared vegetation polygon boundaries and park boundaries on the overlays with features located on the ground. Significant registration problems were found with the Miller map, including: placement discrepancies of vegetation polygon boundaries, park boundaries and major park roads. We attempted to rubbersheet the map using digital raster graphic (DRG) georeferenced USGS 7.5' digital maps of the park as base maps.

We also reviewed the classification system used in the Miller map and compared it with the existing NVC.

Results and Discussion

We found considerable discrepancies in the placement of vegetation polygon boundaries, park boundaries and major park roads between existing vegetation map coverage and the spatially correct USGS 7.5' topographic maps. Rubber sheeting was unsuccessful due to irregular distortion in the digitized map and the lack of adequate control points.

The Miller map described vegetation by lifeform within landform and soil units or by the landform/soil units alone (Table 3). For each unit a list of dominant species were described in the Miller et al. (1977) report. In comparison the NVC describes vegetation alliances, which are usually identified by the floristically dominant species present.

Table 3. Lifeforms and landform/soil units in the Miller map

- Grassland communities
  - Higher elevation grasslands on sand and gravelly alluvium soils
  - Low and mid elevation grasslands on sandy clay loam soils
  - Low elevation grasslands on moderately saline soils with clay
- Half shrub communities
  - Chinde Mesa, shale substrate
  - Southern park sandstone mesas
  - Sandstone slope and cap
  - Sandstone mesas
- Tall shrub communities
  - High elevation sloping plateaus
  - High elevation plateau relict sand dunes
- Woodlands
  - Mesa top
- Riparian
  - Puerco river channel tamarisk and willow
  - Floodplain
- Active sand dunes
  - Active dune vegetation
  - Active dune vegetation interspersed with grasslands
- Saline areas
- Desert pavement
- Badlands

The Miller map serves as an acceptable coarse view of vegetation in the park. It cannot be used to determine the exact location of any one vegetation type; however, relative positioning of vegetation can be determined. The landform/soil units are field discernable and the diagnostic species are indicative of dominant species found in the park. The classification system provides listings of species, but it does not give any indication of the range of cover expected for the diagnostic species. In actuality, the same set of diagnostic species occur in more than one vegetation type in this map, with the distinguishing feature being the landform or soil type. It does not provide as fine of floristic detail as does the NVC, but it does provide more edaphic information on broad landform/soil correlates of dominant species.

Vegetation Changes Over Time

Introduction

Little to no information exists on the history of vegetation composition and dynamics in the park. Grassland ecosystem health can be more fully evaluated within the park with such information. Repeat photography provides a quantitative tool for direct comparison of vegetation between two dates, hence a measure of vegetation over time. We conducted a pilot project to locate historical photos for the park, relocate their location within the park, and to obtain repeat photography at the site. Parallel to the use of repeat photography, a review was made of land use history in the park (see Appendix C).

Methods

We selected over fifty photographs from the Petrified Forest Museum Archives as potential locations for repeat photography sites. These photographs were selected based on prominent background landform features such as tourist locations, roads, signs, buildings, archeological sites and distinct natural landforms that are easily identifiable. Photograph quality was also a consideration in selection; photographs with detail of vegetation were easier to use for comparison with a repeat photograph. Finally only photographs with original negatives were selected for potential repeat.

The general field locations of potential repeat sites were located, when possible, with vehicle surveys. When the general vicinity was located we investigated on foot to locate the exact place where the photograph was originally taken and noted the location using a geographic positioning system.

Later we revisited the sites with a photographer. We estimated photographic lens, distance, angle and height. Photographs were taken using a Pentax 645 with 75mm black and white Kodak TMX ASA 100 film. At each site several photographs were taken and the main vegetation types were also recorded at each site. After the photographs were developed, a visual comparison of the repeat photographs was made to the original photograph.

Results

Seven original photograph sites were located in the field and repeat photographs were obtained.

Location 1: Giant Logs Trail

Location 1 is along the Giant Logs Trail behind the Rainbow Forest Museum at a large piece of petrified wood named “Old Faithful” (Figure 3). Photograph 1 was taken prior to 1941. At that time an unofficial trail was maintained near this area. Photograph 2 was taken October 24, 1998. Since the 1941 photograph, an official trail was constructed and paved. A concrete tier was created to pedestal the “Old Faithful” log. Concrete was placed beneath “Old Faithful” to stabilize it. Concrete was also placed underneath a large broken piece of the log. The tail end of the log was broken and is not seen in photograph 2. A trail marker and a trashcan were also placed along the concrete trail.

Photographic display is almost mimicked in photograph 1 and 2 allowing for direct comparison between the two photographs. In photograph 1 the ground cover is sparse with vegetation mainly around the perimeters of the petrified wood. Several tufts of grass are beneath “Old Faithful” with no vegetation within a 2-meter circumference around the log. Two shadscale (*Atriplex confertifolia*) shrubs are near two smaller pieces of petrified wood with sparse grama species (*Bouteloua* spp.) and perennial shrubs. The soil appeared eroded near the “Old Faithful” log, and consisted of gravel and petrified wood beneath a sandy soil. Photograph 2 has more ground cover in the foreground next to the two pieces of petrified wood. A higher abundance of grass species including: alkali sacaton (*Sporobolus airoides*), four-awn (*Aristida* spp.) and Indian ricegrass (*Achnatherum hymenoides*) are seen. A large four-wing saltbush (*Atriplex canescens*) shrub is also seen in the foreground. In the background, large shrubs and grasses are seen near “Old Faithful”. However, the vegetation is bare, around a 1-meter circumference around “Old Faithful”, with several tufts of grass growing beneath the log.

The cement trail has regulated the human impact and promoted vegetation growth around the “Old Faithful” log since photograph 1. Photograph 2 has more shrubs and grasses in the foreground than does photograph 1. Several large shrubs, not present in photograph 1, are seen in the background of photograph 2. However, the soil in photograph 2 appears to be more barren in a small area directly below “Old Faithful” than in photograph 1. This suggests that visitors still walk around “Old Faithful” in the immediate vicinity, however they are more restricted to the cement trail, promoting vegetation growth in the background. In the approximately 60 years time frame new vegetation has grown due to more restrictions of human access in this area.

Figure 3. Location 1: Giant Logs Trail.

(The top photo (photograph 1) was taken in 1941 and the bottom photo (photograph 2) on October 24, 1998.)

Location 2: Giant Logs Trail

This location is along the Giant Logs trail behind the Rainbow Forest Museum (Figure 4). Photograph 1 was taken on July 15, 1929. At that time the NPS headquarters were maintained near this area. An unofficial trail may have been present then near headquarters. Photograph 2 was taken on October 24, 1998 approximately 70 years since the original photograph. The point where this photo was taken is along the "unofficial" part of the trail that is currently unpaved. Presently, park rangers are discouraging people to explore this part of the trail in order to stop erosion and vegetation loss.

Photograph 1 was taken with a different type of lens and at a different angle than the repeat photograph. These differences limit the range of comparison between the two photographs to approximately half of each photographs' range. Further limiting comparison in the first photograph is that the photo quality is dark and shows few morphological features in the plants. This factor makes it difficult to distinguish the bunch grasses from the perennial subshrubs.

In photograph 1 the ground cover is relatively abundant consisting mainly of grasses and small perennial subshrubs. No large shrubs in the foreground are evident. In the background on a mesa cap a mid-sized one-seed juniper (*Juniperus monosperma*) is seen. A road is visible in the background with prominent scaring. Photograph 2 has a closer range with increased focus enabling species differentiation. The ground cover consists of bigelow's sagebrush (*Artemisia bigelovii*), dunebroom (*Parryella filifolia*), rock goldenrod (*Petradoria pumila*), shadscale (*Atriplex confertifolia*), snakeweed (*Gutierrezia spp.*) and abundant unknown graminoids. A road is slightly visible in the background with little scaring. In the background the same one-seed juniper tree is on top of the mesa cap.

Species distinction is difficult in photograph 1. This lack of evidence makes it almost impossible to compare species abundance between the two photographs. Beneath one large piece of petrified wood in the new photograph more bunch grass and subshrubs are seen. The Bigelow's sagebrush (*Artemisia bigelovii*) appears to be a larger shrub in the second photograph; however, this may simply be due to the closer focal range in the new photograph. Both photos have a one-seed juniper tree on the sandstone cap. A road in the background can be seen in both the new and the old photograph. In the new photograph the road scar is less prominent due to less use of the road. A total vegetation cover comparison between the two photographs is approximately equal. The photographs collectively appear to have similar vegetation cover with little to no change in the seventy year time period.

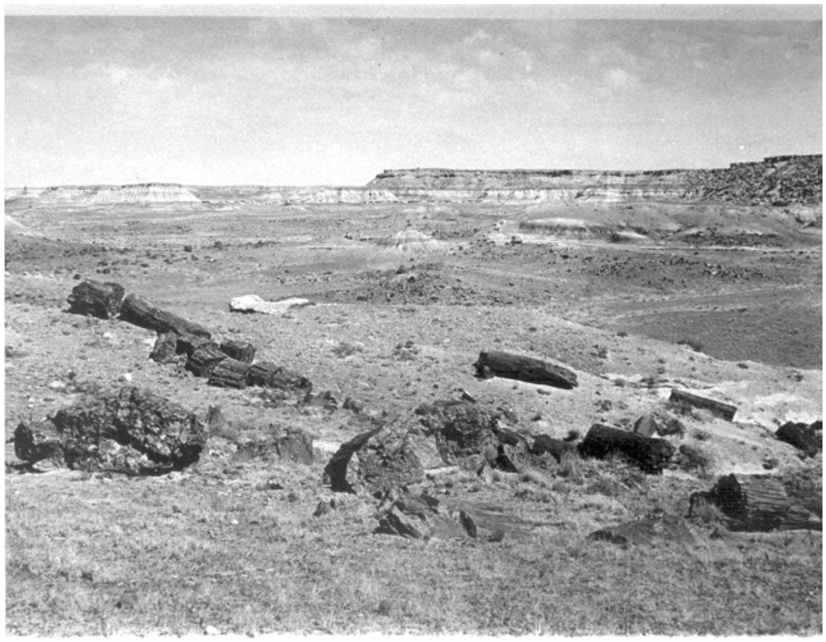

Figure 4. Location 2: Giant Logs Trail.

(The top photo (photograph 1) was taken in July 1929 and the bottom photo (photograph 2) in October 1998.)

Location 3: Giant Logs Trail

This site is behind the Rainbow Forest Museum on the Giant Logs trail (Ffigure 5). George Grant took photograph 1 in October 1934. The photograph was taken soon after the Rainbow Forest Museum was constructed. The building located behind the museum is the old Gisbey's Curio Store. Photograph 2 was taken in October 1998. In this 65 year period the Giant Logs trail was paved and the Rainbow Forest Museum gained an addition. The Curio Store was rebuilt and renamed the Fred Harvey store. Another new addition is the housing complex opposite the Fred Harvey store with ornamental plants in the landscaping.

Several differences between the two photographs limit comparison between the two. Photograph 1 was taken further back and has more foreground than photograph 2. Photograph 1 shows more of the Rainbow Forest Museum and the curio store, whereas photograph 2 shows very little of the Rainbow Forest Museum and the Fred Harvey Store. Photograph 1 was taken from a higher vantage point showing more of the Jim Camp Wash and the Jim Camp Bridge. These framing differences restrict comparison to a small area in front of the two large pieces of petrified wood.

The ground cover in photograph 1 appears to be mostly perennial and annual grasses, subshrubs and perennial herbs. In photograph 1 the soil surface consists of gravel and petrified wood on a sandy soil. Photograph 2 shows only two subshrubs: Bigelow’s sagebrush (*Artemisia bigelovii*) and dunebroom (*Parryella filifolia*). Little to no ground cover is seen in photograph 2 including no grasses. The soil surface in photograph 2 has less gravel and petrified wood and is mostly sandy. Two large Fremont cottonwood (*Populus fremontii*) trees, apparently planted, are seen in the background in photograph 2 near the residences and do not appear in photograph 1.

Effects of human impact on the Giant Logs area is seen in the changes in vegetation over the 65 year time span. Photograph 2 shows only two shrubs, whereas photograph 1 had a fairly abundant foreground of perennial shrubs and grasses. This is probably due to more tourist impact at the photograph 2 site. Another human impact seen in photograph 2 is the growth of two large cottonwood trees near the housing complex. Human impact is also seen in the comparison of the soil surface between the two photographs. Photograph 1 has more petrified wood and gravel; whereas, photograph 2 has more sand and less petrified wood and gravel. Theft and potentially the effect of human foot traffic has removed the gravel and petrified wood pieces. The Giant Logs Trail is the most frequented tourist trail within the park and therefore, is the most severely impacted by tourism.

Figure 5. Location 3: Giant Logs Trail.

(The top photo (photograph 1) was taken in October 1934 and bottom photo (photograph 2) in October 1998.)

Location 4: Jim Camp Wash

This site is between the northwest side of the park road and the east bank of Jim Camp Wash (Figure 6). The photographs were taken looking west towards the Rainbow Forest Museum. Photograph 1 was taken in October of 1934. This photograph shows the Rainbow Forest Lodge and the CCC campgrounds. Photograph 2 was taken in October of 1998. The time span between the photographs is 64 years. The buildings seen in photograph 1 were destroyed and in the new photograph the Fred Harvey store, the Rainbow Forest Museum, picnic tables, and the employee residences are seen.

Photograph 1 shows a much broader background and was apparently taken from a higher vantage point than photograph 2. Photograph 1 shows the Jim Camp wash, whereas in photograph 2 the angle of the camera is not high enough to look into the wash. Photograph 2 is lower to the ground resulting in finer detail in the vegetation morphology, a larger appearing foreground and less skyline in comparison to photograph 1.

Photograph 1 shows high relative vegetation cover. The ground cover contains a high percentage of perennial grasses with a few scattered shrubs. Shrub cover is higher along the banks of the Jim Camp Wash in photograph 1. Jim Camp Wash is prominently displayed in this photograph with sparse vegetation in the drainage. Several one-seed junipers (*Juniperus monosperma*) are also seen in the photograph lining the mesa caps. In comparison, photograph 2 shows a higher shrub to grass cover ratio. Adjacent to the petrified wood Bigelow's sagebrush (*Artemisia bigelovii*) and Torrey's joint-fir (*Ephedra nevadensis*) subshrubs are prevalent along with larger shrubs of four-wing saltbush (*Atriplex canescens*). Dominant grass species in the ground cover are alkali sacaton (*Sporobolus airoides*), blue grama (*Bouteloua gracilis*) and Indian ricegrass (*Achnatherum hymenoides*). The banks of the Jim Camp Wash are not visible in photograph 2; however, high shrub cover appears to extend beyond the banks and to the level ground west of Jim Camp Wash. The shrubs along the banks are predominately rubber rabbitbrush (*Ericameria nauseosa*). In photograph 2 observations were done on the vegetation in the Jim Camp Wash. Numerous species were found in the wash including: dunebroom (*Parryella filifolia*), rubber rabbitbrush, snakeweed (*Gutierrezia sarothrae*) and tumbleweed (*Salsola kali*). In the background one-seed junipers are on top of the mesa caps. Near the residences the trees Fremont cottonwood (*Populus fremontii*) and juniper (*Juniperus* spp.) are seen in the background.

Differences in photographic format do not allow for direct comparison in photograph 1 and 2. However, several main changes are apparent in the repeat photography. Photograph 1 appears to have more of a grass component and less of a shrub component than photograph 2. Photograph 1 is more barren along the banks of the Jim Camp Wash and appears to have less vegetation than in photograph 2. Many more large trees have been planted in photograph 2 that are not seen in photograph 1.

Figure 6. Location 4: Jim Camp Wash.

(The top photo (photograph 1) was taken in October 1934 and the bottom photo (photograph 2) in October 1998.)

Location 5: Agate House

This site is west of "Agate House", approximately 300 meters from the Agate House Trail (Figure 7). Grant took photograph 1 in October 1934; photograph 2 was taken in October 1998. The time span between the repeat photography is 64 years. Photograph 2 was taken after Agate House was reconstructed. Numerous pieces of petrified wood were taken from around Agate House in the restoration of the building.

Differences in photographic angles have caused distortion in the duplication of the original photograph. Photograph 2 was taken closer to Agate House and at more southern angle than photograph 1. One quarter of photograph 1 is not seen in photograph 2 for comparison.

The vegetation in photograph 1 appears to be predominately perennial grasses. In photograph 2 the dominant ground cover is perennial grasses with the dominant species consisting of alkali sacaton (*Sporobolus airoides*) and galleta (*Pleuraphis jamesii*). The ground cover in photograph 1 and 2 appear to have similar percent covers. No major difference is seen in the vegetation between the two photographs. The only noticeable difference seen between these photographs is the removal of the petrified wood around Agate House in photograph 2. Petrified wood was abundant in photograph 1 and almost none is seen around the house in photograph 2, with only bare surface seen around building perimeters.

Figure 7. Location 5: Agate House.

(The top photo (photograph 1) was taken in October 1934 and the bottom photo (photograph 2) in October 1998.)

Location 6: Agate House Trail

This site is west of the Agate House approximately 100 meters from the Agate House Trail (Figure 8). The original photograph was taken in July 1984. Photograph 2 was taken in October 1998, approximately 14 years since the original photograph. No prominent changes in the building structure of the Agate House occurred within the 14-year time period.

Slight differences in the photographic angles and distance of the two photos limits their comparability. Photograph 2 was taken at a further distance and from a more southern angle than photograph 1. Photograph 1 has more focus on the background and little focus on the foreground vegetation, whereas photograph 2 shows distinct resolution in the foreground.

Photograph 1 appears to have a ground cover mainly of perennial bunch grasses. Several large four-wing saltbush (*Atriplex canescens*) shrubs are also seen to the north of Agate House. In photograph 2 the main species are grasses including alkali sacaton (*Sporobolus airoides*) and blue grama (*Bouteloua gracilis*). The large shrubs seen to the north of Agate House are four-wing saltbush (*Atriplex canescens*) and New Mexico saltbush (*Atriplex obovata*).

Both photograph 1 and 2 appear to have the same species dominance. The main species in both photographs are grasses with a couple scattered shrubs. The shrubs appear to be the same species in both photograph 1 and 2.

Figure 8. Location 6: Agate House Trail.

(The top photo (photograph 1) was taken in July1984 and the bottom photo (photograph 2) in October 1998.)

Location 7: King's Throne

This site is approximately 2 miles south of the Blue Mesa turn off and approximately one-half mile east of Dry Wash (Figure 9). This location is not near any marked trails. The photographs were taken facing west towards a large rock structure called "King's Throne". Photograph 1 was taken in 1969 and photograph 2 in October 1998, approximately a 30-year time span.

The photographic angle and distance differed from photograph 1 and 2. Photograph 2 was taken at a further distance and at a more southern angle than photograph 1. These difference cause distortion when comparing the two time periods.

The vegetation in photograph 1 appears to be sparse with clumps of perennial bunch grasses. Petrified wood and gravel appears to be a main component of the soil surface in the photograph. In photograph 2, the ground cover is a mixture of grasses and shrubs. The main species seen in this photograph are: alkali sacaton (*Sporobolus airoides*), blue grama (*Bouteloua gracilis*), galleta (*Pleuraphis jamesii*), shadscale (*Atriplex confertifolia*) and snakeweed (*Gutierrezia sarothrae*).

It appears that in photograph 2 the vegetation cover is approximately doubled from the 1964 photograph. Species richness also appears to have increased from photograph 1 to 2. Species richness and increased total vegetation cover may be due to differences in precipitation and seasonality.

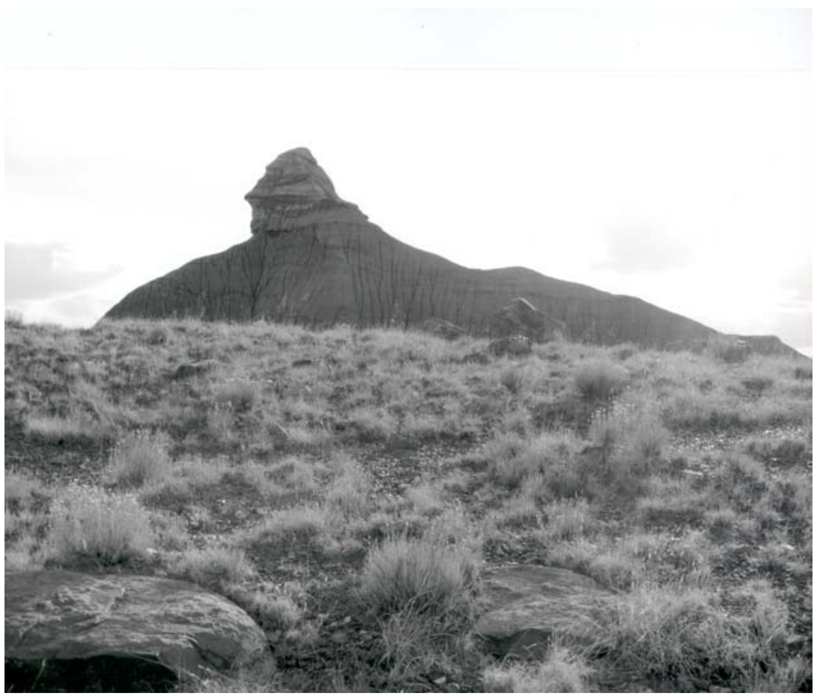

Figure 9. Location 7: King's Throne.

(The top photo (photograph 1) was taken in 1969 and the bottom photo (photograph 2) in October 1998.)

Discussion

Sites that have high tourist visitation have shown changes in the vegetation. Of the seven sites relocated, four of the sites show direct effects of human influence. Three of these sites are located near the Rainbow Forest Museum and the Giant Logs Trail. These locations historically have had the highest impact, due to previous park headquarters being located in this area. Two of these sites show direct adverse repercussions from the high tourist travel along the Giant Logs Trail. Both sites along the Giant Logs Trail show a loss in petrified wood and gravel to the soil component. However, the site of "Old Faithful" shows positive effects of the recent concrete trail, which restricted foot travel and resulted in increased growth in the vegetation. Human influence have also resulted in a change in the buildings structure and increased cultivated plant growth. The other site with direct human impact seen in the repeat photography is adjacent to Agate House. The soil has less of a petrified wood component around Agate House, since much of the petrified wood pieces were used for restoration. However, vegetation around the Agate House has had no visible change within the 64-year time period.

Photographs not in direct proximity to tourist sites showed a variety of changes over time including no apparent change in the vegetation, increased shrub and grass cover and decreased total vegetation cover. The most apparent change in the vegetation was the increase of the shrub to grass component at the Jim Camp Wash site. The shrub component near the Jim Camp Wash has increased substantially over a 64-year time period. Other washes may show similar pattern but there is no documentation. Few sites were located in the grasslands of the park. In the sites that did have a grassland component, grass species composition could not be determined. Grassland areas at two sites seemed to be increasing in total vegetation cover and increasing in shrub component. However, in another site the grass cover seemed to be decreasing. Additional sites are needed to understand historical change in the grassland distributions and to access their overall health. Many more sites are needed in the various vegetation types within the park to further access the vegetation changes.

Conclusions and Recommendations

Petrified Forest NP has had a critical lack of basic information on the flora and vegetation of the park. This report, including Part I and Part II, and Appendices provide critically needed information to the park.

We identified and described twenty-one vegetation alliances at the park an additional barren land cover type. Three of these alliances are new to northern Arizona and proposed in the NVC. The relevé data collected to document the alliances are included on a CD associated with this report.

The intended revision of the Miller map was abandoned as a goal since it had cartographic problems that could not be corrected. The Miller map also reflects a vegetation classification scheme that has been replaced by the NVC structure.

One goal of the NPS Inventory and Monitoring Program is to develop current vegetation maps for the parks. Petrified Forest NP will have a solid basis for proceeding with such mapping with this preliminary identification of alliances and with the relevé data. Additional sampling in the Painted Desert area, along the Puerco River Corridor and in unsampled geological formations is recommended for complete identification of alliance types in the park. The development of finder resolution surficial geology mapping will help identify areas needing more sampling and to clarify the relationships of surficial geology to vegetation expression in the park.

The repeat photography showed impact of visitor use and support the continued management of tourist travel to minimize impact to vegetation. Repeat photography is one means to examine vegetation dynamics during historical times. Fire history, grazing history, response to climate change and increased atmospheric CO_2 can all influence the course of vegetation dynamics. During this preliminary study of the use of repeat photography in the park we were not able to find many useable photos of vegetation away from tourist sites. However, for those photos that were some distance from tourist sties (Location 2, 4, 5, 6 and 7) the vegetation cover had either not diminished or showed increase in shrub or grass cover. Petrified Forest NP may well serve as an example of healthy grassland and steppe vegetation within northern Arizona and the southwestern Colorado Plateau. Invasive exotic species appear to be relatively confined to in proximity to roadways and the Puerco River. The grassland may be showing natural response to release from widespread grazing (see Appendix C) but the evidence is yet inconclusive. Little data currently exists on grassland composition and structure in the southwestern Colorado Plateau to allow comparison. The quantitative composition and structure data provided for each alliance with relevé data provides a basis for comparison of current grassland conditions in Petrified Forest NP to future grassland and steppe conditions and for comparison to grassland and steppe conditions in areas with different intensities of grazing.

In summary we recommend:

1) Characterization of vegetation at Petrified Forest NP will be augmented by the use of a fine resolution surficial geology map and additional relevé sampling of vegetation in those surficial geology units undersampled in 1996 and 1997. Additional sampling is also recommended at fine scale along the Puerco River corridor.
2) A contemporary vegetation map would allow the park to determine the size, locations and environmental context of the vegetation alliances.
3) Vegetation monitoring at the park should include species and habitats of special concern and representative examples of alliances, which occur more extensively.

Understanding of vegetation dynamics during historical times at Petrified Forest NP can be augmented by the development of fire history maps, additional repeat photography, characterization of seasonal and annual variation in vegetation, and cross comparisons of vegetation composition across the southern Colorado Plateau.

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Appendix A: Alliance Descriptions

INTERNATIONAL CLASSIFICATION OF
ECOLOGICAL COMMUNITIES:

TERRESTRIAL VEGETATION OF THE
UNITED STATES

Petrified Forest National Park

Report from
Biological Conservation Datasystem
January 2002

by

NatureServe

1101 Wilson Blvd., 15th floor
Arlington, VA 22209

This subset of the International Classification of Ecological Communities (ICEC) covers vegetation alliances attributed to the Petrified Forest National Park**.** This community classification has been developed in consultation with many individuals and agencies and incorporates information from a variety of publications and other classifications. A fully searchable and periodically updated on-line source for the ICEC is at http://www.natureserveexplorer.org. Comments and suggestions regarding the contents of this subset should be directed to Keith Schulz, Vegetation Ecologist (keith_schulz@NatureServe.org) and Marion Reid, Senior Regional Ecologist (marion_reid@NatureServe.org).

NatureServe

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NatureServe[1]. 2002. International classification of ecological communities: Terrestrial vegetation of the United States. Petrified Forest National Park. NatureServe, Arlington, VA and NatureServe, Boulder, CO [1] NatureServe (formerly called "Association for Biodiversity Information" ("ABI")) is an international organization including NatureServe regional offices, a NatureServe central office, U.S. State Natural Heritage Programs, and Conservation Data Centres (CDC) in Canada and Latin America and the Caribbean. Ecologists from the following organizations have contributed the development of the ICEC:

United States

Central NatureServe Office, Arlington, VA; Eastern Regional Office, Boston, MA; Midwestern Regional Office, Minneapolis, MN; Southeastern Regional Office, Durham, NC; Western Regional Office, Boulder, CO; Alabama Natural Heritage Program, Montgomery AL; Alaska Natural Heritage Program, Anchorage, AK; Arizona Heritage Data Management Center, Phoenix AZ; Arkansas Natural Heritage Commission Little Rock, AR; Blue Ridge Parkway, Asheville, NC; California Natural Heritage Program, Sacramento, CA; Colorado Natural Heritage Program, Fort Collins, CO; Connecticut Natural Diversity Database, Hartford, CT; Delaware Natural Heritage Program, Smyrna, DE; District of Columbia Natural Heritage Program/National Capital Region Conservation Data Center, Washington DC; Florida Natural Areas Inventory, Tallahassee, FL; Georgia Natural Heritage Program, Social Circle, GA; Great Smoky Mountains National Park, Gatlinburg, TN; Gulf Islands National Seashore, Gulf Breeze, FL; Hawaii Natural Heritage Program, Honolulu, Hawaii; Idaho Conservation Data Center, Boise, ID; Illinois Natural Heritage Division/Illinois Natural Heritage Database Program, Springfield, IL; Indiana Natural Heritage Data Center, Indianapolis, IN; Iowa Natural Areas Inventory, Des Moines, IA; Kansas Natural Heritage Inventory, Lawrence, KS; Kentucky Natural Heritage Program, Frankfort, KY; Louisiana Natural Heritage Program, Baton Rouge, LA; Maine Natural Areas Program, Augusta, ME; Mammoth Cave National Park, Mammoth Cave, KY; Maryland Wildlife & Heritage Division, Annapolis, MD; Massachusetts Natural Heritage & Endangered Species Program, Westborough, MA; Michigan Natural Features Inventory, Lansing, MI; Minnesota Natural Heritage & Nongame Research and Minnesota County Biological Survey, St. Paul, MN; Mississippi Natural Heritage Program, Jackson, MI; Missouri Natural Heritage Database, Jefferson City, MO; Montana Natural Heritage Program, Helena, MT; National Forest in North Carolina, Asheville, NC; National Forests in Florida, Tallahassee, FL; National Park Service, Southeastern Regional Office, Atlanta, GA; Navajo Natural Heritage Program, Window Rock, AZ; Nebraska Natural Heritage Program, Lincoln, NE; Nevada Natural Heritage Program, Carson City, NV; New Hampshire Natural Heritage Inventory, Concord, NH; New Jersey Natural Heritage Program, Trenton, NJ; New Mexico Natural Heritage Program, Albuquerque , NM; New York Natural Heritage Program, Latham, NY; North Carolina Natural Heritage Program, Raleigh, NC; North Dakota Natural Heritage Inventory, Bismarck, ND; Ohio Natural Heritage Database, Columbus, OH; Oklahoma Natural Heritage Inventory, Norman, OK; Oregon Natural Heritage Program, Portland, OR; Pennsylvania Natural Diversity Inventory, PA; Rhode Island Natural Heritage Program, Providence, RI; South Carolina Heritage Trust, Columbia, SC; South Dakota Natural Heritage Data Base, Pierre, SD; Tennessee Division of Natural Heritage, Nashville, TN; Tennessee Valley Authority Heritage Program, Norris, TN; Texas Conservation Data Center, San Antonio, TX; Utah Natural Heritage Program, Salt Lake City, UT; Vermont Nongame & Natural Heritage Program, Waterbury, VT; Virginia Division of Natural Heritage, Richmond, VA; Washington Natural Heritage Program, Olympia, WA; West Virginia Natural Heritage Program, Elkins, WV; Wisconsin Natural Heritage Program, Madison, WI; Wyoming Natural Diversity Database, Laramie, WY

Canada

Alberta Natural Heritage Information Centre, Edmonton, AB, Canada; Atlantic Canada Conservation Data Centre, Sackville, New Brunswick, Canada; British Columbia Conservation Data Centre, Victoria, BC, Canada; Manitoba Conservation Data Centre. Winnipeg, MB, Canada; Ontario Natural Heritage Information Centre, Peterborough, ON, Canada; Quebec Conservation Data Centre, Quebec, QC, Canada; Saskatchewan Conservation Data Centre, Regina, SK, Canada; Yukon Conservation Data Centre, Yukon, Canada

Latin American and Caribbean

Centro de Datos para la Conservacion de Bolivia, La Paz , Bolivia; Centro de Datos para la Conservacion de Colombia, Cali Valle, Columbia; Centro de Datos para la Conservacion de Ecuador, Quito, Ecuador; Centro de Datos para la Conservacion de Guatemala, Ciudad de Guatemala , Guatemala; Centro de Datos para la Conservacion de Panama, Querry Heights , Panama; Centro de Datos para la Conservacion de Paraguay, San Lorenzo , Paraguay; Centro de Datos para la Conservacion de Peru, Lima, Peru; Centro de Datos para la Conservacion de Sonora, Hermosillo, Sonora , Mexico; Netherlands Antilles Natural Heritage Program, Curacao , Netherlands Antilles; Puerto Rico-Departmento De Recursos Naturales Y Ambientales, Puerto Rico; Virgin Islands Conservation Data Center, St. Thomas, Virgin Islands.

NatureServe also has partnered with many International and United States Federal and State organizations, which have also contributed significantly to the development of the International Classification. Partners include the following The Nature Conservancy; Provincial Forest Ecosystem Classification Groups in Canada; Canadian Forest Service; Parks Canada; United States Forest Service; National GAP Analysis Program; United States National Park Service; United States Fish and Wildlife Service; United States Geological Survey; United States Department of Defense; Ecological Society of America; Environmental Protection Agency; Natural Resource Conservation Services; United States Department of Energy; and the Tennessee Valley Authority. Many individual state organizations and people from academic institutions have also contributed to the development of this classification.

Introduction

Preface

This is a subset of communities defined in the International Classification of Ecological Communities (ICEC), presented in a hierarchical arrangement consistent with that of the ICEC system. The ICEC was developed by ecologists at NatureServe and The Nature

Conservancy (TNC)[1], in conjunction with the network of state Natural Heritage programs and International Conservation Data Centers (CDCs). What follows is a brief introduction to the classification. Considerably more information on the ICEC's development and its uses has been published by the NatureServe / TNC Ecology Working Group (Grossman et al. 1998, Maybury 1999) and is available at <http://www.natureserve.org> under the Information Resources, Heritage Library link. All references cited are listed above at the end of the main report in references cited pg. 38.

The classification presented here is a snapshot of a work in progress. As the classification is applied in various places and for various purposes there will be additions, modifications, and revisions. For this reason, **printed reports have a suggested shelf life of one year from the "data current as of" date** that you should see in the footer of the document. Please request an updated version if the data in your document is more than one year old.

Development of the Classification

The ICEC grew out of a longstanding recognition on the part of The Nature Conservancy and the Natural Heritage network that ecological communities were important elements of conservation. These organizations employ what is often referred to as a "coarse filter/fine filter" approach to preserving biological diversity (Jenkins 1976, Hunter 1991). This approach involves the identification and protection of the best examples of all ecological communities (coarse filter) as well as rare species (fine filter). Identifying and protecting representative examples of ecological communities assures the conservation and maintenance of biotic interactions and ecological processes, in addition to conservation of most species. Certain species, however, usually the rarest ones, may fall through the community filter. Very rare species often have specialized life histories, or are simply so rare and restricted that their conservation requires explicit planning based on species-specific information. Identification and protection of viable occurrences of rare species served as the fine filter for preserving biological diversity. Using both filters for identifying conservation targets ensures that the most complete spectrum of biological diversity is protected.

In the U.S., state community classifications were developed for many states by the Heritage ecologist(s), with each state using its own classification scheme. This approach works effectively at a state level to assure protection of ecological communities. However, a major obstacle to using communities as conservation units at the regional,

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[1] In 2000, TNC decided to form a new organization that could focus its energies more tightly on developing and providing Heritage network data to Natural Resources decision makers (including those in TNC). Many of the ecologists and other scientists and data managers formerly in TNC's Conservation Science Division are now part of this new organization, called NatureServe. NatureServe and TNC ecologists continue to work together, and to work with Heritage, federal and state agencies, and academic partners, on ICEC development.

national, and global levels was the lack of a consistent classification system developed through analysis of data from a range-wide perspective. To overcome this problem, TNC and the Natural Heritage/CDC network began working to develop a standardized, hierarchical system to classify vegetated terrestrial communities across the U.S.

The first steps taken by TNC regional ecologists were to begin compiling an enormous amount of fine-scale state and local information on vegetation pattern into four regional classifications spanning the U.S. and to decide upon a single, standardized framework for the classifications they were developing. The U.S. regional classifications were of necessity developed somewhat independently. In the western U.S., for example, most of the existing state classifications were based on vegetation and were strongly influenced by the habitat type approach, which allowed a relatively straightforward compilation into a regional classification for the west. In the Midwest, East, and Southeast, there was less of a tradition of floristically-based classifications, and as a result, there was more emphasis on a synthesis of descriptive information on vegetation, often done with close consultation and review by Heritage program ecologists, along with other partner in state and federal agencies, and university scientists.

Synthesis of the four regional classifications into a U.S. National Vegetation Classification was completed and the first iteration of that classification was published (Anderson et al. 1998).

While classification development has so far focused on the United States (and is ongoing there), classification of Canadian vegetation using the ICEC system is proceeding on a relatively fast track, as is classification of the vegetation of portions of northern Mexico. Caribbean vegetation has also been an area of recent classification development.

The ICEC: Foundations And Scope

The following basic tenets underlie the terrestrial portion of the ICEC:

1. The ICEC is based primarily on vegetation, rather than soils, landforms or other non-biologic features.

This was decided upon mainly because plants are easily measured biological expressions of environmental conditions and are directly relevant to biological diversity. Vegetation is complex and continuously variable, with species forming only loosely repeating assemblages in ecologically similar habitats. The ICEC does not solve the problems inherent in any effort to categorize the continuum of vegetation pattern, but it presents a practical set of methods to bring consistency to the description, modeling, and conservation of vegetation.

2. The ICEC system applies to all terrestrial vegetation. In addition to upland vegetation, "terrestrial vegetation" is defined to include all wetland vegetation with rooted vascular plants. It also includes communities characterized by sparse to nearly absent vegetation cover, such as those found on boulder fields or talus.

3. The ICEC focuses on existing vegetation rather than potential natural or climax vegetation.

The vegetation types described in the classification range from the ephemeral to the stable and persistent. Recognizing and accommodating this variation is fundamental to protecting biodiversity. The manner in which a community occurs is, in part, an intrinsic property of the vegetation itself. A classification that is not restricted to static vegetation types ensures that the units are useful both for inventory/site description, and as the basis for building dynamic ecological models.

The following tenets reflect the current scope of the ICEC:

1. While the ICEC framework can be used to classify all vegetation, emphasis has been given to vegetation types that are natural or near-natural, i.e., those that appear to be unmodified or only marginally impacted by human activities. Where anthropogenic impacts are apparent, the resulting physiognomic and floristic patterns have a clear, naturally-maintained analog.

2. Classification development at the finest levels of the system has so far focused on the contiguous United States and Hawaii. Some classification at finer levels has also been done for southeastern Alaska, parts of Canada, the Caribbean, and a few areas in northern Mexico.

The ICEC: The Hierarchy

System level

The top division of the classification hierarchy separates vegetated communities (Terrestrial System) from those of unvegetated deepwater habitats (Aquatic System) and unvegetated subterranean habitats (Subterranean System). The Terrestrial System is broadly defined to include areas with rooted submerged vegetation of lakes, ponds, rivers, and marine shorelines, as well as the vegetation of uplands.

The hierarchy for the Terrestrial System has seven levels: the five highest (coarsest) levels are physiognomic and the two lowest (finest) levels are floristic. The levels of the terrestrial classification system are listed and described below.

VEGETATION CLASSIFICATION SYSTEM:

physiognomic levels	FORMATION CLASS
	FORMATION SUBCLASS
	FORMATION GROUP
	FORMATION SUBGROUP
	FORMATION
floristic levels	ALLIANCE
	ASSOCIATION

Physiognomic levels

The physiognomic portion of the ICEC hierarchy is a modification of the UNESCO world physiognomic classification of vegetation (1973) and incorporates some of the revisions made by Driscoll et al. (1984) for the United States.

Formation class

The physiognomic class is based on the structure of the vegetation as defined by the type, height, and relative percentage of cover of the dominant, uppermost life-forms. There are seven mutually exclusive classes:

Forest: Trees with their crowns overlapping (generally forming 60% - 100% cover).

Woodland: Open stands of trees with crowns not usually touching (generally forming 25% - 60% cover).

Shrubland: Shrubs generally greater than 0.5 meter tall with individuals or clumps overlapping to not touching (generally forming greater than 25% cover, with trees generally less than 25% cover). Vegetation dominated by woody vines is generally treated in this class.

Dwarf-shrubland: Low-growing shrubs, usually less than 0.5 meter tall. Individuals or clumps overlapping to not touching (generally forming greater than 25% cover; with trees and tall shrubs generally less than 25% cover).

Herbaceous: Herbaceous plants dominant (generally forming at least 25% cover, with trees, shrubs, and dwarf-shrubs generally with less than 25% cover).

Nonvascular: Nonvascular cover (bryophytes, non-crustose lichens, and algae) dominant (generally forming at least 25% cover).

Sparse Vegetation: Abiotic substrate features dominant. Vegetation is scattered to nearly absent and generally restricted to areas of concentrated resources (total vegetation cover is typically less than 25%).

Formation subclass

The physiognomic subclass is determined by the predominant leaf phenology of the forest, woodland, shrubland and dwarf-shrubland classes. Subclass is determined by the persistence (perennial or annual) and growth form (graminoid, forb, hydromorphic) of the vegetation for the herbaceous vegetation class. The relative dominance of lichens, mosses, or algae is the determining factor in the nonvascular class, and particle size of the substrate is the determining factor for the sparse vegetation class. Examples include: Evergreen Forest, Deciduous Forest, Deciduous Shrubland, Perennial Graminoid Vegetation, Annual Graminoid or Forb Vegetation, Lichen Vegetation, and Consolidated Rock Sparse Vegetation.

Formation group

The group generally represents vegetation units defined based on leaf characters, such as broad-leaf, needle-leaf, microphyllous, and xeromorphic. These units are identified and named with broadly defined macroclimatic types to provide a structural-geographic orientation, but the ecological climate terms do not define the groups *per se*. Examples include: Temperate or subpolar needle-leaved evergreen forest, Cold-deciduous forest, Cold-deciduous shrubland, Temperate or subpolar grassland, Sparsely vegetated cliffs.

Formation subgroup

The subgroup (or formation subgroup) represents a distinction between planted/cultivated vegetation and natural/semi-natural vegetation. The latter is broadly defined to include all vegetation not actively planted or maintained through intensive management activities by humans. Examples of subgroups include: Natural temperate and subpolar needle-leaved evergreen forest; Cultural temperate and subpolar needle-leaved evergreen forest (e.g., pine and spruce plantations).

Formation

The formation represents a grouping of community types that share a definite physiognomy or structure and broadly defined environmental factors, such as elevation and hydrologic regime. Structural factors such as crown shape and lifeform of the dominant lower stratum are used in addition to the physiognomic characters already specified at the higher levels. The hydrologic regime modifiers were adapted from Cowardin et al. (1979). Examples include: Rounded-crowned temperate or subpolar needle-leaved evergreen forest, Seasonally flooded cold-deciduous forest, Semipermanently flooded cold-deciduous shrubland, Tall sod temperate grassland, Cliffs with sparse vascular vegetation.

Floristic Levels

Alliance

The alliance is a physiognomically uniform group of plant associations (see association below) sharing one or more dominant or diagnostic species, which as a rule are found in the uppermost strata of the vegetation (see Mueller-Dombois and Ellenberg 1974). Dominant species are often emphasized in the absence of detailed floristic information (such as quantitative plot data), whereas diagnostic species (including characteristic species, dominant differential, and other species groupings based on constancy) are used where detailed floristic data are available (Moravec 1993).

For forested communities, the alliance is roughly equivalent to the "cover type" of the Society of American Foresters (Eyre 1980), developed for use primarily by foresters to describe the forest types of North America. The alliance may be finer in detail than a cover type when the dominant tree species extend over large geographic areas and varied environmental conditions (e.g. the *Pinus ponderosa* Forest Alliance, *Pinus ponderosa* Woodland Alliance, and *Pinus ponderosa* Temporarily Flooded Woodland Alliance are all within the *Pinus ponderosa* Cover Type of the SAF). Alliances, of course, have also been developed for non-forested vegetation.

The alliance is similar in concept to the "*series*," as developed for the Habitat Type System to group habitat types that share the same dominant species under "climax" conditions (Daubenmire 1952, Pfister and Arno 1980). Alliances, however, are described by the dominant or diagnostic species for *all* existing vegetation types, whereas series are generally restricted to potential "climax" types and are described by the primary dominant species.

Association

The association is the lowest level, as well as the basic unit for vegetation classification, in the ICEC. The association is defined as "a plant community of definite floristic composition, uniform habitat conditions, and uniform physiognomy" (see Flahault and Schroter 1910 in Moravec 1993). This basic concept has been used by most of the schools of floristic classification (Whittaker 1962, Braun-Blanquet 1965, Westhoff and van der Maarel 1973, Moravec 1993).

The plant association is differentiated from the alliance level by additional plant species, found in any stratum, which indicate finer scale environmental patterns and disturbance regimes. This level is derived from analyzing complete floristic composition of the vegetation unit when plot data are available. In the absence of a complete data set, approximation of this level is reached by using available information on the dominant species or environmental modifiers, and their hypothesized indicator species.

Nomenclature for Alliances and Associations

Alliances are named for constant dominants, codominants, or diagnostic species identified from the dominant and/or top strata of the vegetation. Associations are named with one or more species from the alliance name, and have additional species that represent dominants or indicators from any layer of the vegetation. Species occurring in the same stratum are separated by a hyphen (-); those occurring in different strata are separated by a forward slash (/). Parentheses around one or more species in a name indicate that the species may or may not occur within all associations in the alliance, or an all occurrences (stands) of the association are placed within parentheses.

Vascular plant species nomenclature in the alliance names follows the nationally standardized list, Kartesz (1999), with very few exceptions. Nomenclature for nonvascular plants follows Anderson (1990), Anderson et al. (1990), Egan (1987, 1989, 1990), Esslinger and Egan (1995), and Stotler and Crandall-Stotler (1977).

Association and Alliance names include the formation class (Forest, Woodand, etc.) in which they are placed. Alliances also include the word "alliance" to distinguish them from associations (e.g., *Pinus ponderosa* Woodland Alliance. For wetland alliances, the hydrologic regime that the alliance is found in is always provided for clarity, e.g. *Populus fremontii* Temporarily Flooded Woodland Alliance. All alliances that have no hydrological modifier are upland alliances.

Environmental or geographic descriptors (e.g., serpentine, Interior Plateau) are used sparingly, when species composition for a type is not known well enough to distinguish it using only species in a name. When an environmental/geographic descriptor is used, it is inserted between the floristic nominals and the class descriptor (e.g., *Quercus palustris - Quercus bicolor - Quercus macrocarpa - Acer rubrum* Sand Flatwoods Forest).

A forest, woodland, and shrubland example of the Classification System Hierarchy

	Forest	**Woodland**	**Shrubland**
SUBCLASS	Deciduous Forest	Evergreen Woodland	Deciduous Shrubland
GROUP	Cold-deciduous Forest	Temperate or Subpolar Needle-leaved Evergreen Woodland	Temperate Broad-leaved Evergreen Shrubland
SUBGROUP	Natural/Semi-natural	Natural/Semi-natural	Natural/Semi-natural
FORMATION	Lowland or Submontane Cold-deciduous Forest	Saturated Temperate or Subpolar Needle-leaved Evergreen Woodland	Sclerophyllous Temperate Broad-leaved Evergreen Shrubland
ALLIANCE	*Quercus stellata - Quercus marilandica* Forest Alliance	*Pinus palustris* Saturated Woodland Alliance	*Quercus havardii* Shrubland Alliance
ASSOCIATION	*Quercus stellata - Quercus marilandica - Carya (glabra, texana) / Vaccinium arboreum* Forest	*Pinus palustris / Leiophyllum buxifolium / Aristida stricta* Woodland	*Quercus havardii - (Penstemon ambiguus, Croton dioicus) / Sporobolus giganteus* Shrubland

Ecological Systems

Ecological systems encompass diverse assemblages of communities that occur in similar environments and are driven by similar dynamic processes. They are terrestrial, freshwater, and coastal marine systems that reflect local landscape-scale composition and dynamics that will be useful for habitat modeling, management, and monitoring. NVC associations do not always reflect ecological processes at work at broader scales (even relatively “local” scales like the riparian sedge meadow vs. the riparian sedge/shrub swamp complex). Ecological systems are ‘spatially aggregated’ communities, i.e. they are mappable units that predict the occurrence of a suite of communities. Not all communities will be present in every occurrence, and some communities could be predicted to occur in more than one ecological system type. The spatial scale of the system unit should reflect biotic attributes, environmental factors, and dynamic processes that are required for the system’s existence.

Ecological system distributions are bounded by broad biogeographic provinces. For example, low elevation riparian forests of the desert Southwestern United States, the Great Plains, the Southeastern Coastal Plain, and the Chaco would each constitute a different ecological system because they are comprised of entirely different taxa.

Ecological systems are intended as landscape-scale conservation planning tools and as categories that will be more intuitively understandable and will facilitate communication. They can also be used to develop viability and ranking criteria in a more efficient way. Plant associations are attributes of ecological systems, and ecological systems are attributes of landscapes. The character and "functionality" of a given landscape is derived from the composition, structure, and function of the component systems. Once we've understood and mapped systems across the places we work, we'll be in a better position to develop truly useful and ecologically integrated landscape classifications.

Known Data Gaps - Geographic

The ICEC is primarily comprised of a classification of the vegetation of the contiguous U.S. and Hawaii. Most of the vegetation of Alaska has not yet been incorporated into the ICEC.

Even within the contiguous U.S. and Hawaii, regional differences endure in the U.S. National classification due to regional differences in inventory data and in classification history. Some states or regions have focused their efforts on those alliances and associations that are considered to be imperiled (conservation ranks G1 or G2), while others, like the western U.S. Forest Service Districts, focused on more common communities. Also, while the classification system is intended to develop units with consistent scale, associations are more narrowly defined in some areas, resulting in a greater number of associations per alliance than average. On the other hand, limited inventory and classification work in areas such as the Great Basin area of the southwestern United States might lead a casual observer of the classification to believe that it is an area with low ecological diversity. In fact, it is an area about which little is known.

In the near term, significant refinements to the classification are anticipated with further integration of local and state classification work from Alaska, California, and Canadian provinces. Future classification refinement will also focus on underclassified portions of the U.S. interior southwest and adjacent Mexico.

Known Data Gaps - Taxonomic

In general, more information is available for Forest, Woodland, Shrubland, and Herbaceous classes than for Dwarf-Shrubland, Nonvascular, and Sparse Vegetation classes. Shortgrass prairie vegetation and many riparian types have not been consistently classified. In addition, the degree of classification confidence for upland types is generally higher than for wetland types. The classification of communities that occur as vegetation complexes will also require additional research and analysis.

Caveats About Distribution Data

In general: Absence of a state or ecoregion from any list of the distribution of a type cannot be interpreted to be a definitive statement that the type does not occur there.

Federal Lands: Some data may be available listing federal land units (such as National Park Service units, individual National Forests, etc.) within which an association occurs. However, this field is *extremely incompletely populated* and absence of a federal land management unit should not be considered to indicate that the type is absent on that unit.

Conservation Status Ranking

Associations are given a conservation status rank based on factors such as present geographic extent, threats, number of distinct occurrences, degree of decline from historic extent, and degree of alteration of natural processes affecting the dynamics, composition, or function of the type. Ranks are customarily assigned by the various members of the Natural Heritage programs and the regional offices of NatureServe.

Associations are ranked on a global (G), national (N), and subnational (S) scale of 1 to 5, with 1 indicating critical imperilment and 5 indicating little or no risk of extirpation or elimination. For example, a rank of G1 indicates critical imperilment on a rangewide basis, i.e., a great risk of "extinction" of the type worldwide; S1 indicates critical imperilment in the specific state, province, or other subnational unit, i.e., a great risk of extirpation of the type from the subnation.

Special attention is generally given to taxa of high endangerment, as opportunities for their conservation may be limited in space and time. However, occurrences of relatively secure communities can also be of critical conservation importance. In eastern North America, for example, a large tract of a common forest type in pristine condition that occurs in an intact landscape and with relatively intact ecological processes would be of high priority for conservation. Though the type itself is common, the opportunity to conserve such a high quality example may be very limited.

Global conservation status ranks for natural/near-natural communities are defined as follows:

GX **ELIMINATED** throughout its range, with no restoration potential due to extinction of dominant or characteristic species.
GH **PRESUMED ELIMINATED (HISTORIC)** throughout its range, with no or virtually no likelihood that it will be rediscovered, but with the potential for restoration (e.g., *Castanea dentata* Forest).
G1 **CRITICALLY IMPERILED** Generally 5 or fewer occurrences and/or very few remaining acres or very vulnerable to elimination throughout its range due to other factor(s).
G2 **IMPERILED** Generally 6-20 occurrences and/or few remaining acres or very vulnerable to elimination throughout its range due to other factor(s).

G3 VULNERABLE Generally 21-100 occurrences. Either very rare and local throughout its range or found locally, even abundantly, within a restricted range or vulnerable to elimination throughout its range due to specific factors.
G4 APPARENTLY SECURE Uncommon, but not rare (although it may be quite rare in parts of its range, especially at the periphery). Apparently not vulnerable in most of its range.
G5 SECURE Common, widespread, and abundant (though it may be quite rare in parts of its range, especially at the periphery). Not vulnerable in most of its range.
GU UNRANKABLE Status cannot be determined at this time.
G? UNRANKED Status has not yet been assessed**.**

Modifiers and Rank Ranges:

? A question mark added to a rank expresses an uncertainty about the rank in the range of 1 either way on the 1-5 scale. For example a G2? rank indicates that the rank is thought to be a G2, but could be a G1 or a G3.
G#G# Greater uncertainty about a rank is expressed by indicating the full range of ranks which may be appropriate. For example, a G1G3 rank indicates the rank could be a G1, G2, or a G3.
Q A"Q" added to a rank denotes questionable taxonomy. It modifies the degree of imperilment and is *only* used in cases where the type would have a *less imperiled* rank if it were not recognized as a valid type (i.e., if it were combined with a more common type). A GUQ rank often indicates that the type is unrankable *because of* daunting taxonomic/definitional questions.

Ranks indicating semi-natural/altered communities:

GD RUDERAL Vegetation resulting from succession following anthropogenic disturbance of an area. Generally characterized by unnatural combinations of species (primarily native species, though often containing slight to substantial numbers and amounts of species alien to the region as well).
GM MODIFIED/MANAGED Vegetation resulting from the management or modification of natural/near natural vegetation, but producing a structural and floristic combination not clearly known to have a natural analogue.
GW INVASIVE Vegetation dominated by invasive alien species; the vegetation is spontaneous, self-perpetuating, and is not the (immediate) result of planting, cultivation, or human maintenance.

Ranks indicating planted/cultivated communities:

GC PLANTED/CULTIVATED Areas dominated by vegetation that has been planted in its current location by humans and/or is treated with annual tillage, a modified conservation tillage, or other intensive management or manipulation

Vegetation Alliances of Petrified Forest National Park

III. Shrubland

III.A.4.N.a. Lowland microphyllous evergreen shrubland

III.A.4.N.a.4. Artemisia filifolia Shrubland Alliance
Sand Sagebrush Shrubland Alliance

Alliance Concept
Summary: This alliance includes *Artemisia filifolia*-dominated shrublands occurring mostly in the southern Great Plains, but associations are distributed as far north as the Black Hills, south to the Trans-Pecos of western Texas as well as on the Colorado Plateau. These shrublands typically occur on flat, hummocky, or rolling terrain, as well as on partially stabilized dunes and sand sheets. Soils supporting these communities have low water retention and nutrient availability, and are typically sand or loamy sand, primarily of aeolian origin, but include sand deposits derived from sandstone residuum and cinder deposits. Less xeric sites tend to be more grass-dominated. In western Kansas and eastern Colorado, this alliance is found downwind of major waterways where alluvial sand is blown. In Texas these shrublands occur over sandy soils in the Rolling and High Plains and on gypsum dunes in the Trans-Pecos. On the Colorado Plateau, stands occur on a variety of sites including pockets of sand below sandstone cliffs, dunes and sheets of sand or cinder, floodplain terraces and alluvial fans. Vegetation cover is sparse to moderately dense, with a shrub stratum approximately 1 m tall, dominated by *Artemisia filifolia*, interspersed with areas of bare substrate and scattered tall or mid grasses. Species composition will vary with geography, precipitation, disturbance, and soil texture. Associated species may include: *Andropogon hallii, Artemisia frigida, Bouteloua curtipendula, Bouteloua gracilis, Carex duriuscula (= Carex eleocharis), Calamovilfa gigantea, Calamovilfa longifolia, Calylophus serrulatus, Carex inops ssp. heliophila, Helianthus petiolaris, Hesperostipa comata (= Stipa comata), Heterotheca villosa var. villosa, Ipomoea leptophylla, Lathyrus polymorphus, Lygodesmia juncea, Opuntia* spp., *Penstemon buckleyi, Prosopis glandulosa, Prunus angustifolia, Psoralidium lanceolatum, Schizachyrium scoparium, Sporobolus giganteus, Sporobolus cryptandrus,* and *Yucca glauca*. Communities associated with gypsum dunes have many gypsophiles or gypsum endemics. Colorado Plateau shrub associates include *Ericameria nauseosa, Ephedra torreyana, Ephedra viridis, Gutierrezia sarothrae, Atriplex canescens* and the graminoids *Muhlenbergia pungens, Sporobolus cryptandrus, Bouteloua eriopoda,* and *Achnatherum hymenoides.*
Environment: Shrublands included in this alliance occur on sandy sites in the central and southern Great Plains into the Chihuahuan Desert and on the Colorado Plateau. Elevations range from 1300-1700 m. The climate is semi-arid to arid, and mean annual precipitation ranges from 20-65 cm. Sites include flat to moderately sloping hummocky or rolling terrain to partially stabilized dunes. Stands can occur on any aspect. The soils

are sand or loamy sand, primarily of aeolian origin, but include sand deposits derived from sandstone residuum and cinder deposits. All substrates are well-drained to excessively well-drained. Water retention and nutrient availability of the soils are low because water infiltrates rapidly and percolates deeply into the coarse-textured substrate, and is therefore only available to deep-rooted plants. In southwestern Kansas and southeastern Colorado, this alliance is found downwind of major waterways where alluvial sand is blown (Johnston 1987). In Texas these shrublands occur on sandy soils in the Rolling and High Plains and on gypsum dunes in the Trans-Pecos (Dick-Peddie 1993). On the Colorado Plateau, stands occur on a variety of sites including pockets of sand below sandstone cliffs, partially stabilized dunes and sheets of cinder or sand, floodplain terraces and alluvial fans.

Adjacent vegetation varies by geographic location but is generally grasslands dominated by shortgrass and midgrass prairie species such as *Bouteloua gracilis, Pleuraphis jamesii (= Hilaria jamesii), Calamagrostis canadensis,* and *Hesperostipa comata (= Stipa comata)*. In desert areas it is surrounded by Chihuahuan Desert scrub dominated by *Larrea tridentata*.

Vegetation: This alliance includes *Artemisia filifolia*-dominated shrublands that occur on sandy sites in the central and southern Great Plains (extending as far north as the Black Hills), the Chihuahuan Desert, and the Colorado Plateau. The vegetation is characterized by a sparse to moderately dense woody layer approximately 1 m tall that is dominated by the microphyllous evergreen shrub *Artemisia filifolia*. These shrubs usually do not grow as clumps but as individuals with the interstices most often dominated by a sparse to moderately dense layer of tall, mid or short grasses (Bruner 1931, Steinauer 1989, Ramaley 1939a, b Dick-Peddie 1993).

Associated shrubs and dwarf-shrubs composition will vary with geography, precipitation, disturbance, and soils. In the Great Plains, some stands have *Prunus angustifolia* as a codominant in the shrub layer. This species often grows taller than *Artemisia filifolia* and may form thickets (McGregor and Barkley 1986). In northern stands *Artemisia frigida* is more common, and Chihuahuan Desert stands may include *Dalea lanata, Psorothamnus scoparius, Tiquilia hispidissima,* or *Yucca elata*. On the Colorado Plateau, *Ericameria nauseosa, Ephedra torreyana, Ephedra viridis, Gutierrezia sarothrae,* or *Atriplex canescens* may codominate. Species of *Opuntia* and *Yucca* are common in many stands throughout its range.

The sparse to moderately dense herbaceous layer is typically dominated by graminoids. The most abundant and widespread species are *Achnatherum hymenoides (= Oryzopsis hymenoides), Andropogon hallii, Bouteloua gracilis, Bouteloua curtipendula, Calamovilfa longifolia, Schizachyrium scoparium,* or *Sporobolus cryptandrus*. *Carex inops ssp. heliophila, Carex duriuscula (= Carex eleocharis)*, and *Hesperostipa comata (= Stipa comata)* are more common in northern stands, and *Bouteloua breviseta, Bouteloua eriopoda, Bouteloua trifida, Sporobolus flexuosus, Sporobolus giganteus*, and *Sporobolus nealleyi* are restricted to southern stands. *Muhlenbergia pungens, Sporobolus cryptandrus, Bouteloua eriopoda,* and *Achnatherum hymenoides* are important graminoids on the Colorado Plateau. Forbs are typically not abundant in these communities. Associated species include *Calylophus serrulatus, Heterotheca villosa var. villosa, Helianthus petiolaris, Ipomoea leptophylla, Lathyrus polymorphus, Lepidium montanum, Lygodesmia juncea, Mentzelia* spp., *Penstemon buckleyi*, and *Psoralidium* *lanceolatum*. Communities associated with gypsum dunes have many gypsophiles or gypsum endemics.

Dynamics: These shrublands occur as any one of several stages in a successional sequence. Drought or overgrazing stands of this alliance will reduce vegetation cover and can allow the wind to cause blowouts or active dunes (Ramaley 1939b. Ramaley (1939b describes the succession in Colorado from loose sand to a sandhills - mixed community dominated by *Muhlenbergia pungens*. It then may proceed to an *Artemisia filifolia* (sand sage) community or skip this stage and succeed to the sand prairie, late seral community dominated by *Hesperostipa comata, Calamovilfa longifolia*, and *Andropogon hallii*. This can happen relatively quickly with adequate precipitation and rest from grazing. Ramaley (1939b) also reported that unless protected from overgrazing and fires, the sand sage community will not succeed into the sand prairie community. However, in regions with marginal precipitation, such as occurs over much of eastern Colorado, the sand sage community may be the last successional stage (Ramaley 1939b).

A 10-year grazing study on sand sage pastures in Colorado by Sims et al. (1976) and Dahl and Norris (1965) found that *Bouteloua gracilis* abundance increased with increased cattle grazing, whereas *Calamovilfa longifolia* and *Hesperostipa comata* decreased. With heavy grazing, *Artemisia filifolia* density increased because of seedling recruitment. This may be due to decreased competition with grasses. In the lightly grazed treatments, *Hesperostipa comata* abundance more than doubled and the *Artemisia filifolia* density decreased slightly. Weaver and Albertson (1956) reported *Artemisia filifolia* and *Sporobolus cryptandrus* both increasing with grazing in sandhills of Oklahoma.

In Colorado, fire frequency and extent are thought to be low in these stands because sand sage areas are usually surrounded by other communities that are too moist or too sparse to carry a fire well (Ramaley 1939b). In the Great Plains, Wright and Bailey (1980) reported that after fire *Artemisia filifolia* will resprout and will also reproduce vigorously as seedlings. The shrubs *Prunus angustifolia* and *Rhus* spp. also vigorously resprouted after fire (Jackson 1965). Generally, however, fire reduces the vegetation cover that protects these shrublands from blowouts.

Timing and amount of growing-season precipitation can greatly affect species abundance from year to year. Normal to wet springs with a dry summer often result in biomass being dominated by cool-season species such as *Hesperostipa comata*. A year with a dry spring and normal to wet summer results in biomass being dominated by warm-season species such as *Andropogon hallii* and *Calamovilfa longifolia*. Similarly, timing of grazing can have the same result. Forb abundance and diversity can be very high during summers with significantly higher than average precipitation. *Panicum virgatum, Sorghastrum nutans*, and *Prunus pumila var. besseyi* are present in low abundance in good condition stands in Colorado but are often eliminated by heavy grazing (Soil Conservation Service 1978).

Similar Alliances:

Andropogon Hallii Herbaceous Alliance (A.1193)

Calamovilfa Longifolia Herbaceous Alliance (A.1201)

Similar Alliance Comments: Stands in the two similar alliances, V.A.5.N.a *Andropogon hallii* Herbaceous Alliance (A.1193) and V.A.5.N.a *Calamovilfa longifolia* Herbaceous Alliance (A.1201), often contain *Artemisia filifolia* and occur in similar habitats; however, physiognomic differences (i.e., graminoid-dominated and shrub canopy <25%)

can usually be used to classify stands. Stands with sparse cover of both *Artemisia filifolia* and graminoids still pose classification problems.
Synonymy:
Sand Sage Community. Colorado (Ramaley 1939a)
Sandsage Prairie (Kuchler 1974)
Sandsage-Midgrass Series. Texas (Diamond 1993)
Artemisia filifolia Series #303 (Johnston 1987)
Sand Sagebrush. New Mexico (Dick-Peddie 1993)
Artemisia filifolia / Sporobolus cryptandrus - Schizachyrium scoparium shrubland association (Hoagland 1997)
Comments: Communities within this alliance are characterized by sparse to moderate vegetation cover and dominance by *Artemisia filifolia* with tall, medium, or short grasses. Communities in two graminoid-dominated alliances, V.A.5.N.a *Andropogon hallii* Herbaceous Alliance (A.1193) and V.A.5.N.a *Calamovilfa longifolia* Herbaceous Alliance (A.1201), often contain *Artemisia filifolia*; however, physiognomic differences (i.e., the amount of shrub canopy) can usually be used to distinguish stands. Stands that have moderate amounts of *Artemisia filifolia* and a greater amount of herbaceous vegetation cover may still pose classification problems. These stands may be somewhere in between this shrubland alliance and herbaceous alliances. Stands described by Ramaley (1939b) are dominated by *Artemisia filifolia*, but have low cover (10%) and may be too sparse to be classified as a shrubland. Stands in the *Artemisia filifolia* dune shrubland association are also sparse and may be better classified as a sparsely vegetated type.

Range site descriptions (Soil Conservation Service 1978) for good-condition stands in Colorado describe *Artemisia filifolia* as occurring in low abundance, suggesting that good condition stands would be classified as herbaceous communities with a shrub component. Stands that are impacted by heavy grazing have *Artemisia filifolia* in greater abundance.

Alliance Distribution
Range: This alliance occurs on sandy sites in the Great Plains and Chihuahuan Desert from the Black Hills in southwestern South Dakota south to Trans-Pecos Texas and southern New Mexico.
Nations: US
States/Provinces: AZ CO KS NE NM OK SD TX UT WY
TNC Ecoregions: 19:C, 24:C, 25:C, 26:C, 27:C, 28:C, 29:P
USFS Ecoregions: 313A:CC, 313D:CC, 313E:CC, 315A:C?, 315B:CC, 315C:CC, 321A:CC, 331B:CC, 331C:CC, 331F:CC, 331H:CC, 331I:CC, 332E:CC, M313B:CC
Federal Lands: NPS (Badlands, Petrified Forest, Zion)

Alliance Sources
Authors: GREAT PLAINS PROGRAM 1-95, JT, mod by K. Schulz, WCS **Identifier:** A.816
References: Aldous and Shantz 1924, Bruner 1931, Bunin 1985, Costello and Turner 1944, Dahl and Norris 1965, Daley 1972, Diamond 1993, Dick-Peddie 1986, Dick-Peddie 1993, Evans 1964, Faber-Langendoen et al. 1996, Garrison et al. 1977, Great

Plains Flora Association 1986, Green 1969, Hoagland 1997, Jackson 1965, Johnston 1987, Kuchler 1974, Maxwell and Brown 1968, McGregor and Barkley 1986, McMahan et al. 1984, Muldavin and Mehlhop 1992, Muldavin et al. 2000b, Ramaley 1916, Ramaley 1939a, Ramaley 1939b, Rogers 1950, Rogers 1953, Savage 1937, Sims et al. 1976, Soil Conservation Service 1978, Steinauer 1989, Weaver and Albertson 1956, Wright and Bailey 1980

III.A.4.N.a.23. Ericameria nauseosa Shrubland Alliance
Rubber Rabbitbrush Shrubland Alliance

Alliance Concept

Summary: This alliance includes both natural and semi-natural stands from localized areas across the northern Great Plains and throughout the western U.S. Naturally occurring stands have been described from areas of partially stabilized sands, in a region of actively moving dune deposits, from 1525-1800 m elevation in southeastern Idaho and in other areas of high natural disturbance such as on steep colluvial slopes, along drainages or in floodplains. The semi-natural stands included in this alliance are seral shrubland communities resulting from over-grazing by livestock, road building, or other cultural disturbance of typically grass-dominated communities. Elevations range from 1220-1800 m. Soils are variable, but generally well-drained and coarse-textured. The vegetation is characterized by a open to moderately dense, short-shrub layer (15-60% cover) that is dominated by *Ericameria nauseosa.* Depending on geography, associated shrubs may include scattered *Artemisia tridentata, Artemisia filifolia, Chrysothamnus viscidiflorus, Gutierrezia sarothrae, Rhus trilobata, Opuntia* spp*., Prunus virginiana, Symphoricarpos occidentalis,* and *Yucca* spp. The herbaceous layer can vary from moderately dense and dominated by graminoids to absent. Common native grasses include *Achnatherum hymenoides (= Oryzopsis hymenoides), Bouteloua* spp*., Elymus trachycaulus ssp. trachycaulus, Leymus flavescens (= Elymus flavescens), Pascopyrum smithii, Pleuraphis jamesii, Pseudoroegneria spicata,* and *Sporobolus cryptandrus.* Native forbs generally have low cover. Disturbed stands typically have high cover of introduced annual *Bromus* species*.*

Environment: This alliance includes both natural and semi-natural stands from localized areas across the northern Great Plains and throughout the western U.S. Naturally occurring stands have been described from areas of partially stabilized sands, in a region of actively moving dune deposits, from 1525-1800 m elevation in southeastern Idaho and in other areas of high natural disturbance such as on steep colluvial slopes, along drainages, or in floodplains. Natural stands in the dune systems of southern Idaho occur in very specific environments, roughly 30-210 m windward from the pioneer vegetation type, *Leymus flavescens* Herbaceous Vegetation (CEGL001563*)*. These sand deposits have generally been stable for approximately 40 years. The soils are sand, from a few centimeters to over 4 m deep, left behind as the dunes advance. Stands on the Colorado Plateau occur in a variety of habitats such as gentle or steep slopes, dunes, and washes. Elevations range from 1220-1800 m. Substrates may be aeolian, alluvial, colluvial, or derived from sandstone residuum. Soils are variable, but are generally well-drained and coarse-textured. The semi-natural stands included in this alliance are seral shrubland

communities resulting from over-grazing by livestock, road building, or other cultural disturbance of typically grass-dominated communities.
Vegetation: This alliance includes both natural and semi-natural stands from localized areas across the northern Great Plains and throughout the western U.S. The vegetation is characterized by a open to moderately dense, short-shrub layer (15-60% cover) that is dominated by *Ericameria nauseosa.* Depending on geography, associated shrubs may include scattered *Artemisia tridentata, Artemisia filifolia, Chrysothamnus viscidiflorus*, *Gutierrezia sarothrae*, *Rhus trilobata, Opuntia* spp*., Prunus virginiana, Symphoricarpos occidentalis,* and *Yucca* spp. The herbaceous layer can vary from moderately dense and dominated by graminoids to absent. Common native grasses include *Achnatherum hymenoides (= Oryzopsis hymenoides), Bouteloua* spp*., Elymus trachycaulus ssp. trachycaulus, Leymus flavescens (= Elymus flavescens), Pascopyrum smithii, Pleuraphis jamesii, Pseudoroegneria spicata,* and *Sporobolus cryptandrus*. Native forbs generally have low cover, but may include species such as *Psoralidium lanceolatum (= Psoralea lanceolatum), Machaeranthera canescens (= Aster canescens), Lygodesmia grandiflora,* and *Phacelia hastata (= Phacelia leucophylla).* Disturbed stands typically have high cover of introduced annual *Bromus* species such as *Bromus tectorum, Bromus japonicus*, and *Bromus rubens*. Introduced forbs may include *Melilotus officinalis, Salsola kali,* and *Bassia scoparia (= Kochia scoparia)*.
Dynamics: In southern Idaho this shrubland is the second seral stage of five vegetation types found on this dune complex. The types are found in bands transverse to the direction of dune movement. The width of the vegetation bands is quite consistent throughout the sandhills area, and each band advances across the landscape at about the same rate as the dune advancement. This association has an approximate duration on a given deposit of 10-70 years. Semi-natural stands have largely been overlooked in the classification literature. Daubenmire (1970) described *Ericameria nauseosa*-dominated stands (to 40% cover) from the steppes of eastern Washington as the second level of degeneration of the *Bromus tectorum* zootic climax (when overgrazing by livestock continues after perennial grasses are replaced by *Bromus tectorum)*.
Similar Alliances:
Ericameria Nauseosa Shrub Short Herbaceous Alliance (A.1546)
Similar Alliance Comments: Stands included in this alliance may have moderately high graminoid cover, but are dominated by shrubs**.**
Synonymy:
Comments: This alliance's concept has been recently expanded to include semi-natural vegetation. More classification information is needed to fully describe this alliance throughout its range of distribution.

Alliance Distribution
Range: This alliance includes shrublands from localized areas across the northern Great Plains and throughout the western U.S.
Nations: US
States/Provinces: AZ ID MT ND NV SD UT
TNC Ecoregions: 11:C, 19:C, 6:C
USFS Ecoregions: 313A:CC, 313D:CC, 322A:CC, 341D:CC, 341E:CC, 342C:CC, 342D:CC, M332:C, M341A:CC

Federal Lands: NPS (Zion, Petrified Forest)

Alliance Sources
Authors: K. SCHULZ, WCS **Identifier:** A.835
References: Chadwick and Dalke 1965, Reid et al. 1994, Daubenmire 1970.

III.A.4.N.c. Temporarily flooded microphyllous shrubland

***III.A.4.N.c.1. Tamarix* Spp. Semi-Natural Temporarily Flooded Shrubland Alliance**
Tamarisk species Semi-natural Temporarily Flooded Shrubland Alliance

Alliance Concept
Summary: This alliance is composed of shrublands which form moderately dense to dense thickets on banks of larger streams, rivers and playas across the western Great Plains, interior and southwestern U.S., and northern Mexico. Stands are dominated by introduced species of *Tamarix*, including *Tamarix ramosissima, Tamarix chinensis, Tamarix gallica*, and *Tamarix parviflora*. Introduced from the Mediterranean, *Tamarix* spp. have become naturalized in various sites, including salt flats, springs, and especially along streams and regulated rivers, often replacing *Salix* or *Prosopis* spp. shrublands or other native vegetation. A remnant herbaceous layer may be present, depending on the age and density of the shrub layer. These species have become a critical nuisance along most large rivers in the semi-arid western U.S. Because of the difficulty to remove, *Tamarix* spp. may have irreversibly changed the vegetation along many rivers.
Environment: The riparian shrublands included in this alliance occur across the western Great Plains, interior western and southwestern U.S., and northern Mexico. These widespread shrublands are common along larger streams, rivers, and around playas. Elevation ranges from 75 m below sea level to 1860 m. *Tamarix* spp. have become naturalized in various sites, including riverbanks, floodplains, basins, sandbars, side channels, springs, salt flats, and other saline habitats. Stands grow especially well along regulated rivers where flood-regenerated native species of *Populus* are declining. Substrates are commonly thin sandy loam soil over alluvial deposits of sand, gravel or cobbles.
Vegetation: This semi-natural shrubland alliance occurs along streams, rivers and playas where it forms a moderate to dense tall-shrub layer that is solely or strongly dominated by species of *Tamarix* including *Tamarix ramosissima, Tamarix chinensis, Tamarix gallica*, and *Tamarix parviflora*. Other shrubs may include species of *Salix* (especially *Salix exigua*) and *Prosopis, Rhus trilobata*, and *Sarcobatus vermiculatus,* but with low cover (if shrub species are codominant then stand is classified as a natural shrubland). Scattered *Acer negundo, Salix amygdaloides, Populus* spp., or *Elaeagnus angustifolia* trees may also be present. Depending on stand age and density of the shrub layer, an herbaceous layer may be present. Associated species include *Distichlis spicata, Sporobolus airoides*, and introduced forage species such as *Agrostis gigantea, Agrostis stolonifera*, and *Poa pratensis*. Introduced herbaceous species such as *Polypogon monspeliensis, Conyza canadensis, Lepidium latifolium*, and others have been reported from shrublands in this association. *Tamarix* spp. has become a critical nuisance along most large rivers in the semi-arid western U.S. and, because of the difficulty to remove, may have irreversibly changed the vegetation along many rivers.

Dynamics: *Tamarix* spp. are highly competitive shrubs that have invaded many riparian and wetland environments in the western U.S. Hansen et al. (1995) report that these shrubs are extremely drought- and salt-tolerant, produce prolific wind-dispersed seeds over much of the growing season, can resprout after burning or cutting, and if kept moist, buried or broken branches will develop adventitious roots and grow. Stands seem to favor disturbed and flow-regulated rivers, but establish well in pristine areas, too. Under optimum conditions riparian areas can be converted to a dense thicket in less than 10 years (Hansen et al. 1995). Once established, stands are extremely difficult to eradicate, requiring cutting and herbicide application on stumps to prevent resprouting (Smith 1989).

Similar Alliances:

Tamarix Spp. Tidal Shrubland Alliance (A.1888)

Similar Alliance Comments:

Synonymy:

Tamarix chinensis shrubland series (Hoagland 1997)

Saltcedar Series (Dick-Peddie 1993)

No equivalent (Diamond 1993)

Tamarix chinensis Community Type (Hansen et al. 1995)

Tamarisk Scrub (Holland 1986)

Saltcedar Alliance (Muldavin et al. 2000a

Tamarisk series (Sawyer and Keeler-Wolf 1995)

Tamarix ramosissima (Salt cedar) Association (Nachlinger and Reese 1996)

Salt cedar series (Paysen et al. 1980)

Tamarix pentandra Community Type (Szaro 1989)

Comments: This broadly defined alliance is composed of many diverse *Tamarix* spp.-dominated vegetation communities from a wide variety of environments. Common species of *Tamarix* include *Tamarix ramosissima, Tamarix chinensis*, and *Tamarix parviflora*, but other species are reported from the western U.S., such as *Tamarix africana, Tamarix aphylla*, *Tamarix aralensis, Tamarix canariensis, Tamarix gallica,* and *Tamarix tetragyna* (Kartesz 1999). Powell (1988) reports that *Tamarix* spp. are a critical nuisance, most notably along the Rio Grande and Pecos River. Muldavin et al. (2000a) described eight community types that will be reviewed as possible USNVC associations. Currently the sole USNVC tamarix association, *Tamarix* spp. Temporarily Flooded Shrubland (CEGL003114), is equally broadly defined.

Alliance Distribution

Range: This semi-natural shrubland alliance is found along drainages in the semi-arid western Great Plains, interior west and southwestern U.S., and northern Mexico, from central and eastern Montana south to Colorado, western Oklahoma and Texas west to California.

Nations: MX US

States/Provinces: AZ CA CO MT MXCH MXCO MXSO NM NV OK TX UT WY?

TNC Ecoregions: 10:C, 19:C, 22:C, 23:C, 24:C, 26:C, 27:C, 28:C

USFS Ecoregions: 261A:CC, 261B:CC, 262A:CC, 311A:PP, 313A:CC, 313B:CC, 313C:CC, 313D:CC, 313E:CC, 313J:CC, 315E:PP, 321A:CC, 322A:CC, 331B:CP,

331I:CC, 332E:PP, 341C:CC, M261A:CC, M261E:CC, M261F:CC, M262A:CC, M262B:CC
Federal Lands: NPS (Big Bend, Wupatki, Petrified Forest, Zion); USFWS (Ouray)

Alliance Sources
Authors: M.S. REID, MOD. K. SCHULZ, JT, WCS **Identifier:** A.842
References: Brown 1982, Campbell and Dick-Peddie 1964, Dick-Peddie 1993, Hansen et al. 1995, Hefley 1937, Hoagland 1997, Little 1996, Muldavin et al 2000a. Powell 1988, Sawyer and Keeler-Wolf 1995, U.S. Bureau of Reclamation 1976, Holland 1986, Nachlinger and Reese 1996, Paysen et al. 1980, Smith 1989, Szaro 1989, Thompson 2001, Von Loh et al. 2002

III.A.5.N.b. Facultatively deciduous extremely xeromorphic subdesert shrubland

***III.A.5.N.b.6. Atriplex canescens* Shrubland Alliance**
Fourwing Saltbush Shrubland Alliance

Alliance Concept
Summary: This alliance occurs primarily in arid and semi-arid areas of the southwestern U.S. from western Texas to southern and eastern California and into Chihuahua, Mexico. It is also found in the western Great Plains to the Great Basin from western Kansas, Colorado, and Wyoming to Utah, Nevada and eastern Oregon. Associations in this alliance vary throughout the range and occur in a variety of environmental settings. In western Texas, this alliance occupies alkaline flats, depressions among gypsum ridges, saline, or sandy soils. Overall, shrublands in this alliance occur on lowland and upland sites with elevation ranging from 75 m below sea level to 2400 m. Lowland sites include alluvial flats, drainage terraces, playas, washes and interdune basins. Upland sites include bluffs and gentle to moderately steep, sandy or rocky slopes. Stands occur on all aspects. Soils are variable with depths ranging from shallow to moderately deep, and texture ranging from sand to loam to clay. The lowland sites may be moderately saline or alkaline. Stands typically have a sparse to moderately dense (10-60% cover) short-shrub canopy (approximately 1.5 m tall) that is dominated by the facultative deciduous, xeromorphic shrub *Atriplex canescens*, with bare ground usually dominating the ground surface. Associated shrubs may include: *Artemisia bigelovii, Artemisia tridentata, Ephedra viridis, Krascheninnikovia lanata, Purshia stansburiana (= Purshia mexicana var. stansburiana), Psorothamnus polydenius, Parthenium confertum, Sarcobatus vermiculatus*, and species of *Chrysothamnus, Ericameria,* and *Lycium*. Dwarf-shrubs, such as *Gutierrezia sarothrae* or *Eriogonum* spp., may be common in some stands. The sparse to moderately dense graminoid layer (1-60% cover) is typically dominated by warm-season, medium-tall and short grasses. The species present depend on geographic range of the grasses and past land use. Species may include: *Bouteloua gracilis, Distichlis spicata, Elymus elymoides, Hesperostipa comata, Pleuraphis jamesii (= Hilaria jamesii), Achnatherum hymenoides (= Oryzopsis hymenoides), Muhlenbergia porteri, Scleropogon brevifolius, Pascopyrum smithii,* and *Sporobolus spp*. Forb cover is generally sparse, but annual forbs such as *Calycoseris parryi* may be abundant in wet years. Common forbs include species of *Sphaeralcea, Dalea, Cymopterus, Chenopodium, Kochia, Iva, Picradeniopsis*, and *Ratibida*. Cacti from the genus *Opuntia* are associated

species in some stands. Trees are typically not present, but occasionally scattered *Juniperus* spp. occur. Very little is known about the expression of this alliance in the Midwest.

Environment: Shrublands included in this alliance occur on lowland and upland sites throughout much of the arid and semi-arid western U.S. with elevations ranging from 75 m below sea level to 2400 m. Lowland sites include alluvial flats, drainage terraces, playas, washes and interdune basins. Upland sites include bluffs and gentle to moderately steep, sandy or rocky slopes. Stands occur on all aspects. Soils are variable with depths ranging from shallow to moderately deep, and texture ranging from sands to loams to clay. The lowland sites may be moderately saline or alkaline. Bare ground usually dominates the ground surface. Francis (1986) described stands in northwestern New Mexico with approximately 80% bare soils and 15% litter. In the Great Basin/Mojave Desert transition zone, Beatley (1993) found these shrublands occurred within a mosaic of *Atriplex confertifolia*- or *Lycium andersonii - Grayia spinosa*-dominated shrublands, and were associated with sandy soils. Adjacent vegetation includes *Bouteloua gracilis*-dominated uplands in the Great Plains to various desert shrublands in the southern deserts.

Vegetation: Shrublands included in this alliance occur across the western United States on arid and semi-arid sites. Very little is known about its expression in the Midwest. Stands have a sparse to moderately dense (10-60% cover) short-shrub canopy (to approximately 1.5 m tall) that is dominated by the facultatively deciduous, xeromorphic shrub *Atriplex canescens*. Associated shrubs may include: *Artemisia tridentata, Artemisia bigelovii, Krascheninnikovia lanata, Purshia stansburiana (= Purshia mexicana var. stansburiana), Psorothamnus polydenius, Ephedra viridis, Parthenium confertum, Sarcobatus vermiculatus,* and species of *Chrysothamnus* and *Lycium*. Dwarf-shrubs such as *Gutierrezia sarothrae* or *Eriogonum* spp. may be common in some stands. Warm-season, medium-tall and short grasses typically dominate the sparse to moderately dense (1-60% cover) graminoid layer. The species present depend on geographic range of the grasses, alkalinity/salinity and past land use. Species may include: *Bouteloua gracilis, Distichlis spicata, Elymus elymoides, Hesperostipa comata, Pleuraphis jamesii (= Hilaria jamesii), Achnatherum hymenoides (= Oryzopsis hymenoides), Pascopyrum smithii, Muhlenbergia porteri, Scleropogon brevifolius, Sporobolus airoides, Sporobolus cryptandrus*, *Sporobolus flexuosus, Sporobolus nealleyi,* and *Sporobolus wrightii*. Forb cover is generally sparse, but annual forbs such as *Calycoseris parryi* may be abundant in wet years. Common forbs include species of *Sphaeralcea, Dalea, Cymopterus, Chenopodium, Kochia, Iva, Picradeniopsis*, and *Ratibida*. Cacti from the genus *Opuntia* are associated species in some stands. Trees are typically not present, but occasionally scattered *Juniperus* spp. may occur.

Dynamics: *Atriplex canescens* is tolerant of saline or alkaline soils, but is not restricted to those soils. Therefore, it is not a reliable indicator of those conditions (USFS 1937). This shrub is considered good forage for deer and many classes of livestock because it is highly nutritious and palatable (USFS 1937).

Similar Alliances:

Prosopis glandulosa Shrubland Alliance (A.1031)

Bouteloua eriopoda Microphyllous Evergreen Shrub Herbaceous Alliance (A.1545)

Similar Alliance Comments: Both III.B.3.N.a *Prosopis glandulosa* Shrubland Alliance (A.1031) and V.A.7.N.j *Bouteloua eriopoda* Microphyllous Evergreen Shrub Herbaceous Alliance (A.1545) include an association with *Atriplex canescens* as a nominal species.
Synonymy:
Chihuahuan Desertscrub, Saltbush Series, *Atriplex canescens* Association (Brown 1982)
Atriplex canescens Series (Dick-Peddie 1993)
Fourwing saltbush series (Sawyer and Keeler-Wolf 1995)
Sarcobatus vermiculatus Shrublands (Chappell et al. 1997)
Saltbush series in the Chihuahuan Desert Region, Saltbush series and (Donart et al. 1978a)
Mesquite-Saltbush Series, in part (Diamond 1993)
Alkali Sacaton-Fourwing Saltbush Series, in part (Diamond 1993)
Fourwing Saltbush Alliance (Muldavin et al. 2000b
Comments: Shrublands in this alliance can grade into grasslands dominated by *Sporobolus airoides* or *Pleuraphis mutica*, or occur within a matrix of other desert shrublands. Further review of this alliance is necessary before comparisons can be made with other vegetation types. Some of the stands referenced, such as in Francis (1986), may not have enough vegetation cover to be classified as shrublands.

Alliance Distribution
Range: Shrublands included in this alliance occur primarily in arid and semi-arid areas the southwestern U.S. from west Texas to southern and eastern California and into Chihuahua, Mexico. They also are found in the western Great Plains to the Great Basin, from western Kansas, Colorado, and Wyoming to Utah, Nevada and eastern Oregon.
Nations: MX US
States/Provinces: AZ CA CO KS NM NV OR TX UT WY
TNC Ecoregions: 10:C, 11:C, 17:C, 18:C, 19:C, 24:C, 27:C, 28:?, 29:?, 6:C
USFS Ecoregions: 313A:CC, 313B:CC, 313D:CC, 315A:CC, 321A:CC, 322A:CC, 331H:CC, 331I:CC, 341B:CC, 341C:CC, 342B:CC, 342C:C?, 342G:C?, M313B:CC, M341C:CC
Federal Lands: NPS (Grand Canyon, Petrified Forest, Zion); USFWS (Ouray)

Alliance Sources
Authors: K. SCHULZ, JT, WCS **Identifier:** A.869
References: Aldous and Shantz 1924, BIA 1979, BLM 1979a, BLM 1979b, Baker 1984, Beatley 1976, Beatley 1993, Betancourt and Van Devender 1981, Brown 1982, Chappell et al. 1997, Culver et al. 1996, Diamond 1993, Dick-Peddie 1986, Dick-Peddie 1993, Donart et al. 1978a, Faber-Langendoen et al. 1996, Francis 1986, Hyder et al. 1966, Johnston 1987, Klipple and Costello 1960, Maxwell 1975, Miller et al. 1977, Muldavin and Mehlhop 1992, Muldavin et al. 2000b, Peterson 1984, Price et al. 1981, Roberts et al. 1992, Sawyer and Keeler-Wolf 1995, Shaw et al. 1989, Shute and West 1977, Soil Conservation Service 1978, ., U.S. Bureau of Reclamation 1976, USFS 1937, Vest 1962, Warren et al. 1982

III.B.2.N.d. Temporarily flooded cold-deciduous shrubland

III.B.2.N.d.28. Forestiera pubescens Temporarily Flooded Shrubland Alliance
Wild-privet Temporarily Flooded Shrubland Alliance

Alliance Concept
Summary: This shrubland alliance is reported from sandy terraces along major rivers and washes in southwestern Colorado and northeastern Arizona., but likely occurs elsewhere in the southwestern U.S. Elevation ranges from 1500-1650 m. Stands typically form a narrow, but continuous, band about 3 m above the channel on streambanks and natural levees at the interface between the riparian and drier uplands. They occur on the outer edge of the active floodplain. Soils range from silty clays over clay loam to sandy loam. Vegetation within this alliance is classified as temporarily flooded, cold-deciduous shrubland and is characterized by a moderate to dense short-shrub layer dominated by *Forestiera pubescens* with 15-80% cover. In Colorado, *Rhus trilobata* and *Cornus sericea* are common shrub associates with 5-40% cover. *Atriplex canescens* and *Ericameria nauseosa* are common associates in Arizona. The herbaceous layer may be sparse to moderately dense depending on shrub cover. One stand had high cover of *Sporobolus airoides.* Forb cover is usually insignificant. In Colorado, *Salix exigua* shrublands and *Eleocharis palustris* wetlands occur in adjacent riparian areas.
Environment: This shrubland alliance is reported from sandy terraces along major rivers and washes in southwestern Colorado and northeastern Arizona, but likely occurs elsewhere in the southwestern U.S. Elevation ranges from 1500-1650 m. Stands typically form a narrow, but continuous, band about 3 m above the channel on streambanks and natural levees, at the interface between the riparian and drier uplands. They occur on the outer edge of the active floodplain. Soils range from silty clays over clay loam to sandy loam. In Colorado, *Salix exigua* shrublands and *Eleocharis palustris* wetlands occur in adjacent riparian areas.
Vegetation: Vegetation within this alliance is classified as temporarily flooded, cold-deciduous shrubland and is characterized by a moderate to dense short-shrub layer dominated by *Forestiera pubescens* with 15-80% cover. In Colorado *Rhus trilobata* and *Cornus sericea* are common shrub associates with 5-40% cover. *Atriplex canescens* and *Ericameria nauseosa* are common associates in Arizona. The herbaceous layer is sparse to moderately dense depending on shrub cover. One stand had high cover of *Sporobolus airoides.* Forb cover is usually insignificant. In Colorado, *Salix exigua* shrublands and *Eleocharis palustris* wetlands occur in adjacent riparian areas.
Dynamics: This appears to be a flood-tolerant plant association located along stream margins in Colorado. *Forestiera pubescens* usually occupies slightly drier ground than *Salix exigua* (Kittel et al. 1999).

Alliance Distribution
Range: This alliance is currently reported from southwestern Colorado and northeastern Arizona. Based on the range of distribution of *Forestiera*, it is likely to occur in the Mojave and Sonoran deserts of southern California, east across southern Nevada, southeastern Utah, and northern Arizona to New Mexico. It may also extend into Oklahoma and Texas and south to Baja California and Chihuahua, Mexico.
Nations: MX? US
States/Provinces: AZ CO NM? UT?

TNC Ecoregions: 17:C, 19:C, 20:C
USFS Ecoregions: 313D:CC, 322A:CC, 341B:CC, M331G:CC, M331H:CC
Federal Lands: NPS (Petrified Forest)

Alliance Sources
Authors: D. CULVER, MOD. BY K. SCHULZ, WCS **Identifier:** A.969
References: Dick-Peddie 1993, Kittel and Lederer 1993, Kittel et al. 1999, Sawyer and Keeler-Wolf 1995, Welsh et al. 1987

IV. Dwarf-shrubland

IV.A.2.N.a. Extremely xeromorphic evergreen subdesert dwarf-shrubland

IV.A.2.N.a.7. Artemisia bigelovii Dwarf-Shrubland Alliance
Bigelow Sagebrush Dwarf-shrubland Alliance

Alliance Concept
Summary: Stands included in this dwarf-shrubland alliance are found on the Colorado Plateau and in southeastern Colorado. Sites include gentle to moderately steep shale hillslopes and mesas in Arizona and breaks and shale plains in the shortgrass steppe west to the foothills near the Colorado Front Range. Soils are typically shallow, well-drained, calcareous loams, clay loams, and clays derived from limestone, sandstone, shale and alluvium. The soil surface has high cover of bare soil and rock. The vegetation is characterized by a sparse to moderately dense dwarf-shrub layer that is dominated or codominated by *Artemisia bigelovii*. Dwarf-shrub associates from the shortgrass steppe include: *Yucca glauca, Krascheninnikovia lanata, Frankenia jamesii*, and *Glossopetalon spinescens var. meionandrum*. These species may be present to codominant. On the Colorado Plateau, stands may be codominated by *Ephedra* spp., *Eriogonum corymbosum*, *Parryella filifolia,* or *Purshia stansburiana*. *Gutierrezia sarothrae* and species of *Atriplex* and *Yucca* are common in most stands. Scattered *Juniperus* spp. trees are occasionally present. A sparse to moderate graminoid layer is usually present. Dominant grasses include: *Aristida purpurea*, *Achnatherum hymenoides (= Oryzopsis hymenoides), Bouteloua gracilis, Hesperostipa neomexicana (= Stipa neomexicana), Pleuraphis jamesii (= Hilaria jamesii), Sporobolus cryptandrus,* or less commonly *Pascopyrum smithii*. On the Colorado Plateau forbs are generally sparse. However, cushion plants are common on shortgrass steppe slopes. Other forbs, such as *Astragalus missouriensis, Heterotheca villosa, Melampodium cinereum, Picradeniopsis oppositifolia, Stanleya pinnata*, and *Zinnia grandiflora*, are usually present. Exotic annuals, such as *Bromus japonicus, Bromus tectorum, Salsola kali*, and *Descurainia sophia*, may be present to common depending on disturbance, and amount and season of precipitation. Diagnostic of this alliance is the *Artemisia bigelovii*-dominated or codominated dwarf-shrub layer.
Environment: Stands included in this dwarf-shrubland alliance are found on the Colorado Plateau and in southeastern Colorado. Elevation ranges from 1350-1800 m. Climate is semi-arid 22-35 cm of mean annual precipitation occurring during the growing season. Sites are nearly flat to moderate and include shale hillslopes and mesas in

Arizona and breaks and shale plains in the shortgrass steppe west to the foothills near the Colorado Front Range. Soils are typically shallow, well-drained, calcareous loams, clay loams, and clays derived from limestone, sandstone, shale and alluvium. The soil surface has high cover of bare soil and rock.

Vegetation: Stands included in this dwarf-shrubland alliance are found on the Colorado Plateau and in southeastern Colorado. The vegetation is characterized by a sparse to moderately dense dwarf-shrub layer that is dominated or codominated by *Artemisia bigelovii*. Dwarf-shrub associates for the shortgrass steppe include *Yucca glauca, Krascheninnikovia lanata, Frankenia jamesii*, and *Glossopetalon spinescens var. meionandrum*, which may be present to codominant. Scattered shrubs such as *Atriplex canescens, Cercocarpus montanus, Ericameria nauseosa (= Chrysothamnus nauseosus), Lycium pallidum*, and *Rhus trilobata* are occasionally present. On the Colorado Plateau, stands may be codominated by *Ephedra* spp., *Eriogonum corymbosum*, *Parryella filifolia,* or *Purshia stansburiana*. *Gutierrezia sarothrae* and species of *Atriplex* and *Yucca* are common in most stands. Scattered *Juniperus* spp. trees are occasionally present. A sparse to moderately dense graminoid layer is usually present. Dominant grasses include *Achnatherum hymenoides (= Oryzopsis hymenoides), Hesperostipa neomexicana (= Stipa neomexicana), Bouteloua gracilis, Pleuraphis jamesii (= Hilaria jamesii), Sporobolus cryptandrus, Aristida purpurea*, or less commonly *Pascopyrum smithii*. On the Colorado Plateau forbs are generally sparse. However, on shortgrass steppe slopes, cushion plants like *Arenaria hookeri, Eriogonum lachnogynum, Tetraneuris acaulis (= Hymenoxys acaulis)*, and *Paronychia sessiliflora* are common. Other forbs, such as *Astragalus missouriensis, Heterotheca villosa, Melampodium cinereum, Picradeniopsis oppositifolia, Stanleya pinnata*, and *Zinnia grandiflora*, are usually present. Exotic annuals, such as *Bromus japonicus, Bromus tectorum, Salsola kali*, and *Descurainia sophia*, may be present to common depending on disturbance, and amount and season of precipitation. Diagnostic of this alliance is the *Artemisia bigelovii*-dominated or codominated dwarf-shrub layer.

Dynamics: Livestock grazing must be managed carefully to prevent the loss of highly palatable mid grasses such as *Schizachyrium scoparium, Bouteloua curtipendula, Hesperostipa neomexicana,* and *Achnatherum hymenoides*. The effects of fire on this vegetation are unknown. However, the vegetation is usually too sparse to carry a fire under most circumstances.

Similar Alliances:

Bouteloua gracilis Dwarf-Shrub Herbaceous Alliance (A.1571)

Similar Alliance Comments: Within the *Bouteloua gracilis* Dwarf-shrub Herbaceous Alliance (A.1571) there is *Artemisia bigelovii / Bouteloua gracilis* Dwarf-shrub Herbaceous Vegetation (CEGL001742). Stands in this association have a sparse dwarf-shrub layer of *Artemisia bigelovii* and have been described by Muldavin and Melhop (1992) and Muldavin et al. (2000b)from White Sands Missile Range in south-central New Mexico. Floristically, these stands are similar to stands in the *Artemisia bigelovii* Shrubland Alliance (A.1103), but these stands are dominated by graminoids not dwarf-shrubs.

Synonymy:

Limestone Breaks SCS Range Site #58, in part (Soil Conservation Service n.d.)

Shaley Plains SCS Range Site, in part (Soil Conservation Service n.d.)

Sandstone Breaks SCS Range Site #53, in part (Soil Conservation Service n.d.)
Artemisia bigelovii/Ceratoides lanata Plant Community, in part (Shaw et al. 1989)
Glossopetalon meionandra/Frankenia jamesii Plant Community, in part (Shaw et al. 1989)
Artemisia bigelovii/Bouteloua gracilis Plant Community, in part (Shaw et al. 1989)
Comments: The vegetation in some stands included in this alliance may be too sparse to be classified in a dwarf-shrubland. An alliance review is needed to determine if *Artemisia bigelovii / Bouteloua gracilis* Dwarf-shrub Herbaceous Vegetation (CEGL001742) and *Artemisia bigelovii / Achnatherum hymenoides* Dwarf-shrubland (CEGL000990) could be included in the same alliance. Known occurrences from Arizona are limited to 12 plots from Petrified Forest National Park.

Alliance Distribution
Range: Stands included in this dwarf-shrubland alliance are found in Arizona on the Colorado Plateau and in southeastern Colorado.
Nations: US
States/Provinces: AZ CO
TNC Ecoregions: 19:C, 27:C
USFS Ecoregions: 313D:CC, 331I:CC
Federal Lands: NPS (Petrified Forest, Walnut Canyon)

Alliance Sources
Authors: K. SCHULZ, WCS **Identifier:** A.1103
References: CONHP 1983, Muldavin and Mehlhop 1992, Muldavin et al. 2000b, Shaw et al. 1989, Soil Conservation Service 1978,.

IV.A.2.N.b. Facultatively deciduous subdesert dwarf-shrubland

IV.A.2.N.b.1. Atriplex obovata Dwarf-Shrubland Alliance
New Mexico Saltbush Dwarf-shrubland Alliance

Alliance Concept
Summary: This alliance occurs in the northern Chihuahuan Desert and Colorado Plateau from western Texas, south-central and northwestern New Mexico, and northeastern Arizona. Climate is semi-arid to arid. Elevation ranges from 1530-1830 m. Stands are known from valley bottoms, alluvial flats, lower to upper hillslopes, often in a 'badlands' landscape. Soils are generally shallow, poorly developed, and alkaline. Textures range from fine sandy loam to silty clay loam and clay in New Mexico and Arizona. In western Texas, substrates are silt loams and clay soils that may be saline or gypseous. Parent materials include alluvium and colluvium derived from igneous or sedimentary materials such as basalt, shale, and clay. There is high cover of bare soil. Typically, areas have been severely degraded by erosion. The vegetation is characterized by a sparse to locally moderately dense dwarf-shrub layer (10-60% cover) that is dominated or codominated by *Atriplex obovata.* Shrub associates may include: scattered *Atriplex confertifolia*, *Ericameria nauseosa, Isocoma drummondii, Gutierrezia sarothrae, Prosopis glandulosa var. torreyana*, *Opuntia* spp., or *Suaeda* spp. The herbaceous layer ranges from moderately dense to absent, and is usually dominated by perennial grasses such as

Sporobolus airoides. Other associated species may include: *Achnatherum hymenoides*, *Sporobolus cryptandrus, Pleuraphis jamesii (= Hilaria jamesii), Bouteloua gracilis*, *Elymus elymoides*, and the scattered cacti *Opuntia polyacantha* and *Opuntia imbricata*. Where this alliance is known to occur in Texas, *Suaeda mexicana* and *Coryphantha ramillosa* are often present, and after rains, annuals such as *Tidestromia carnosa* may be locally abundant.
Environment: This alliance occurs in the northern Chihuahuan Desert and Colorado Plateau. Climate is semi-arid to arid. Elevation ranges from 1530-1830 m. Stands are known from valley bottoms, alluvial flats, lower to upper hillslopes often in a 'badlands' landscape. Soils are generally shallow, poorly developed, and alkaline. Textures range from fine sandy loam to silty clay loam and clay in New Mexico and Arizona (Francis 1986, Henrickson 1974, TNC 1997). Substrates are silt loams and clay soils that may be saline or gypseous. Parent materials include alluvium and colluvium derived from igneous or sedimentary materials such as basalt, shale, and clay. There is high cover of bare soil. Typically, areas have been severely degraded by erosion.
Vegetation: This alliance occurs in western Texas, northwestern and south-central New Mexico, and northeastern Arizona. The vegetation is characterized by a sparse to locally moderately dense dwarf-shrub layer (10-60% cover) that is dominated or codominated by *Atriplex obovata* (3-40% cover*).* Shrub associates may include: scattered *Atriplex confertifolia*, *Ericameria nauseosa, Isocoma drummondii, Gutierrezia sarothrae, Prosopis glandulosa var. torreyana*, *Opuntia* spp., or *Suaeda* spp. The herbaceous layer ranges from moderately dense to absent (50-0% cover) and is usually dominated by perennial grasses such as *Sporobolus airoides.* Other associated species may include: *Achnatherum hymenoides*, *Sporobolus cryptandrus, Pleuraphis jamesii (= Hilaria jamesii), Bouteloua gracilis*, *Elymus elymoides*, and the scattered cacti *Opuntia polyacantha* and *Opuntia imbricata* (Francis 1986). Where this alliance is known to occur in Texas, *Suaeda mexicana* and *Coryphantha ramillosa* are often present, and after rains, annuals such as *Tidestromia carnosa* may be locally abundant.
Dynamics: Grazing has significantly impacted much of the vegetation in the Rio Puerco basin of northwestern New Mexico, which has had a long history of settlement and heavy livestock use. With proper livestock management and time, palatable species such as *Sporobolus airoides* may increase, and *Opuntia* spp. may decline (Francis 1986).
Similar Alliances:
Pleuraphis jamesii Dwarf-Shrub Herbaceous Alliance (A.1572)
Similar Alliance Comments: *Atriplex obovata* may also occur in V.A.8.N.a *Pleuraphis jamesii* Dwarf-shrub Herbaceous Alliance (A.1572), but the abundance is less and the herbaceous layer is generally denser with higher diversity.
Synonymy:
Atriplex obovata/*Sporobolus airoides* - *S. cryptandrus* Plant Community 26 (Francis 1986)
Comments: This alliance often occurs in 'badland' landscapes adjacent to barren and sparsely vegetated areas and may include vegetation that may be too sparse to be classified as a dwarf-shrubland. Further study is needed throughout its range, especially to assess the effects of livestock grazing on vegetation structure. Similar vegetation is classified in a closely related association, *Atriplex obovata / Pleuraphis jamesii -*

Sporobolus airoides Dwarf-shrub Herbaceous Vegetation (CEGL001775), which is included in the *Pleuraphis jamesii* Dwarf-shrub Herbaceous Alliance (A.1572).

Alliance Distribution
Range: Communities in this alliance are described from the southeastern part of the Colorado Plateau in the upper Rio Puerco watershed in northwestern New Mexico and Arizona; the Trans-Pecos region in Brewster County, western Texas; and in south-central New Mexico. The alliance probably also occurs in Utah and Chihuahua, Mexico.
Nations: MX? US
States/Provinces: MXCO? AZ NM TX
TNC Ecoregions: 19:C, 24:C
USFS Ecoregions: 313B:CC, 313D:CC, 321A:CC, 321B:CC, M313A:CC
Federal Lands: NPS (Big Bend, Petrified Forest)

Alliance Sources
Authors: K. SCHULZ, JT, WCS **Identifier:** A.1108
References: Francis 1986, Henrickson 1974, Reid et al. 1994, TNC 1997, Welsh et al. 1987

IV.B.2.N.a. Caespitose cold-deciduous dwarf-shrubland

IV.B.2.N.a.200. Gutierrezia sarothrae Dwarf-Shrubland Alliance
Snakeweed Dwarf-shrubland Alliance

Alliance Concept
Summary: This dwarf-shrubland alliance was described from Utah and Arizona where it occurs on stream terraces, plains, gently sloping hillslopes, ridges, plateaus and bluffs on all aspects. Elevations range from 1350-2000 m. Soils are variable, ranging from sandy loam to clay derived from alluvium or colluvium. Disturbance may be important in maintaining this vegetation community as some stands have been created by chaining of trees and improper grazing by livestock. This broadly defined alliance is characterized by an open to moderately dense dwarf-shrub canopy (10-50% cover) that is dominated by *Gutierrezia sarothrae* frequently with *Opuntia* spp. and a sparse to moderately dense herbaceous layer (1-45% cover). Some stands have a diverse woody layer that includes low cover of several shrub species and occasional *Pinus edulis* or *Juniperus osteosperma* trees. The herbaceous layer is typically dominated by graminoids with several species present including: *Achnatherum hymenoides, Aristida purpurea, Bouteloua gracilis, Elymus elymoides, Hesperostipa comata*, *Pascopyrum smithii, Pleuraphis jamesii,* or *Sporobolus airoides*. There is usually only sparse cover of native forbs like *Chamaesyce* spp. or *Sphaeralcea coccinea*, however, introduced species such as *Bromus tectorum* or *Salsola kali* may dominate the herbaceous layer of some disturbed stands.
Environment: This alliance is described from Utah and Arizona. Elevations range from 1350-2000 m. Sites include stream terraces, plains, gently sloping hillslopes, ridges, plateaus and bluffs. Stands occur on all aspects. Soils are variable, but tend to be fine-textured and may occur over gravel and cobbles. Disturbance may be important in maintaining this vegetation community in some areas as some stands may have been created by chaining of trees and improper grazing by livestock.

Vegetation: This broadly defined alliance is characterized by an open to moderately dense dwarf-shrub canopy (10-50% cover) dominated by *Gutierrezia sarothrae*, frequently with *Opuntia* spp. and a sparse to moderately dense herbaceous layer. Some stands have a diverse woody layer that includes low cover of: *Artemisia nova, Atriplex canescens, Atriplex confertifolia, Atriplex obovata, Chrysothamnus viscidiflorus, Coleogyne ramosissima, Ephedra* spp., *Eriogonum* spp., *Grayia spinosa, Lycium pallidum, Parryella filifolia, Purshia tridentata*, *Yucca* spp., or occasional *Pinus edulis* or *Juniperus osteosperma* trees. The herbaceous layer is typically dominated by graminoids with several species present to abundant including: *Pleuraphis jamesii, Achnatherum hymenoides, Aristida purpurea, Bouteloua gracilis, Elymus elymoides, Hesperostipa comata*, *Pascopyrum smithii,* or *Sporobolus airoides*. There is usually only sparse cover of native forbs like *Chamaesyce* spp. or *Sphaeralcea coccinea*; however, introduced species such as *Bromus tectorum, Erodium cicutarium, Sisymbrium altissimum*, or *Salsola kali* may dominate the herbaceous layer of some disturbed stands.
Dynamics: *Gutierrezia sarothrae* occurs in many natural grassland and steppe communities in the western U.S. and is known to increase when these communities are disturbed mechanically or by over-grazing (Stubbendieck et al. 1992, USFS 1937). The role of disturbance in this association needs further study to understand its successional nature.
Similar Alliances:
Bouteloua eriopoda Microphyllous Evergreen Shrub Herbaceous Alliance (A.1545)
Pleuraphis jamesii Shrub Herbaceous Alliance (A.1532)
Pleuraphis rigida /Gutierrezia sarothrae Shrub Herbaceous Alliance (A.1529)
Similar Alliance Comments: Each of the 3 similar alliances includes a *Gutierrezia sarothrae* shrub herbaceous vegetation association that with heavy grazing or other disturbance could be altered to resemble this alliance. *Gutierrezia sarothrae* is common in many other grasslands at low cover.
Comments: This broadly defined dwarf-shrubland includes stands that could also be classified as a dwarf-shrub herbaceous association.

Alliance Distribution
Range: This alliance is reported from Utah and Arizona, but is likely more widespread throughout the semi-arid western U.S.
Nations: US
States/Provinces: AZ UT
TNC Ecoregions: 10:C, 19:C, 21:C
USFS Ecoregions: 313A:CC, 313D:CC, 341C:CC, M313A:CC
Federal Lands: NPS (Petrified Forest, Walnut Canyon, Zion); USFWS (Ouray)

Alliance Sources
Authors: K. SCHULZ, WCS **Identifier:** A.2528
References: Thompson 2001, Von Loh et al. 2002

V. Herbaceous Vegetation

V.A.5.N.c. Medium-tall sod temperate or subpolar grassland

V.A.5.N.c.36. Sporobolus airoides Sod Herbaceous Alliance
Alkali Sacaton Sod Herbaceous Alliance

Alliance Concept
Summary: This alliance has been described from the Tularosa Basin in the northern Chihuahuan Desert and the southern Colorado Plateau. Elevation ranges from 1185-2730 m. Stands are reported from playas, sandy floodplains and mesas. The vegetation is characterized by a dense perennial graminoid layer of medium-tall and short grasses that form a sod (>50% cover) that is codominated by *Sporobolus airoides* and *Bouteloua gracilis*. Occasional shrubs may be present including: *Atriplex* spp., *Ephedra* spp., *Ericameria nauseosa,* or *Gutierrezia sarothrae*. Little information is available about vegetation in this alliance.
Environment: Vegetation included in this alliance has been described from the Tularosa Basin in the northern Chihuahuan Desert and Petrified Forest National Park in Arizona. Mean annual precipitation is approximately 20-22cm. Climate is arid to semi-arid at higher elevations, with two-thirds of the highly variable annual precipitation occurring from July to October. Elevation ranges from 1185-2730 m. Stands occur in a playa in the Tularosa Basin (Muldavin et al. 2000b) and on sandy floodplains and mesas in the southern Colorado Plateau. Little information is available about this alliance.
Vegetation: Vegetation in this alliance is characterized by a dense perennial graminoid layer (>50% cover) of medium-tall and short grasses that form a sod that is codominated by *Sporobolus airoides* and *Bouteloua gracilis*. *Pleuraphis jamesii* and *Opuntia* spp. may be present with low cover. Occasional shrubs may include: *Atriplex* spp., *Ephedra* spp., *Ericameria nauseosa,* or *Gutierrezia sarothrae*. No other information is available about vegetation in this alliance.
Similar Alliances:
Sporobolus airoides Herbaceous Alliance (A.1267)
Sporobolus airoides Intermittently Flooded Herbaceous Alliance (A.1331)
Similar Alliance Comments: This alliance is separated from other *Sporobolus airoides* and *Bouteloua gracilis* grasslands by the codominance of these species and the atypical sod-forming growth form. The similar alliances have a medium-tall graminoid layer dominated by *Sporobolus airoides*, but with a bunchgrass growth form or a differing flood regime.
Synonymy:
Sacaton Series, in part (Dick-Peddie 1993)
Bouteloua gracilis Super Alliance (Muldavin et al. 2000b
Comments: This alliance has a single plant association that is classified from stands of vegetation only from the White Sands Missile Range, New Mexico (Muldavin and Mehlhop 1992) and the Petrified Forest National Park. More research and survey are needed to clarify the attributes that separate this alliance from other *Sporobolus airoides* alliances elsewhere. Additional inventory will help to determine if these grasslands are restricted to the Tularosa Basin in the northern Chihuahuan Desert and Colorado Plateau, or if their range extends beyond into the Great Plains, Great Basin and northern Mexico, as do other *Sporobolus airoides*-dominated grasslands. Muldavin et al. (2000b) now classify the White Sands Missile Range vegetation in the *Bouteloua gracilis/Sporobolus*

airoides Plant Association, which is included in the *Bouteloua gracilis* Super Alliance. Classification review is needed to resolve this question.

Alliance Distribution
Range: Vegetation in this alliance has been described from the White Sands Missile Range in south-central New Mexico and Petrified Forest National Park in Arizona.
Nations: MX? US
States/Provinces: AZ, NM
TNC Ecoregions: 19:C
USFS Ecoregions: 313B:??, 313D:CC, 313E:??, 321A:CC
Federal Lands: NPS (Petrified Forest, White Sands)

Alliance Sources
Authors: K. SCHULZ, WCS **Identifier:** A.1241
References: Dick-Peddie 1993, Muldavin and Mehlhop 1992, Neher and Bailey 1976

V.A.5.N.d. Medium-tall bunch temperate or subpolar grassland

V.A.5.N.d.24. Sporobolus airoides Herbaceous Alliance
Alkali Sacaton Herbaceous Alliance

Alliance Concept
Summary: This grassland alliance occurs in the western and southern Great Plains, Great Basin, and across the southwestern United States from Texas to California. It is reported from saline habitats in the Central Valley and in valleys and lower slopes of transmontane California from the Modoc Plateau to the Owens Valley. Elevations range from near sea level to 2100 m, but typically from 1000-1700 m. Climate is arid to semi-arid. Stands occur in a wide variety of lowland sites such as stream terraces, swales, interdune basins, and alluvial flats. This alliance in not defined by a flood regime, but the soil often has a high water table because of land position and impermeable subsurface horizons. Soils are non-saline to moderately saline and usually alkaline. Soil surface textures are sandy to clayey. The soils morphology often includes a claypan, caliche layer or other subsurface horizon that impedes water movement. Parent material is typically alluvium derived from limestone, shale, or sandstone. The vegetation is characterized by a sparse to moderately dense graminoid layer of medium-tall bunch grasses with smaller densities of short grasses and forbs. Widely scattered (<10% cover) xeromorphic or halophytic shrubs and dwarf-shrubs may also be present. *Sporobolus airoides* is the dominant or codominant grass. Typical codominant grasses include: *Muhlenbergia porteri, Panicum obtusum*, or *Scleropogon brevifolius*. Not included in this alliance are stands codominated by *Achnatherum hymenoides*, *Bouteloua gracilis, Distichlis spicata, Pleuraphis jamesii (= Hilaria jamesii)*, or *Hordeum jubatum*, although they may be present in small amounts. Other common grasses are *Buchloe dactyloides, Pascopyrum smithii, Hordeum pusillum*, and *Sporobolus cryptandrus*. Forbs and shrubs are typically sparse. Common forb associates are *Chaetopappa ericoides* and species of *Sphaeralcea, Machaeranthera, Ratibida, Aster*, and *Helianthus*. Scattered shrubs may include: *Allenrolfea occidentalis, Atriplex canescens, Chrysothamnus* spp., and *Sarcobatus vermiculatus*. Species of *Salicornia* and *Suaeda* occur in more saline habitats. The dwarf-shrub *Gutierrezia*

sarothrae is common in many stands. Some stands have significant amounts of prickly pear and cholla cacti (*Opuntia* spp.).

Environment: Grasslands included in this alliance occur in the western and southern Great Plains, Great Basin, and across the southwestern U.S. from Texas to California. The climate is arid to semi-arid. Stands are reported from a variety of lowland sites such as stream terraces, swales, toeslopes, interdune basins and alluvial flats. Elevations range from near sea level to 2100 m, but the alliance occurs primarily from 1000-1700 m. Holland (1986) reported *Sporobolus airoides*-dominated communities from saline habitats in the Central Valley and in valleys and lower slopes of transmontane California, from the Modoc Plateau to the Owens Valley at elevations up to 2100 m. This alliance is not defined by a flood regime, but the soil often has a high water table because of land position or an impermeable subsurface horizon. Soils are non-saline to moderately saline and usually alkaline. Soil surface textures are sandy to clayey. The soil morphology often includes a claypan, caliche layer or other subsurface horizon that impedes water movement. Parent material is typically alluvium derived from limestone, shale, or sandstone.

Adjacent vegetation varies greatly regionally. In the plains, nearby vegetation is likely grassland-steppe or shrublands dominated by species of *Bouteloua, Atriplex,* or *Sarcobatus*, or less frequently woodland dominated by *Pinus edulis* or *Juniperus* spp. In southern deserts, desertscrub dominated by *Larrea tridentata, Flourensia cernua, Ambrosia dumosa, Prosopis* spp., or *Parkinsonia* spp. often borders these grasslands. In the Colorado Plateau and Great Basin, *Artemisia tridentata* and *Atriplex* spp. shrublands likely surround it. Adjacent vegetation at high elevations may include woodlands dominated by *Juniperus osteosperma* and species of *Pinus*, or Great Basin shrublands. Where this vegetation occurs near riparian areas, adjacent vegetation may include mesic shrublands and forests dominated by species of *Salix* or *Populus*.

Vegetation: Vegetation included in this alliance occurs in lowlands primarily in the Great Plains, Great Basin, Colorado Plateau and southwestern deserts. It is characterized by a sparse to moderately dense graminoid layer of medium-tall bunch grasses that is dominated by *Sporobolus airoides* in pure and mixed stands. Typical codominant grasses include *Muhlenbergia porteri, Panicum obtusum,* or *Scleropogon brevifolius*. Not included in this alliance are stands codominated by *Bouteloua gracilis, Distichlis spicata, Pleuraphis jamesii (= Hilaria jamesii)*, or *Hordeum jubatum*, although these species may be present in small amounts. Other common grasses are *Buchloe dactyloides, Pascopyrum smithii, Hordeum pusillum*, and *Sporobolus cryptandrus*. Forbs and shrubs are typically sparse. Common forb associates are *Chaetopappa ericoides* and species of *Sphaeralcea, Machaeranthera, Ratibida, Aster*, and *Helianthus*. Species of *Salicornia* or *Suaeda* may be present in more saline habitats. The dwarf-shrub *Gutierrezia sarothrae* is common in many stands. Scattered shrubs may include *Allenrolfea occidentalis, Atriplex canescens, Atriplex confertifolia, Atriplex obovata, Chrysothamnus* spp., *Ericameria nauseosa*, and *Sarcobatus vermiculatus* typically with less than 10% total cover. Some stands have significant amounts of prickly pear and cholla cacti (*Opuntia* spp.). Culver et al. (1996) described stands from southeastern Colorado with the following percent canopy cover: *Sporobolus airoides* (5-42%), *Pascopyrum smithii* (1-11%), *Bouteloua gracilis* (0-11%), *Distichlis spicata* (0-9%), *Hordeum pusillum* (0-5%), and *Symphyotrichum falcatum (= Aster falcatus)* (0-7%). In New Mexico, Francis (1986) reported a nearly pure stand of *Sporobolus airoides* with 14% cover and mixed stands with canopy cover of 7-30% for *Sporobolus airoides*, 2-4% for *Pascopyrum smithii*, and less than 2% each for *Bouteloua gracilis, Sporobolus cryptandrus*, and *Pleuraphis jamesii*.

Dynamics: *Sporobolus airoides* will decrease in abundance with increased soil salinity. If a moderate salinity level is maintained, this grass forms hummocks that accumulate sand and gradually lose salinity and moisture. This creates a microhabitat for invasion by salt-intolerant species (Ungar 1974, as cited by Johnston 1987).

Similar Alliances:

Sporobolus airoides Intermittently Flooded Herbaceous Alliance (A.1331)
Sporobolus airoides Sod Herbaceous Alliance (A.1241)
Distichlis spicata - (Hordeum jubatum) Temporarily Flooded Herbaceous Alliance (A.1341)
Pleuraphis jamesii Herbaceous Alliance (A.1287)
Hordeum jubatum Temporarily Flooded Herbaceous Alliance (A.1358)

Similar Alliance Comments: Most *Sporobolus airoides* herbaceous associations fall into this alliance. One of the similar alliances, V.A.5.N.i *Sporobolus airoides* Intermittently Flooded Herbaceous Alliance (A.1331), is separated because of an intermittent flood regime. This affects soil moisture and salinity which can alter species composition. Another alliance, V.A.5.N.c *Sporobolus airoides* Sod Herbaceous Alliance (A.1241), is separated by an atypical sod formed by *Sporobolus airoides* and *Bouteloua gracilis*. *Sporobolus airoides* is a wide-ranging western grass species and is a nominal species in several associations with shrubs such as *Atriplex* spp., *Artemisia tridentata* and *Sarcobatus vermiculatus*, and graminoid species such as *Pleuraphis jamesii* and *Distichlis spicata*. Other similar alliances include V.A.5.N.j *Distichlis spicata - (Hordeum jubatum)* Temporarily Flooded Herbaceous Alliance (A.1341), V.A.5.N.e *Pleuraphis jamesii* Herbaceous Alliance (A.1287), and V.A.5.N.j *Hordeum jubatum* Temporarily Flooded Herbaceous Alliance (A.1358).

Synonymy:

Sporobolus airoides Series (Johnston 1987)
Tussock Grass, Type 37 (Aldous and Shantz 1924)
Alkali Meadow, Type 45310, in part (Holland 1986)
Sacaton Series, in part (Dick-Peddie 1993)
Alkali Sacaton Series (Sawyer and Keeler-Wolf 1995)
Valley sacaton grassland (Holland 1986)
Alkali Sacaton-Fourwing Saltbush Series, in part (Diamond 1993)

Comments: This alliance is found primarily in the western Great Plains. It is largely in the western United States. Classification of types found in California are provisional and need further description. Further survey may locate stands of this alliance in Nevada.

Alliance Distribution

Range: This widespread alliance occurs primarily in the western and southern Great Plains, across the southwestern United States from the Chihuahuan Desert into southern and western California, Colorado Plateau and throughout the Great Basin. It also likely occurs in the adjacent Mexican states of Coahuila, Chihuahua, Sonora, and Baja California.

Nations: MX US
States/Provinces: AZ CA? CO KS MT MXCO ND NM SD TX
TNC Ecoregions: 10:C, 19:C, 20:C, 24:C, 25:C, 26:C, 27:C
USFS Ecoregions: 251:?, 262:P, 313B:CC, 313D:CC, 313E:CC, 315A:CC, 315B:CP, 321A:CC, 322:P, 331E:C?, 331F:CC, 331G:C?, 331I:CC, 332:?, 341C:CC, 342G:P?, M331G:CC, M331I:CC, M334A:CC
Federal Lands: NPS (Petrified Forest) USFWS (Ouray)

Alliance Sources
Authors: K. SCHULZ, JT, WCS **Identifier:** A.1267
References: Aldous and Shantz 1924, Bock and Bock 1986, Brown 1982, Burgess and Klein n.d., Burgess and Northington 1977, Cooper 1984, Culver et al. 1996, Diamond 1993, Dick-Peddie 1993, Faber-Langendoen et al. 1996, Faber-Langendoen et al. 1997, Francis 1986, Henrickson 1974, Henrickson et al. 1985, Holland 1986, Johnston 1987, Kartesz 1994, Kittel and Lederer 1993, Lesica and DeVelice 1992, Lindauer 1970, Muldavin and Mehlhop 1992, Muldavin et al. 2000b, Neher and Bailey 1976, Sawyer and Keeler-Wolf 1995, Soil Conservation Service 1978, Steward 1982, Ungar 1968, Ungar 1972, Ungar 1974a, Whitfield and Anderson 1938

V.A.5.N.e. Short sod temperate or subpolar grassland

V.A.5.N.e.9. Bouteloua gracilis Herbaceous Alliance
Blue Grama Herbaceous Alliance

Alliance Concept
Summary: This widespread alliance includes grassland dominated or codominated by *Bouteloua gracilis*, and is found across the Great Plains from near the United States-Mexico border to southern Canada. The bulk of this alliance occurs in the western Great Plains and southwestern United States, but one extensive and one restricted community occurs in the midwestern United States. Stands are found on flat to rolling uplands such as plains, plateaus, foothills, valley bottoms, and sand sheets and dunes with a variety of soil types. Surface soils can range from sandy loam to loamy clay. Subsoils are often finer than the surface soils and may be somewhat impermeable to water. The upland position and heavy soils often result in much of the precipitation running off, and drought conditions prevail for much of the year. This trend is more pronounced in the northern part of this alliance. In the southern portions of its range, the greater temperatures and lack of precipitation allow this shortgrass alliance to occur on coarser soils. Vegetation within this alliance is dominated by short grasses with mid grasses present to codominant. Mid grasses are more abundant in the eastern portions of this alliance. Coverage by short grasses is moderate to almost complete. The foliage is typically 7-19 cm tall with flowering stalks reaching 45 cm. Midgrass species are usually dwarfed because of dry conditions and may not exceed 0.7 m except in especially wet years. Shrubs are very rare except in the southern parts of this alliance's range where scattered desert shrubs may occur (<10% cover). Typical codominant species are *Buchloe dactyloides* or *Pleuraphis jamesii (= Hilaria jamesii)*. Other common to codominant graminoids may include: *Aristida purpurea, Bouteloua curtipendula, Bouteloua hirsuta, Carex filifolia*, *Carex inops ssp. heliophila, Carex duriuscula (= Carex eleocharis), Elymus elymoides,*

Hesperostipa neomexicana (= *Stipa neomexicana*), *Pascopyrum smithii, Sporobolus cryptandrus,* or *Sporobolus airoides*. There are a variety of forbs found in stands of this alliance, although they do not contribute greatly to the total vegetation cover. Common forbs include: *Astragalus* spp., *Gaura coccinea, Machaeranthera pinnatifida var. pinnatifida, Opuntia polyacantha, Plantago patagonica, Psoralidium tenuiflorum, Ratibida columnifera*, and *Sphaeralcea coccinea*.

Environment: Associations included in this semi-arid grassland alliance are common in the western Great Plains, Chihuahuan Desert and Colorado Plateau on flat to rolling uplands such as plains, plateaus, foothills, valley bottoms, and sand sheets and dunes with a variety of soil types (Heitschmidt et al. 1970, Johnston 1987). Surface soils can be sandy loam, loam, silty loam, or loamy clay (Weaver and Albertson 1956, Johnston 1987, Steinauer 1989). Subsoils are often finer than the surface soils and may be somewhat impermeable to water. The upland position and heavy soils may result in much of the precipitation running off, and dry soil conditions prevail for much of the year. This trend is more pronounced in the northern range of this alliance. In the southern portions of its range, the greater temperatures and lack of precipitation allow this shortgrass alliance to occur on coarser soils.

Vegetation: This is a widespread alliance found across the Great Plains from southern Canada to near the United States-Mexico border and west to the Colorado Plateau. Most of the communities are located in the western and southwestern Great Plains, but one extensive and one restricted community occur in the midwestern U.S. Stands within this alliance are dominated by short grasses with mid grasses present to codominant. Mid grasses are more abundant in the eastern portions of this alliance (Kuchler 1974). Coverage by short grasses is moderate to almost complete. The foliage is typically 7-19 cm tall with flowering stalks reaching 45 cm (Hanson 1950, Weaver and Albertson 1956). Midgrass species are usually dwarfed due to the dry conditions and may not exceed 0.7 m except in especially wet years. Shrubs are very rare except in the southern parts of this alliance's range where scattered desert shrubs may occur (<10% cover) (Bruner 1931, Weaver and Albertson 1956). *Bouteloua gracilis* dominates or codominated with *Buchloe dactyloides* or *Pleuraphis jamesii (= Hilaria jamesii)*. Other common graminoids that may be present to codominate are *Aristida purpurea, Bouteloua curtipendula, Bouteloua hirsuta, Carex filifolia, Carex inops ssp. heliophila, Carex duriuscula (= Carex eleocharis), Elymus elymoides, Hesperostipa neomexicana (= Stipa neomexicana)*, *Pascopyrum smithii, Sporobolus cryptandrus,* or *Sporobolus airoides*. There are a variety of forbs found in stands of this alliance, although they do not contribute greatly to the total vegetation cover. Common forbs include: *Astragalus* spp., *Gaura coccinea, Machaeranthera pinnatifida ssp. pinnatifida, Opuntia polyacantha, Plantago patagonica, Psoralidium tenuiflorum, Ratibida columnifera*, and *Sphaeralcea coccinea*.

Dynamics: *Bouteloua gracilis* is an extremely drought- and grazing-tolerant shortgrass species. It is one of the most widely distributed grasses in the western U.S., and is present in many different grassland, shrubland and woodland communities. It evolved with grazing by large herbivores and generally forms a short sod. However, in some stands ungrazed plants develop the upright physiognomy of a bunchgrass.

Similar Alliances:

Pseudoroegneria spicata - Bouteloua gracilis Herbaceous Alliance (A.1239)

Hesperostipa comata - Bouteloua gracilis Herbaceous Alliance (A.1234)
Bouteloua gracilis Dwarf-Shrub Herbaceous Alliance (A.1571)
Pascopyrum smithii Herbaceous Alliance (A.1232)
Hesperostipa comata Bunch Herbaceous Alliance (A.1270)
Similar Alliance Comments: Stands within this alliance may be similar to stands in the V.A.5.N.c *Pascopyrum smithii* Herbaceous Alliance (A.1232) and the V.A.5.N.d *Hesperostipa comata* Bunch Herbaceous Alliance (A.1270). Abundance of the diagnostic mid grasses usually serves to differentiate these alliances in Wyoming where their ranges overlap. These alliances all share *Bouteloua gracilis* as a dominant or codominant species in the herbaceous layer and differ mainly in the presence and abundance of mid grasses and shrubs.
Synonymy:
Bouteloua gracilis herbaceous series (Hoagland 1997)
Blue grama-Buffalograss Series, in part (Diamond 1993)
Sideoats Grama-Black Grama Series, in part (Diamond 1993)
Sideoats Grama Series, in part (Diamond 1993)
Plains-Mesa Grassland (Dick-Peddie 1993)
Grama-Buffalo Grass (65) (Kuchler 1964)
Grama-Galleta Steppe (53) (Kuchler 1964)
Grama-Tobosa Prairie (54) (Kuchler 1964)
Northern Grama-Buffalograss Prairie. Kansas (Kuchler 1974)
Southern Grama-Buffalograss Prairie. Kansas (Kuchler 1974)
Short Grass Type. Nebraska (Hopkins 1951)
Bulbilis-Bouteloua Association. Oklahoma (Bruner 1931)
Comments: Stands containing a mix of *Bouteloua gracilis, Carex filifolia*, and moderate amounts of *Pascopyrum smithii* or *Hesperostipa comata* may present classification problems. *Bouteloua gracilis* increases with heavy grazing pressure as other species decline in many western plant communities, often resulting in difficulties in classification.

Alliance Distribution
Range: Grasslands in this widespread alliance occur in the Great Plains, Chihuahuan Desert and Colorado Plateau from Saskatchewan, North Dakota and Wyoming, south to Texas, and the Mexican states of Chihuahua and Coahuila, and west to Utah and Arizona.
Nations: CA MX US
States/Provinces: AZ CO KS ND NE NM OK SD SK TX UT WY
TNC Ecoregions: 19:C, 20:C, 21:C, 22:C, 24:C, 26:?, 27:C, 28:C, 33:C
USFS Ecoregions: 311A:CC, 313B:CC, 313D:CC, 313E:CC, 315A:CC, 315B:CC, 315C:CC, 321A:CC, 331A:C?, 331B:CC, 331C:CC, 331F:CC, 331G:CC, 331H:CC, 331I:CC, 331J:CC, 332E:??, M313A:CC, M313B:CC, M331F:??
Federal Lands: NPS (Petrified Forest, Sunset Crater, Walnut Canyon)

Alliance Sources
Authors: B. HOAGLAND/D. DIAMOND 11, JT, WCS **Identifier:** A.1282
References: Albertson and Tomanek 1965, Armstrong 1972, Badaracco 1971, Beavis et al. 1982, Bock and Bock 1986, Bonham and Hannan 1978, Bonham and Lerwick 1976,

Bourgeron et al. 1993, Bruner 1931, Bujakiewicz 1975, Clements and Goldsmith 1924, Costello 1944, Costello and Turner 1944, Diamond 1993, Dick-Peddie 1986, Dick-Peddie 1993, Donart et al. 1978b, Dwyer and Pieper 1967, Faber-Langendoen et al. 1996, Fink 1907, Fisser 1970, Fisser et al. 1965, Francis 1986, Gardner 1951, Gregg 1963, Hanson 1951, Heerwagen 1958, Heitschmidt et al. 1970, Hoagland 1997, Hopkins 1951, Jameson 1969, Johnston 1987, Klipple 1964, Knight et al. 1987, Kuchler 1964, Kuchler 1974, Masek 1979, Maxwell 1975, Milchunas et al. 1989, Mitchell 1971, Moir and Trlica 1976, Moulton et al. 1981, Muldavin and Mehlhop 1992, Muldavin et al. 2000b, Mutel 1976, Pieper 1968, Pieper et al. 1971, Ramaley 1914, Rippel et al. 1983, Robbins 1917, Rogers 1953, Schroeder 1977, Senft et al. 1983, Shantz 1911, Shantz 1923, Soil Conservation Service 1978, Stearns-Roger Inc. 1978, Steinauer 1989, Terwilliger et al. 1979, Thilenius 1971, Thilenius and Brown 1990, Van Pelt 1978, Vestal 1913, Vestal 1914, Weaver and Albertson 1956, Williams 1961, Zimmerman 1967

V.A.5.N.e.12. Bouteloua hirsuta Herbaceous Alliance
Hairy Grama Herbaceous Alliance

Alliance Concept

Summary: Grasslands in this alliance are dominated by *Bouteloua hirsuta* and occur in the southern Great Plains, on foothills in the southern Rocky Mountains, on mountain slopes and mesa escarpments in the Chihuahuan Desert and on the Colorado Plateau. Sites range from gently sloping plains, valleys and mesas tops to very steep slopes in the mountains. Elevation ranges from 1450-2000 m. Stands grow on relatively cooler sites at low elevations and warmer sites at high elevations. Ground cover is variable. Soils are generally sandy, but include silty loams and are derived from calcareous limestone, siltstone, igneous (rhyolite), and/or plutonic rocks. The vegetation is characterized by a sparse to moderately dense graminoid layer (10-65% cover) dominated by short sod-forming grasses. Mid grasses and sparse scattered shrubs may be also be present. The grass layer is dominated or codominated by the shortgrass *Bouteloua hirsuta*. Codominant grasses may include: *Bouteloua curtipendula, Bouteloua radicosa, Digitaria californica, Eragrostis intermedia*, and *Hesperostipa neomexicana (= Stipa neomexicana)*. Forb cover is generally sparse (less than 10%). Scattered shrubs and dwarf-shrubs may be present, but make up less than 10% cover. Common shrubs include *Prosopis glandulosa, Nolina microcarpa, Agave palmeri*, *Gutierrezia sarothrae*, and *Dasylirion wheeleri*. Scattered cacti are also characteristic and often include *Opuntia imbricata, Opuntia phaeacantha*, and *Coryphantha* sp.

Environment: Grasslands in this alliance occur on the southern Great Plains, slopes of foothills in the southern Rocky Mountains, on mountain slopes and mesa escarpments in the Chihuahuan Desert and on the Colorado Plateau. Sites range from gently sloping plains, valleys and mesas tops to very steep slopes in the mountains. Climate is semi-arid. Elevation ranges from 1450-2000 m. Stands grow on relatively cooler sites at low elevations and warmer sites at high elevations. Ground cover is variable. Bourgeron et al. (1993) found bare ground, gravel/rock, and litter cover range from 5-50%, 20-60%, and 3-60%, respectively. Soils are generally sandy but range to silty loam and are derived from calcareous limestone, siltstone, igneous (rhyolite), and/or plutonic rocks. In the Chihuahuan Desert mountains, adjacent communities at lower elevations are usually

Bouteloua curtipendula- or *Bouteloua eriopoda*-dominated. Communities upslope are typically shrublands dominated by *Cercocarpus montanus*. In the plains, grasslands in this alliance occupy rocky hilltops and sandy sites (Weaver and Albertson 1956).
Vegetation: Grasslands in this alliance occur in the southern Great Plains, on foothills in the southern Rocky Mountains on mountain and mesas slopes in the Chihuahuan Desert, and the Colorado Plateau. Stands have a sparse to moderately dense graminoid layer ranging from 10-65% canopy cover. The grass layer is dominated or codominated by the shortgrass *Bouteloua hirsuta*. Codominant grasses may include *Bouteloua curtipendula, Bouteloua radicosa, Digitaria californica, Eragrostis intermedia*, and *Hesperostipa neomexicana (= Stipa neomexicana)*. Forb cover is generally sparse (less than 10%). Characteristic forbs include *Croton pottsii, Eriogonum wrightii, Mollugo verticillata, Sphaeralcea* spp., and *Zinnia grandiflora*. Sparse scattered shrubs and dwarf-shrubs may be present, but make up less than 10% cover. Common shrubs and dwarf-shrubs include *Prosopis glandulosa, Nolina microcarpa, Krameria* spp., *Agave palmeri*, *Gutierrezia sarothrae*, and *Dasylirion wheeleri*. Scattered cacti are also characteristic and often include *Opuntia imbricata, Opuntia phaeacantha*, and *Coryphantha* spp.
Dynamics: Wood et al. (1998) suggest communities in this alliance are weakly associated with relatively mesic sites and disturbance.
Similar Alliances:
Bouteloua hirsuta - Bouteloua gracilis - Bouteloua eriopoda Shrub Herbaceous Alliance (A.1548)
Hesperostipa neomexicana Herbaceous Alliance (A.1272)
Bouteloua curtipendula Herbaceous Alliance (A.1244)
Synonymy:
Bouteloua hirsuta herbaceous series. This only includes southern Great Plains associations. (Hoagland 1997)
Bouteloua hirsuta Series. This also includes some of the shrub herbaceous alliances. (e Wood et al. 1998)
Blue grama-Buffalograss Series. in part? (Diamond 1993)
Sideoats Grama-Black Grama Series. in part? (Diamond 1993)
Sideoats Grama Series, in part (Diamond 1993)
Comments: *Bouteloua hirsuta* is a widespread grass in the western U.S. and is codominant in several grassland, shrubland and woodland associations and one other alliance. The key characteristic of this alliance is the dominance of the shortgrass *Bouteloua hirsuta* with only minor amounts of *Bouteloua gracilis* present and the lack of a significant shrub or tree layer.

Alliance Distribution
Range: Grasslands in this alliance occur on the plains and slopes of foothills and mesas in Oklahoma, Texas, New Mexico, and Arizona. The alliance is also found in the Mexican states of Chihuahua and Coahuila.
Nations: MX US
States/Provinces: AZ? MXCH? NM OK TX CO
TNC Ecoregions: 19:C, 20:C, 21:C, 24:C, 27:C, 28:C
USFS Ecoregions: 313D:CC, 315A:CC, 321A:CC, 331I:CC, M313B:CC, M331F:CC
Federal Lands: NPS (Petrified Forest)

Alliance Sources
Authors: GREAT PLAINS PROGRAM 1-95, JT, MOD by K. SCHULZ WCS
Identifier: A.1285
References: Bourgeron et al. 1993, Bourgeron et al. 1995, Diamond 1993, Hoagland 1997, Muldavin and Mehlhop 1992, Muldavin et al. 1994, Muldavin et al. 2000b, Weaver and Albertson 1956, Wood et al. 1998

V.A.5.N.e.14. Pleuraphis jamesii Herbaceous Alliance
James' Galleta Herbaceous Alliance

Alliance Concept
Summary: This alliance occurs in arid and semi-arid regions in the southwestern Great Plains, Colorado Plateau, Great Basin and throughout the southwestern U.S. on a variety of landforms including plains, mesas, alluvial flats, floodplains, swales, hillslopes, dunes, badlands and bajadas. Soils are variable and range from sand to clay textures. The vegetation is characterized by an herbaceous layer with sparse to moderately dense cover of perennial grasses that is usually dominated by *Pleuraphis jamesii (= Hilaria jamesii)*, either growing in nearly pure stands or is codominated by *Sporobolus airoides*. *Pleuraphis jamesii* typically grows as a bunchgrass, but under favorable conditions produces a sod. Other common perennial grasses such as *Sporobolus cryptandrus, Achnatherum hymenoides (= Oryzopsis hymenoides)*, and *Bouteloua gracilis* occur in small amounts (less than half the cover of *Pleuraphis jamesii*). The sparse forb layer often includes *Sphaeralcea coccinea* and *Astragalus* spp. Occasional scattered shrubs and dwarf-shrubs species of *Artemisia, Atriplex, Chrysothamnus*, *Ericameria*, *Ephedra,* and *Yucca*, as well as *Gutierrezia sarothrae* and *Krascheninnikovia lanata*, may occur with less than 10% total cover.
Environment: This alliance occurs in arid and semi-arid regions in the southwestern U.S. on a variety of landforms such as plains, mesas, alluvial flats, floodplains, swales, hillslopes, dunes, badlands and bajadas. Stands occur on all slopes and aspects. Substrates are variable and range from sand- to clay-textured soils. Parent materials include alluvium, colluvium and aeolian deposits derived from igneous, metamorphic and, most commonly, sedimentary rocks, especially shale and sandstone (Weaver and Albertson 1956).
Vegetation: This alliance is characterized by an herbaceous layer with sparse to moderately dense cover of perennial grasses that is usually dominated by *Pleuraphis jamesii (= Hilaria jamesii)*, either growing in nearly pure stands or is codominated by *Sporobolus airoides*. *Pleuraphis jamesii* typically grows as a bunchgrass, but under favorable conditions produces a sod (West et al. 1972). Other common perennial grasses such as *Sporobolus cryptandrus, Achnatherum hymenoides (= Oryzopsis hymenoides)*, and *Bouteloua gracilis* may occur in small amounts (less than half the cover of *Pleuraphis jamesii*). The sparse forb layer often includes *Sphaeralcea coccinea* and *Astragalus* spp. Occasional shrubs and dwarf-shrubs such as *Artemisia bigelovii, Atriplex canescens, Atriplex confertifolia, Atriplex obovata, Ericameria nauseosa, Ephedra* spp., *Gutierrezia sarothrae, Krascheninnikovia lanata*, *Opuntia* spp., or *Yucca* spp. may occur with less than 10% total cover.

Dynamics: *Pleuraphis jamesii* is both drought- and grazing-resistant (USFS 1937, Weaver and Albertson 1956, West et al. 1972). In parts of its range it increases under grazing, and in others parts it decreases. The grass is favored in mixed grass stands because it is only moderately palatable to livestock, but decreases when heavily grazed during drought and in the more arid portions of its range where it is the dominant grass (West et al. 1972). This grass reproduces extensively from scaly rhizomes. These rhizomes make the plant resistant to trampling by livestock and have good soil binding properties (USFS 1937, Weaver and Albertson 1956, West et al. 1972).
Similar Alliances:
Pleuraphis jamesii Shrub Herbaceous Alliance (A.1532)
Artemisia tridentata Shrubland Alliance (A.829)
Artemisia tridentata ssp. *tridentata* Shrubland Alliance (A.830)
Atriplex canescens Shrubland Alliance (A.869)
Atriplex confertifolia Shrubland Alliance (A.870)
Krascheninnikovia lanata Dwarf-Shrubland Alliance (A.1104)
Ericameria parryi Shrubland Alliance (A.818)
Coleogyne ramosissima Shrubland Alliance (A.874)
Artemisia nova Dwarf-Shrubland Alliance (A.1105)
Atriplex gardneri Dwarf-Shrubland Alliance (A.1110)
Bouteloua eriopoda Herbaceous Alliance (A.1284)
Bouteloua gracilis Herbaceous Alliance (A.1282)
Similar Alliance Comments: The similar alliance, *Pleuraphis jamesii* Shrub Herbaceous Alliance (A.1532), has *Pleuraphis jamesii* as diagnostic ground cover for the alliance. All others have *Pleuraphis jamesii* as diagnostic ground cover for at least one association in the alliance. The strong dominance of *Pleuraphis jamesii* (and possible *Sporobolus airoides* codominance) is diagnostic of this alliance.
Synonymy:
Hilaria jamesii - Sporobolus airoides Plant Community. Plant community #37 (Francis 1986)
Highland Grass, in part (Nichol 1937)
Comments: Francis (1986) described two plant codominated by *Pleuraphis jamesii* and *Sporobolus airoides*. Some stands in this alliance described by Francis (1986) have low vegetation cover, which averaged less than 15% total vegetation cover.

Alliance Distribution
Range: The distribution of this southwestern alliance is centered in the Colorado Plateau region of Colorado, New Mexico, Arizona, and Utah. It is also found in the shortgrass steppe in eastern Colorado and New Mexico (and possibly the panhandles of Oklahoma and Texas), and the Great Basin as far west as east-central California.
Nations: US
States/Provinces: AZ CA CO NM NV UT
TNC Ecoregions: 10:C, 11:C, 17:C, 19:C
USFS Ecoregions: 313A:CC, 313B:CC, 313D:CC, 321A:??, 322A:CC, 341C:CC, 341D:CC, 341E:CC, M313A:C?
Federal Lands: NPS (Canyonlands, Petrified Forest, Wapatki, Zion); USFWS (Ouray)

Alliance Sources

Authors: K. SCHULZ, WCS **Identifier:** A.1287

References: Cannon 1960, Donart et al. 1978b, Francis 1986, Francis and Aldon 1983, Heerwagen 1956, Helm 1981, Kleiner 1968, Kleiner 1983, Kleiner and Harper 1972, Kleiner and Harper 1977, Marr et al. 1973, Nichol 1937, Stewart et al. 1940, U.S. Forest Service (USFS) 1937, Utah Environmental and Agricultural Consultants 1973, Weaver and Albertson 1956, West et al. 1972

V.A.7.N.e. Medium-tall temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer

V.A.7.N.e.12. Pleuraphis jamesii Shrub Herbaceous Alliance

James' Galleta Shrub Herbaceous Alliance

Alliance Concept

Summary: This alliance has been described from the southern Colorado Plateau in northwestern New Mexico and adjacent Arizona. Climate is semi-arid. The elevation ranges from 1500-1860 m, but stands likely occur over a wider elevational and geographical range. Sites occur on a variety of landforms including mesas, plains, alluvial flats and fans, floodplains, and hillslopes. Soils are shallow, poorly developed and alkaline. Soil textures range from fine sandy loam to silty clay loam to clay. The ground surface has high cover of bare ground (to 90%) with little litter or rock cover. The vegetation is dominated by a sparse to moderately dense herbaceous layer of perennial grasses that is characterized by *Pleuraphis jamesii (= Hilaria jamesii)* with an open short-shrub canopy (10-25% cover). *Pleuraphis jamesii* typically grows as a bunchgrass, but under favorable conditions may produce a sod. It dominates the herbaceous layer growing in nearly pure stands or is codominated by *Sporobolus airoides* or *Sporobolus cryptandrus*. Other common perennial grasses such as *Achnatherum hymenoides (= Oryzopsis hymenoides)*, *Elymus elymoides, Muhlenbergia torreyi, Schedonnardus paniculatus,* or *Bouteloua gracilis* may occur in small amounts (less than half the cover of *Pleuraphis jamesii*). Forb cover is sparse and typically includes *Sphaeralcea coccinea* and *Astragalus* spp. The open short-shrub layer is often dominated by *Atriplex obovata* or *Gutierrezia sarothrae*, but may include other shrubs and dwarf-shrubs such as *Artemisia bigelovii, Atriplex canescens, Atriplex confertifolia, Ericameria nauseosa*, *Ephedra* spp., *Krascheninnikovia lanata*, *Opuntia* spp., or *Yucca* spp., with less than 25% total cover.

Environment: This alliance has been described from the southern Colorado Plateau in northwestern New Mexico and adjacent Arizona. The elevation ranges from 1500-1860 m, but stands likely occur over a wider elevational and geographical range. Climate is semi-arid with most of the highly variable precipitation falling in July and August. The driest month is April. Mean annual precipitation ranges from 22-32 cm within the Rio Puerco watershed. Sites occur on a variety of landforms including mesas, plains, alluvial flats and fans, floodplains, and hillslopes. Soils are shallow, poorly developed and alkaline. Soil textures range from fine sandy loam to silty clay loam to clay. The ground surface has high cover of bare ground (to 90%) with little litter or rock cover (Francis 1986). Additional survey and description work is needed to fully describe the environment of this alliance.

Vegetation: This minor alliance is found on mesas in northwestern New Mexico and adjacent Arizona. The vegetation is dominated by a sparse to moderately dense herbaceous layer of perennial grasses that is characterized by *Pleuraphis jamesii (= Hilaria jamesii)* with a open short-shrub canopy (10-25% cover). *Pleuraphis jamesii* typically grows as a bunchgrass, but under favorable conditions may produce a sod. It dominates the herbaceous layer growing in nearly pure stands or is codominated by *Sporobolus airoides* or *Sporobolus cryptandrus*. Other common perennial grasses such as *Achnatherum hymenoides (= Oryzopsis hymenoides)*, *Elymus elymoides, Muhlenbergia torreyi, Schedonnardus paniculatus,* or *Bouteloua gracilis* may occur in small amounts (less than half the cover of *Pleuraphis jamesii*). Forb cover is sparse and typically includes *Sphaeralcea coccinea* and *Astragalus* spp. The open short-shrub layer is often dominated by *Atriplex obovata* or *Gutierrezia sarothrae*, but may include may other shrubs and dwarf-shrubs such as *Artemisia bigelovii, Atriplex canescens, Atriplex confertifolia, Ericameria nauseosa*, *Ephedra* spp*., Krascheninnikovia lanata*, *Opuntia* spp., or *Yucca* spp., with less than 25% total cover. Total vegetation cover ranges from 10-75% with graminoids making up 8-60% cover. The sparse stands described by Francis (1986) may indicate a seral/degraded state and need further review.
Dynamics: Grazing has significantly impacted much of the vegetation in this region, which has had a long history of settlement and heavy livestock use. With proper livestock management and time, palatable species such as *Krascheninnikovia lanata* and *Sporobolus airoides* may increase, and *Gutierrezia sarothrae* and *Opuntia* spp. may decline in abundance (Francis 1986).
Similar Alliances:
Pleuraphis jamesii Herbaceous Alliance (A.1287)
Artemisia tridentata Shrubland Alliance (A.829)
Artemisia tridentata ssp. *tridentata* Shrubland Alliance (A.830)
Atriplex canescens Shrubland Alliance (A.869)
Atriplex confertifolia Shrubland Alliance (A.870)
Atriplex obovata Dwarf-Shrubland Alliance (A.1108)
Krascheninnikovia lanata Dwarf-Shrubland Alliance (A.1104)
Ericameria parryi Shrubland Alliance (A.818)
Coleogyne ramosissima Shrubland Alliance (A.874)
Artemisia nova Dwarf-Shrubland Alliance (A.1105)
Atriplex gardneri Dwarf-Shrubland Alliance (A.1110)
Bouteloua eriopoda Herbaceous Alliance (A.1284)
Bouteloua gracilis Herbaceous Alliance (A.1282)
Similar Alliance Comments: Two of the similar alliances have *Pleuraphis jamesii* as diagnostic species for the alliance. All others have *Pleuraphis jamesii* as diagnostic ground cover for at least one association in the alliance.
Synonymy:
Gutierrezia sarothrae / Sporobolus airoides - Hilaria jamesii Plant Community. (Francis 1986)
Atriplex obovata - Gutierrezia sarothrae/Hilaria jamesii - Sporobolus airoides. Included within the Atriplex obovata Series. (Francis 1986).
Gutierrezia sarothrae / Hilaria jamesii - Sporobolus cryptandrus Plant Community. This plant community is in the Hilaria jamesii series. (Francis 1986)

Comments: The main difference between stands in this alliance and the *Pleuraphis jamesii* Herbaceous Alliance (A.1287) is the presence of a significant woody layer composed of shrubs and dwarf-shrubs. However, stands described by Francis (1986) have less than 10% total vegetation cover and may be better classified in a sparsely vegetated alliance. Further confusing this type, Francis (1986) includes degraded stands of the *Sporobolus airoides - Pleuraphis jamesii* alluvial flats plant community in this mesa top plant community. Francis (1986) also described many other plant communities in the Upper Rio Puerco watershed, some of which may also fit the concept of this alliance. This alliance description is based on two plant community descriptions by Francis (1986) and work done at Petrified Forest National Monument. Some stands included in this alliance may form a transitional stage between *Pleuraphis jamesii - Sporobolus airoides* grasslands and *Atriplex obovata* dwarf-shrublands. Further study is needed, especially on the effects of livestock grazing on vegetation structure.

Alliance Distribution
Range: This alliance is described from the upper Rio Puerco watershed in northwestern New Mexico and adjacent Arizona. It is likely that it occurs in other parts of the Colorado Plateau.
Nations: US
States/Provinces: AZ, NM
TNC Ecoregions: 19:C
USFS Ecoregions: 313B:CC, 313D:CC
Federal Lands: NPS (Petrified Forest)

Alliance Sources
Authors: K. SCHULZ, WCS **Identifier:** A.1532
References: Francis 1986, West et al. 1972

V.A.7.N.h. Medium-tall temperate grassland with a sparse xeromorphic (often thorny) shrub layer

V.A.7.N.h.5. Achnatherum hymenoides Shrub Herbaceous Alliance
Indian Ricegrass Shrub Herbaceous Alliance

Alliance Concept
Summary: Stands of this alliance occur on mesas, hillslopes, sand dunes, and along drainage channels on the Colorado Plateau and Great Basin. Elevation ranges from 1530-1920 m. Climate is semi-arid. Slopes vary from 0-30% depending on landform. All aspects are possible. The soil ranges from sand to sandy loam derived from aeolian deposits overlaying sandstone. Vegetation included in this alliance is characterized by a moderately dense graminoid layer (25-40% cover) dominated by the medium-tall bunchgrass *Achnatherum hymenoides (= Oryzopsis hymenoides).* There is a sparse (10-25% cover) xeromorphic short-shrub layer typically dominated by *Ephedra viridis* or *Ephedra torreyana,* mixed with occasional *Artemisia bigelovii, Atriplex canescens, Ericameria nauseosa, Eriogonum corymbosum, Gutierrezia sarothrae,* or *Parryella filifolia. Bouteloua gracilis*, *Hesperostipa comata (= Stipa comata), Muhlenbergia*

porteri, Pleuraphis jamesii, Sporobolus airoides, or *Sporobolus cryptandrus* may be present to codominant. Forbs have sparse cover.
Environment: This alliance occurs on mesas, hillslopes, sand dunes, and along drainage channels on the Colorado Plateau and Great Basin. Stands were described from a woodland park at 1920 m elevation on Rone Bailey Mesa in southern Utah (Van Pelt 1978) and at 1530-1600 m at Petrified Forest National Park in northern Arizona. Climate is semi-arid. Annual precipitation is highly variable with a mean of 30 cm. Slopes vary from 0-30% depending on landform. Slopes are moderate (less than 15%); all aspects are possible. The soil ranges from sand to sandy loam derived from aeolian deposits overlaying sandstone. Some stands are surrounded by a *Juniperus* woodlands or *Artemisia tridentata - Ephedra viridis*-dominated shrublands.
Vegetation: This alliance is found in the Colorado Plateau and Great Basin and is characterized by a moderately dense graminoid layer dominated by the medium-tall bunchgrass *Achnatherum hymenoides (= Oryzopsis hymenoides)*. There is a sparse xeromorphic short-shrub layer dominated by *Ephedra viridis* or *Ephedra torreyana* mixed with occasional *Artemisia bigelovii, Atriplex canescens, Ericameria nauseosa, Eriogonum corymbosum, Gutierrezia sarothrae,* or *Parryella filifolia. Bouteloua gracilis*, *Hesperostipa comata (= Stipa comata), Muhlenbergia porteri, Pleuraphis jamesii, Sporobolus airoides,* or *Sporobolus cryptandrus* may be present to codominant. Forbs have sparse cover. The medium-tall bunchgrass *Sporobolus cryptandrus* and patches of the sod-forming shortgrass *Bouteloua gracilis* are commonly present in varying abundance. Van Pelt (1978) described a stand with a canopy cover of 12% *Ephedra viridis*, 12% *Achnatherum hymenoides*, 4% *Sporobolus cryptandrus*, and 17% *Bouteloua gracilis*. Forbs cover is generally sparse and includes species of *Machaeranthera*.
Similar Alliances:
Achnatherum hymenoides Herbaceous Alliance (A.1262)
Ephedra viridis Shrubland Alliance (A.858)
Ephedra torreyana Shrubland Alliance (A.858)
Similar Alliance Comments: This alliance is similar to the *Achnatherum hymenoides* Herbaceous Alliance (A.1262), but does not have a significant shrub layer. The *Ephedra viridis* Shrubland Alliance (A.858) represents shrublands where *Ephedra* reaches at least 25% cover.
Synonymy:
Ephedra cutleri/Oryzopsis hymenoides Plant Association (Van Pelt 1978)
Comments: This alliance has two associations that are based on the Van Pelt (1978) description of communities dominated by *Ephedra cutleri* and *Achnatherum hymenoides* on Rone Bailey Mesa, Utah. Additional information came from four plots at Petrified Forest National Park in Arizona. Information on other occurrences is needed to describe the full range of this alliance.

Alliance Distribution
Range: Vegetation in this grassland alliance was described from Utah and northern Arizona, but may occur on sandy sites throughout much of the Colorado Plateau and Great Basin.
Nations: US
States/Provinces: AZ UT

TNC Ecoregions: 11:C, 19:C
USFS Ecoregions: 313:C, 313D:CC, 341:C
Federal Lands: NPS (Petrified Forest)

Alliance Sources
Authors: K. SCHULZ, WCS **Identifier:** A.1543
References: Van Pelt 1978

V.A.8.N.a. Short temperate or subpolar lowland grassland with a sparse needle-leaved or microphyllous dwarf-shrub layer

V.A.8.N.a.7. Bouteloua gracilis Dwarf-Shrub Herbaceous Alliance
Blue Grama Dwarf-shrub Herbaceous Alliance

Alliance Concept
Summary: This alliance is reported from the Tularosa Basin of southern New Mexico and the Colorado Plateau in southwestern Utah and northern Arizona. Elevations range from 1200-2700 m. Climate is semi-arid. Sites include valley bottoms, plains, hillslopes, mesa tops, sand sheets and dunes. Soils range from loamy sand to silt texture and are derived from alluvium and colluvium from sandstone and other parent materials. The vegetation is dominated by a sparse to moderately dense graminoid layer of the perennial shortgrass *Bouteloua gracilis* with an open (10-25% cover) dwarf-shrub layer. *Hesperostipa comata, Pleuraphis jamesii,* or *Sporobolus airoides* may codominate the graminoid layer in some stands. Other associated grasses are *Achnatherum hymenoides*, *Bouteloua curtipendula, Hesperostipa neomexicana, Muhlenbergia montana, Poa fendleriana,* and *Sporobolus cryptandrus. Artemisia bigelovii* or *Gutierrezia sarothrae* are commonly present and may dominate the open dwarf-shrub layer. Other dwarf-shrubs and shrubs may include: *Arctostaphylos patula, Artemisia tridentata, Ephedra torreyana, Ephedra viridis, Ericameria nauseosa, Quercus gambelii, Tetradymia canescens,* and *Yucca* spp. An occasional *Pinus edulis* or *Juniperus* spp. tree may be present in higher elevation stands.
Environment: This alliance occurs in the Tularosa Basin of southern New Mexico and the Colorado Plateau in southwestern Utah and northern Arizona. Elevation ranges from 1200-2700 m. Climate is semi-arid. Mean annual precipitation is approximately 22 cm with over half occurring during the late summer monsoon season often as high-intensity convection storm. Sites include valley bottoms, plains, hillslopes, mesa tops, sand sheets and dunes. Soils range from loamy sand to silt in texture and are derived from alluvium and colluvium from sandstone and other parent materials
Vegetation: This alliance is dominated by a sparse to moderately dense graminoid layer of the perennial shortgrass *Bouteloua gracilis* with an open (10-25% cover) dwarf-shrub layer. *Hesperostipa comata, Pleuraphis jamesii,* or *Sporobolus airoides* may codominate the graminoid layer in some stands. Other associated grasses are *Achnatherum hymenoides*, *Bouteloua curtipendula, Hesperostipa neomexicana, Muhlenbergia montana, Poa fendleriana,* and *Sporobolus cryptandrus. Artemisia bigelovii* or *Gutierrezia sarothrae* are commonly present and may dominate the open dwarf-shrub layer. Other dwarf-shrubs and shrubs may include: *Arctostaphylos patula, Artemisia*

tridentata, Ephedra torreyana, Ephedra viridis, Ericameria nauseosa, Quercus gambelii, Tetradymia canescens, and *Yucca* spp. An occasional *Pinus edulis* or *Juniperus* spp. tree may be present in higher elevation stands.
Similar Alliances:
Artemisia bigelovii Dwarf-Shrubland Alliance (A.1103)
Muhlenbergia setifolia / Artemisia Bigelovii Shrub Herbaceous Alliance (A.1530)
Bouteloua eriopoda Dwarf-Shrub Herbaceous Alliance (A.1570)
Juniperus monosperma Woodland Alliance (A.504)
Similar Alliance Comments: Stands from the *Artemisia bigelovii* Dwarf-shrubland Alliance (A.1103) are described from southeastern Colorado and are geographically separate from the others. The structure and composition of stands included in these alliances is similar and needs further examination. Stands from the other similar alliances all occur in New Mexico and share *Artemisia bigelovii* in the sparse dwarf-shrub layer, but have a different graminoid component dominating the herbaceous layer or have a tree layer.
Comments: The two associations included in this alliance are described from only two stands on the White Sands Missile Range, 12 plots from Petrified Forest National Park, and 4 plots from Zion National Park. More classification work in needed to clarify how it differs from the similar alliances, especially the stands in the *Artemisia bigelovii* Dwarf-shrubland Alliance (A.1103).

Alliance Distribution
Range: Grasslands in this alliance have been described from the Oscura Mountains in the Tularosa Basin in south-central New Mexico and the Colorado Plateau in southwestern Utah and northern Arizona.
Nations: US
States/Provinces: AZ NM
TNC Ecoregions: 18:C, 19:C
USFS Ecoregions: 313A:CC, 313D:CC, 321A:CC, M341C:CC
Federal Lands: NPS (Petrified Forest, Zion), DOD (White Sands Missile Range)

Alliance Sources
Authors: K. SCHULZ, WCS **Identifier:** A.1571
References: Muldavin and Mehlhop 1992, Muldavin et al. 2000b, Neher and Bailey 1976

VII. Sparse Vegetation

VII.C.3.N.b. Dry slopes

VII.C.3.N.b.201 Painted Desert Sparse Vegetation Alliance
Painted Desert Sparse Vegetation Alliance

Alliance Concept
Summary: This alliance occurs in the southern Colorado Plateau in southern Utah and northern Arizona. It includes sparsely vegetated 'badlands' of the exposed Chinle and

Moenkopi formations. Elevation ranges from 1200-1700 m. Stands typically occur on steep eroded slopes on any aspect, but also occur on alluvial flats and fans, drainage channels and gentle hillslopes. Substrates are typically deep, poorly drained, fine-textured soils derived from marine shales, siltstone, mudstones and sandstones. Sandy clay and silty clay are common soil textures because the shales weather to clay. Erosion is common and extensive. Bare ground cover is very high with total vegetation cover generally less than 10%. The vegetation has varied species composition. It is typically composed of scattered dwarf-shrubs and shrubs such as *Atriplex confertifolia, Atriplex obovata, Coleogyne ramosissima, Ericameria nauseosa, Eriogonum corymbosum, Eriogonum leptophyllum, Gutierrezia sarothrae, Parryella filifolia, Psorothamnus fremontii,* or *Zuckia brandegeei.* Sparse cover of *Achnatherum hymenoides, Elymus elymoides, Pleuraphis jamesii, Sporobolus airoides or* other perennial graminoids may be present. Forb cover is very sparse and may include species of *Cryptantha* or *Physaria.* The introduced annual grass *Bromus tectorum* is common on some sites.
Environment: This alliance occurs in the southern Colorado Plateau in southern Utah and northern Arizona. It includes sparsely vegetated 'badlands' of the exposed Chinle and Moenkopi formations. Elevation ranges from 1200-1700 m. Stands typically occur on steep eroded slopes on all aspects, but may occur on alluvial flats and fans, drainage channels and gentle hillslopes. Substrates are typically deep, alkaline, poorly drained, fine-textured soils derived from marine shales, siltstone, mudstones and sandstones. Sandy clay and silty clay are common soil textures because the shales weather to clay. Erosion is common and extensive. Bare ground cover is very high with total vegetation cover generally less than 10%.
Vegetation: The sparse vegetation (<10% total cover) included in this alliance has varied species composition. Stands are typically composed of scattered dwarf-shrubs and shrubs such as *Atriplex confertifolia, Atriplex obovata, Coleogyne ramosissima, Ericameria nauseosa, Eriogonum corymbosum, Eriogonum leptophyllum, Gutierrezia sarothrae, Parryella filifolia, Psorothamnus fremontii,* or *Zuckia brandegeei. Achnatherum hymenoides, Elymus elymoides, Pleuraphis jamesii,* or *Sporobolus airoides* may be present. Forb cover is very sparse and may include species of *Cryptantha* or *Physaria*. The introduced annual grass *Bromus tectorum* is common on some sites.
Dynamics: Harsh substrates, hot xeric sites, and high rates of erosion limit plant growth where this alliance occurs.

Alliance Distribution
Range: This alliance is found throughout much of the southern Colorado Plateau where Chinle and Moenkopi formations are exposed.
Nations: US
States/Provinces: AZ UT
TNC Ecoregions: 19:C
USFS Ecoregions: 313A:CC, 313D:CC
Federal Lands: NPS (Petrified Forest, Zion)

Alliance Sources
Authors: K. Schulz. WCS **Identifier:** A.254

Appendix B: Decision rules used to classify Petrified Forest NP grasslands

The following illustrates the decisions rules, developed in conjunction with NatureServe, used to distinguish the grassland alliances of the three main grass species in the park: blue grama (*Bouteloua gracilis*), alkali sacaton (*Sporobolus airoides*) and galleta (*Pleuraphis jamesii*). Some variations of the alliances have not been observed in the park and are noted by “not observed”; however, if these characteristics did occur in the park these rules would have applied.

- Blue grama ≥ 10%
  - Galleta < 10% cover or ≥ 10% but less than 2X blue grama cover
    - Shrubs ≥ 10% — Blue Grama Dwarf-shrub Herbaceous Alliance
    - Shrubs < 10% — Blue Grama Herbaceous Alliance
  - Galleta ≥ 10% and at least 2X blue grama cover
    - Alkali sacaton less than 2X galleta cover , grass cover < 50%
      - Shrubs ≥ 10% — Galleta Shrub Herbaceous Alliance (not observed)
      - Shrubs < 10% — Galleta Herbaceous Alliance (not observed)
    - Alkali sacaton cover 2X galleta cover, grass cover ≥50%
      - Alkali Sacaton Sod Alliance
- Blue grama < 10%
  - Galleta ≥ 2% and 2X as much as blue grama cover
    - Alkali sacaton ≥ 10% and 2X galleta cover
      - Alkali Sacaton Herbaceous Alliance
    - Alkali sacaton <10%
      - Shrubs ≥ 10% — Galleta Shrub Herbaceous Alliance
      - Shrubs < 10% — Galleta Herbaceous Alliance
  - Galleta <2% or > 2% but less than 2X blue grama cover
    - Alkali sacaton < 10%
      - Shrubs ≥ 10% — Blue Grama Shrub Herbaceous Alliance
      - Shrubs < 10% — Blue Grama Herbaceous Alliance
    - Alkali sacaton > 10% — Alkali Sacaton Herbaceous Alliance

Appendix C: Historic Land Use in the Puerco River Valley

The desert landscape of Arizona's Painted Desert and Puerco River Valley presents a highly diverse and complex mosaic of geomorphologic features and vegetation elements. Different land uses in historic and prehistoric times, before the establishment of the National Park in 1906, have had an impact on this environment. This review of land use history at the park provides a synopsis of the types of activities that may have occurred and affected the expression of vegetation that we see today at the park.

Previous reports for the upper Little Colorado River watershed have been limited to specific land use impacts such as nomadic grazing (Bailey 1980, Iverson 1981), ranching (Greever 1954, Lockwood 1932, Morissey 1950, Sheridan 1995), farming (Abruzzi 1993 and 1995, McClintock 1985), land use by prehistoric peoples (Burton 1993, Plog 1981, Steward 1980, Wendorf 1953, Jones 1993, Jones 1994) and tourism (Lubick 1988, Lubick 1996). These reports deal with the impact on northeastern Arizona in general or concentrate on the Little Colorado River Basin east of Holbrook. This report is limited to the Little Colorado River watershed in northeastern Arizona with special emphasis on the Petrified Forest area.

In this review we separate land use impacts into three time periods: Ancient Cultures (15,000 BC–1450 AD), Historic Cultures (1450 AD–1906 AD) and the Park Period (1906 AD–present). In each period humans used the park for habitation. However, the intensity of use and the ways in which they built their homes; obtained food, energy, and water; traveled throughout the park; and recreated differed. In many cases specific details of human land use in the park are unknown. Land uses in the general area are described with specific uses in Petrified Forest National Park, referenced as information is available. All references cited are listed above at the end of the main report in references cited pg. 38.

Ancient Cultures (15,000 BC – 1450 AD)

Nearly a century of archaeological research has yielded more than 600 archaeological sites in Petrified Forest NP (Jones 1993). Nevertheless, the archaeological survey for Petrified Forest NP is far from complete (Jones 1994). Besides selected sites surveys, surveys at the park include the boundary survey in the 1980's (95 miles, ¼ mile wide), the Mainline Road survey in the late 1970's (Park Road and Blue Mesa Road, approximately ½-1 mile wide), a survey of the connecting strip between the northern and southern sections of the park and a survey of approximately 15% of the southern section of the park. The badlands in the northern sections have not yet been surveyed.

The summary of early human cultures in the Petrified Forest area is drawn from Burton (1990, 1993), Burton et al. (1991, 1993) Jones (1993), Jones (1994) and Wells (1989) and follows the basic chronology introduced by Wells (1988, 1989).

Paleo-Indian Period (15,000 - 6,000 BC)

The prehistoric records from the Paleo-Indian period are rare at Petrified Forest NP. Only two Folsom-type projectile points have been identified from the park and they were restricted to surface finds. No evidence for megafauna hunting (e.g. campsites, killsites) has been found in the area, although it is believed this hunting style occurred elsewhere.

Archaic Period (6,000 BC - 300 AD)

During the Archaic period hunting and gathering was characteristic, with annual travel between the gathering sites replacing the nomadic lifestyle of megafauna hunting characteristic of the Paleo-Indian Period. Hunting switched to deer, pronghorn and rabbit. Among others staples, Indian ricegrass (*Achnatherum hymenoides*) seeds were collected as a food source. Grinding stones (metates) are known from the park, but no pottery of this time period has been found. Seasonal Archaic campsites have been found in the park and are located atop mesas scattered throughout the entire park. At one site charred kernels of corn were found, making radio carbon dating possible, placing the site in the last millennium BC. Findings from these data suggest that agricultural attempts took place during this period, possibly suggesting that agriculture began during the Archaic period.

Basketmaker II/III Period (300 AD - 700 AD)

During the Basketmaker period, remains of agricultural activities have suggested a more sedentary lifestyle. The park contains numerous small settlements with up to 25 pithouses and associated slab-lined storage pits. Basketmaker settlements are found either on bluffs and isolated buttes in the higher country or on dunes and low ridges in the lower lands. The largest cluster of sites is located on the bluff overlooking the confluence of Dead Wash and the Puerco River. Most of the lowland sites are found in the Dry Wash drainage. At Sivu'ovi, near the Rainbow Forest, remains of corn, Indian ricegrass (*Achnatherum hymenoides*) and goosefoot (*Chenopodium* ssp.) were found in storage vessels. These vessels are among the earliest reported for the area. Their pottery techniques were probably introduced by the influx of people from south of the Mogollon rim. The stone tool technology also progressed from simple bi-facial tools, which were used throughout the Archaic period, to more sophisticated tools manufactured using flake-technology. The new techniques provided these early farmers with a broad variety of tools, which were also used as trading goods (Ash 1972).

Basketmaker III/Pueblo I Period (700 AD - 950 AD)

The first permanently occupied settlements occurred during the late Basketmaker period and early Pueblo period. Pithouses were deeper than in the early Basketmaker villages, and they often contain separate ceremonial pithouses as well as storage rooms and trash areas. During this period, trading and inter-settlement contact is evident. Two thirds of the sites received ‘white ware’ pottery from the Zuni and Chaco area. The climatic conditions in this period were drier than usual (Dean et al.1985) and some of the villages were abandoned. As with Basket Maker II/III most of the sites were found on the bluff overlooking Dead Wash and Puerco River. Additional sites have also been found in the Dry Wash basin and along the southern boundaries of the park.

Pueblo II/III Period (950 AD - 1300 AD)

The Pueblo II/III period is marked by architectural and cultural developments. Pueblo II/III sites have been found throughout the whole survey area of the park, implying that in this period the use area was expanded into new and potentially unexploited microenvironments. One of these expansions was directed northward and led to the inhabitation of ‘Headquarter Mesa’, which overlooks the Painted Desert. The number of sites with evidence of occupation increases dramatically to about 200. Typical settlements are small pueblos with about 10-20 rooms and a kiva. Usually several smaller masonry sites and artifact scatters are found in the vicinity of these central pueblo sites, suggesting a system of central dwellings surrounded by field houses and other infrequently used structures. The central sites themselves are clustered around ‘great kiva’ sites, such as McCreery Pueblo, Plaza Site and Sundown Site. However, this period of prosperity was ended by abandonment of most of the upland areas in the Southwest between 1150 and 1250 and has been suggested to be due to climatic changes (Dean et al. 1985).

It has been assumed that during the mid-Pueblo Period that both major farming techniques were used: flood farming in drainages and dry farming in upland environments. During this period, all possible soils were farmed. However, the preferred soils consisted of sandy loams, found in the uplands, which drain faster than clay soils and are not as vulnerable to wind erosion as sand dunes. Both drainage bottoms and dry upland areas were used, increasing the chance of a good harvest in either dry or wet years. It is also assumed that irrigation attempts at the confluence of Puerco River, Nine Mile Wash and Dead Wash could have taken place, although no evidence for irrigation systems has been found.

Pueblo IV Period (1300 AD - 1450 AD)

Settlement pattern and social organization in the late Pueblo period changed from small villages to large multi room pueblos along the major river corridors (Little Colorado River, Puerco River). Occupational sites now had more than 100 rooms, several kivas and usually a central plaza. These pueblos are typical of the ‘big’ pueblos found throughout the southwest (e.g. Bandelier, Chaco Canyon, Homolovi, Wupatki). Pueblo settlement occurred near reliable water sources, possibly indicating that climatic changes brought drier and unstable conditions (Dean et al. 1985). As the pueblos became larger the number of archaeological sites found declined from 200 in the mid-Pueblo period to 16 in the late-Pueblo period. Only two major Pueblos were found at Petrified Forest NP: Puerco Pueblo overlooking Puerco River and Stone Axe Pueblo at Wallace tank, a spring four miles southeast of Puerco Pueblo. The other sites are usually artifact scatters and rock art sites. After about 120 years, the Petrified Forest NP pueblos area were completely abandoned.   No quantitative evidence has been found on the abandonment of the settlements; however, one hypothesis suggests that the residents may have migrated to the Zuni or Hopi Pueblos.

Historic Cultures (1450 AD – 1906 AD)

In the late Pueblo period, Pueblo people continued to use the area as a travel corridor between the Zuni Pueblos in the east and the Hopi settlements northwest of the Puerco River Drainage. Major attracting points in the area were springs and natural wells (e.g. Tanner Spring, Navajo Spring and Jacob's Well).

The nomadic tribes of the Navajo and Apache arrived in the Southwest between 1300 and 1600, but probably did not enter northeastern Arizona until the nineteenth century (Underhill 1953, Bailey 1980). Upon arrival, the Navajo and Apache established themselves in the mountain ranges in eastern Arizona. These tribes were successful at deterring settlement and ranching attempts by Euro-American settlers.

However, Euro-American settlement overcame these obstacles with the help of two major events. First, the Navajo and Apache were militarily overcome by the US government and forced to live in reservations in the 1860's and 1870's (Ferrin-Pare 1965, Lockwood 1932). Secondly, the railroad was establishment in1881-1883, which allowed ready access of the area from the East Coast and California. This allowed for the quick movement of even more settlers into northeastern Arizona, facilitating large cattle ranches that resulted in increased use of the natural resources. Due to profit orientated stocking policies, range productivity was not profitable and many of these enterprises had to be abandoned. Nevertheless, ranching never stopped in the area, only the stock density is lower today. Nowadays, the Puerco River valley is still a major travel corridor in the Southwest along Interstate-40 and the Santa Fe Railroad as well as it is also used as a grazing range.

Navajo and Apache Settlement

The nomadic Navajo and Apache tribes of the region are Athabascan tribes originating from northern Canada. One chronology attributes their arrival in the Southwest in the 1500's, where they settled amongst the Pueblo Indians of the Rio Grande Basin. Droughts in 1682-90 and 1734-39 (Scurlock 1998), Spanish raids and the need of new grazing grounds due to their fast growing herds drove them out of their settlement area in the Rio Grande Basin around 1709-1740 into the wetter mountain areas of the Cebolleta-San Mateo ranges. The next drought period (1748-59) and the pressure of Comanche/Ute raids in the 1740's led to a complete abandonment of the Rio Grande River basins and scattered the Navajos to the southwest and the west toward today's Arizona/New Mexico border (Scurlock 1998). Canyon de Chelly was reached in the 1750's (Underhill 1953) and the Petrified Forest area in the 1850's (Underhill 1953, Bailey 1980).

These tribes usually selected temporary campsites near reliable water sources that were close to potentially good hunting, farming and plant collecting areas. These locations were found on the upper edge of grasslands or in the pinion-juniper woodlands on terraces, hills and mesas (Scurlock 1998, Bailey 1980). The tribes were known for their corn horticulture, observed by the Spanish in the late 1500's, grown by flood farming along the rivers and seasonally flowing arroyos and in dry farming on mesa tops (Scurlock 1998). Nevertheless, hunting remained the Navajo's most important method of food procurement (Scurlock 1998).

Although the Spanish explorer Coronado introduced the first sheep, cattle, and horses into the Southwest, the Navajo and Apache were quickly able to incorporate these livestock into their cultural practices. The Spaniards prohibited the usage of horses by Native Americans, but nomadic Apache, Ute, and Navajo nevertheless acquired horses between 1620-1670 (Scurlock 1998). The initial introduction of sheep and goats to the Navajo and Apache tribes is believed to be from the Pueblo Indians of Northern New Mexico, who had acquired sheep and goats since the early 1600's from the Spanish Missions. The introduction to the Navajo occurred during or after the Pueblo Revolt (1680) when refugees from Jemez and other pueblos lived with the Navajo.

By 1700 the Navajo had acquired at least 1,000 sheep, which then doubled within 7.5 years. The number of sheep reached 64,000 by 1742 and about half a million in the 1850's (Young 1968). By this time, the Navajo extended their grazing grounds to about 23,000 square miles, grazing their herds between the Little Colorado River to the south, the San Juan River to the north, the San Francisco Peaks to the west and the Rio Puerco to the east. They increased their herds not only by raiding Spanish and Pueblo settlements (the US Marshall recorded the theft of 12,000 mules, 7,000 horses, 31,000 cattle and 450,000 sheep during 1846-1850 from the Rio Grande villages (Underhill 1953)), but also by good animal husbandry.

As Euro-American settlement in the southwest increased conflict between the Navajos and the new colonizers inevitably developed. This culminated in strikes lead by Kid Carson against the Navajo in 1863-64. He overran the Navajo's stronghold in Canyon de Chelly and forced about 8,000 Navajo into imprisonment. The Navajo lost most of their herds and were taken to the Mescalero Apache Indian Reservation of Bosque Redondo in southern New Mexico (Wyllys 1950). When the interned Navajo signed the 'Navaho treaty' in 1868, they received about 15,000 sheep from the government on their release from Bosque Redondo. The herds recovered very fast, probably due to approximately 1,000 Navajo and some 10,000 sheep remaining free from imprisonment by Carson's troops (Bailey 1980). In 1878 Lieutenant Hegewald encountered Navajo sheepherders at Bear Spring (the head of Lithodendron Wash), north of the current park boundaries (Lubick 1988).

In 1873 it was reported (Bailey 1980) that Navajo sheepherders had 225,000 sheep. In 1880 Agent F. T. Bennett's report calculated that they had 1,100,000 sheep, 400,000 goats and 60,000 horses (Young 1968). These numbers indicate rapid increase in herds resulting in erosion and range deterioration (Iverson 1981). In 1914 Fr. Anselm Weber (Young 1968), an advocate for the Navajo, wrote a report detailing the effects of rapid increase in sheep herds on the landscape. The livestock raised to 1,800,000 sheep, 43,000 cattle, 87,000 horses and a couple 1,000 burros and mules, two-third of which were held on the reservation. The range's productivity decreased with direct changes in landscape of arroyo cutting, shifting sand, and other signs of rapid erosion. Fr. Weber stated (Weber 1914):

> 'As a result the soil is eroding badly in many places and the sheep belonging to the Indian make a scant living. Over considerable areas in the eastern division of the Navajo district very little plant life is left except sagebrush and scrub juniper and pinon. The former heavy stand of grama grass over much of this region is nearly extinct.'

U.S. Government Exploration Expeditions

Flora and fauna reports of northern Arizona before the arrival of the Euro-American settlers and ranchers are rare. Besides some short eyewitness statements by early settlers and the diaries of the early exploration, government exploration missions are the only source of information. The rancher's and settler's notes usually describe the range conditions in more general terms without giving detailed insight into the encountered grassland and riparian area ecosystems. The exploration missions, on the other hand, outfitted by the US Government in the 1850's had a vital interest in meticulously describing the encountered landscape.

Sitgraves expedition left Zuni Pueblo in September 1851. They explored the Zuni River and followed the Little Colorado River until they reached Grand Falls, where they turned west through the San Francisco Peaks area and eventually continued on to California. The expedition's naturalist was Dr. Woodhouse, a physician from the East Coast. Significant remarks of the landscape are summarized below, Table C-1.

Table C-1. Remarks by Sitgrave's expedition 1851.

Location	Observer[1]	Description[2]
Zuni River	WH	Saw a few cottonwoods and a beaver dam. Near the stream: 'grama grasses', 'cedars'.
Little Colorado River; upper reaches	SG	'The Little Colorado is an insignificant stream … flowing through a narrow valley destitute of timber, but covered with a thick growth of rank unnutritious grass.'
Little Colorado River, slightly upstream of Holbrook	WH	Beaver lodges, 'swamp willow' on the banks, grass of 'good quality' and no timber.
Silver creek	WH	Barren appearance of the land, mule deer, antelope and black-tailed hare are quite abundant.
Near Leupp	SG	'the grass upon the hills was invariably better and more abundant than on the river bottom, but the absence of wood and water … generally obliged us to make our camp near the river'.

[1] SG= Sitgraves, WH= Woodhouse
[2] From Davis (1982) and Leopold (1951).

Whipple's expedition left in late autumn of 1853 to explore the 35th parallel and to find a possible route for the railroad. It began on the Zuni River and proceeded westward along the Little Colorado River, following the Sitgraves route. They crossed the Puerco River and proceeded westward along the Little Colorado River. Several scientists, amongst them Dr. Bigelow, a botanist, and Möllhausen, a German painter and naturalist, accompanied the expedition. Significant remarks of the naturalists in the expedition were compiled in Table 5.

Table C-2. Remarks by Whipple's expedition 1853.

Location[1]	Observer[2]	Description[3]
Jacob's Well	MH	'Permanent pond. Herds of black-tailed deer and antelope.'
West of ZR and close to PR	MH	'Sandy and bleak region, pronghorn at Lithodendron Wash.'
LC	MH	'Beaver dams, mule deer abundant between PR and Chevlon Creek.'
LC, at Chevlon Creek	MH	'Hunting deer, abundant beaver, adjacent grasslands only with jackrabbits and rodents.'
LC, at East Clear Creek	WI	'LC branches into a network of channels, bordered with cottonwood. A forest extends about 4 miles downstream.'

[1] ZR= Zuni River, LC= Little Colorado Rive, PR= Puerco River
[2] WI= Whipple, MH= Möllhausen
[3] From Davis (1982) and Leopold (1951)

A 1856 a zoological report by C.B.R. Kennerly (Davis 1982) states:

‘a succession of cedar groves and grassy valleys, abounding in black-tailed deer and antelope’ between the Zuni River and the Little Colorado River. Along the Little Colorado he notices ‘the beaver … however was very common in many places, as well as the Canadian porcupine…. They find a bountiful subsistence in the bark and tender twigs and buds of the young cottonwood trees … which grows luxuriantly in the sandy soil of the river bottom’.

One year later (1857) Beale’s expedition, equipped with 33 dromedary camels, left the Zuni villages in New Mexico to explore a wagon route to the Colorado River. They departed on August 31, 1857 and proceeded on a route similar to Whipple’s expedition. They crossed Puerco River and continued west along Leroux Wash, reaching the Little Colorado River west of today’s Holbrook. Significant remarks of the landscape were compiled in Table C-3.

Table C-3. Remarks by Beale’s expedition 1857.

Location[1]	Observer[2]	Description[3]
West of ZR	BE	‘Rolling plains with good growth of grass.
Jacob’s Well	BE	He saw antelopes and noted the lack of trees (besides ‘greasewood’ around the well). He also mentioned few small willows and ‘cedars’ at the edge of the pond.
West of Jacob’s Well	BE	Described the country as rolling prairie with ‘the finest grama grass’. Found good grass and water at Navajo spring.
PR	BE	He mentioned 'cottonwoods along the Puerco River
PR/LCR confluence	BE	‘grass plentiful in the bottoms, as well as on the hills …. There is abundance of large cotton-wood trees in the bottom, which resembles … the Rio Grande’.
LCR, near Cottonwood Wash	BE	Signs of beaver inhabitation.
LCR, near today’s Winslow	BE	Traveled on the northern bank of the river. Describes the land as very good stock country, exclaims ‘have never seen anything alike it’. He mentions ‘grama and bunch grass’ and says that the river is ‘well wooded with cottonwood’.

[1] ZR= Zuni River, LCR= Little Colorado River, PR=Puerco River
[2] BE= Beale,
[3] From Davis (1982) and Leopold (1951)

As an aside, Beale’s expedition established a wagon road from Fort Defiance along the Puerco River to the Little Colorado River, following the 35th parallel. This route was one of the most important transcontinental transportation routes (Cleeland 1988). Beale’s route was later included into the National Old Trails Road and became the predecessor of Route 66, later replaced by Interstate 40 (Wurtz 1987).

Early Euro-American Ranching

Non-Indian ranching of either sheep or cattle in northeastern Arizona began in the second half of the 19th century. Triggered by the California gold rush, large flocks of sheep and cattle were driven through Arizona in the 1850's (Lockwood 1932). Felix Aubrey and his men recorded at least one drive in northern Arizona; they guided 350 sheep from Santa Fe to California in 1857 (Anonymous A, citing Lt. Beales' diary 1857). Another attempt in 1864 to herd cattle from Albuquerque into Yavapai County over the Beale route ended with the nearly complete loss of the herd due to Indian raids (Lockwood 1932). Such herding was difficult with no established settlement in northeast Arizona. The 1864 census (Arizona, 1938) counts only 1,039 people for the third juridical district, which includes all Arizona north of the Gila River and east of the 114th degree of longitude. Only 10 people were identified as ranchers, the rest were soldiers and miners.

After the end of the Civil War and the military subjugation of the Navajo in the 1860's by Carson and the Apache in the 1870's by Cook, northern Arizona range was open to Anglo-American livestock stocking. Livestock was usually herded into or through northern Arizona along the Beale wagon road (Morrisey 1950) or along the Zuni River (Sitgraves route, 1851). The numbers of animals transported were rather small, the distance between individual ranches was large and there was "free" pasture for grazing.

Anonymous stories tell that the first settlers drove sheep into the Little Colorado River valley in 1862 (Hoffman 1981). In the late 1860's several New Mexican cattle and sheepherders extended their ranges into the upper Little Colorado River valley and established camps, small farms and settlements; all which have been destroyed today (Hoffman 1981, Lockwood 1932). Sheep herding was usually performed in the tradition of Spanish pastoralism (Scurlock 1998), where the sheep are allowed to graze free on the range and are watched by a shepherd and his dogs. Sheepherders followed prescribed routes on their movement from summer pastures to the winter ranges. The herd moved at a rate of 5-10 miles per day over a total distance of up to 150 miles (Ferrrin-Pare 1965).

One of the first recorded ranching attempts in northern Arizona took place in 1866 by James Baker in Chino Valley, who drove his cattle herd in from California (Lockwood 1932). During the summer of 1867 about 800 cattle, in three herds, were grazing in the Little Colorado River valley (Lockwood 1932). Juan Candelaria also herded sheep near Concho (east of St. Johns) in 1866 (Wyllys 1950).

In 1873 St. Johns, the main town in the Little Colorado River valley, was founded. Pioneer trader, Solomon Barth, won several thousand sheep and several thousand dollars from New Mexican ranchers at the nearby El Vadito ("The little crossing") (Hoffman 1981, McClintock 1985). He settled down, claimed 1,200 acres of land and named the site San Juan, which was later changed to St. Johns (Abruzzi 1993, McClintock 1985).

The ranches were usually entirely on public domain. They acquired ‘range rights’ that were usually respected between the ranchers. However, this situation changed rapidly after the construction of the railroad along the 35th parallel by the Atlantic and Pacific Railroad Company. In 1866, Congress passed a law authorizing the Atlantic and Pacific railroad to construct a transcontinental line from St. Louis through Albuquerque to the Pacific, following the 35th parallel (Greever 1954). To aid in the construction, an initiative was given by the United States upon completion of the railroad, a land grant of alternate odd-numbered sections for forty miles to either side of the tracks, in addition to a 100 feet right of way, would be given to the railroad. The railroad was completed in 1881-1883; it reached Holbrook in August 1881, Flagstaff in August 1882 and Kingman in March 1883 (Schlegel 1992).

Edward Kinsley, a railroad stockholder, visited the area for an inspection trip in 1884. He encountered, after an unusually wet winter, an ‘abundance of lush, nutritious grass in the range lands and water along the Little Colorado River’ (Trimble 1986). Back in New York, he initiated the foundation of the Aztec Land & Cattle Company (the “Hashknife”), which soon thereafter performed the first land purchase from the railroad company. They bought approximately one million acres south of the tracks between Flagstaff and Holbrook and stocked it with about 36,000 head of cattle in 1886 (Schlegel 1992). Hashknife owned only each odd-numbered section, the even numbered sections were still public domain. However, the Hashknife forced all other ranchers out of their claimed area (Schlegel 1992, Sheridan 1995, Abruzzi 1995), therefore increasing the grazing pressure on the neighboring land.

Several promotional leaflets and books, written on behalf of the territorial legislature (e.g. Hamilton 1883, Schlegel 1992) attracted other ranchers and settlers to the area. Large ranches such as the Arizona Cattle Company (the ‘A-1) of 132,000 acres was formed around Flagstaff in 1883 and the Babbitt brothers C.O. Bar in 1886 (Schlegel 1992).

One other reason for this influx of ranchers was the deterioration of their previously occupied ranges. These ranges were unfavorable due to droughts (Barnes 1941, Schlegel 1992) in California 1872, Utah 1878, and New Mexico 1885-86 (Abruzzi 1995); overstocking in Colorado 1884; and the introduction of unfavorable land laws in Texas in 1879 and 1883 (Barnes 1941, Schlegel 1992, Abruzzi 1995).

Will C. Barnes, who settled in the Little Colorado Valley in 1883 ran as many as 7,000 cattle in the area until 1900 (Schlegel 1992). He describes changes in the landscape descriptively in Barnes (1913) and Greever (1954):

> ‘I well remember in 1885 the disgust which fell upon my outfit, then located upon the Little Colorado River in northern Arizona, over the advent of a neighbor. Our nearest had been twenty-five miles distant, and the newcomer had the temerity to turn loose 1000 head of west Texas heifers at a point fully twenty miles above us. Our own cattle seldom wandered more than five miles away from the rough camp where we had established ourselves. Between the new neighbor and us was an almost untouched stretch of grassland, and back of us lay a virgin country fifty

> miles wide with not a settler or domestic animal on it. …This was the beginning of the end of our splendid isolation, and when we lived to see stockman's cabins at every very water hole and available location all over the country. Where we felt crowded by 2000 cattle, 50,000 were hunting grass and water on the same range a few years later.'

Barnes settled about 25 miles west of Holbrook, ten miles from St. Joseph. By his own account (Barnes 1941) he had at least 50 square miles of rangeland 'for his own'. He also reports on 'some fine springs surrounded by a wonderful vega, or hay-meadow' about four miles away from the river (Barnes 1941), where he filled a homestead claim and founded his Esperanza ranch.

Adam Hanna and Jim Cart herded several thousand sheep in the Petrified Forest (Lubick 1996, Barnes 1988) from 1879 - 1890. Adam Hanna later moved to Adamana where he operated a ranch and hotel. Another ranching operation in the late 19th century was Spur ranch at Tanner Springs, north of the park (Barnes 1988). The Reynolds Brothers from Texas operated it between 1886 and 1900.

The population in Apache County alone increased from about 7,000 in 1882 (Mendelsohn 1927) to about 17,000 in 1900 (Schweitzer 1998), with Apache County divided into Navajo and Apache County in 1895. Arizona's population rose exponentially from about 7,000 in 1867 to about 30,000 in 1875 and 100,000 at the turn of the century (Mendelsohn 1927); all census counts excluded the Native American population. Concurrently, with the rapid influx of people the number of livestock increased alike.

According to a report on the sheep industry by the USDA in 1994 (Sheridan 1995) the number of sheep ran by non-Indians in Arizona increased about hundred times within one decade from about 800 in 1870 to 76,000 in 1880 (Table C-4). Another probably conservative estimate of a tenfold increase of 700,000 in 1890 was recorded for the next decade in Arizona (Sheridan 1995). The *Arizona Star* claimed that 78,500 sheep were present in 1879 for Yavapai County alone (Sheridan 1995). Raising of sheep was mostly restricted to Northern Arizona, where about 95% of Arizona's sheep were raised in Apache, Coconino and Yavapai County (Sheridan 1995, Hamilton 1883). About 100,00 sheep were herded in the Little Colorado River valley before the Aztec Land & Cattle Company took over (Abruzzi 1995).

Table C-4. Sheep numbers for Arizona (Non-Indian owned)

Year	Area	Estimated # sheep	Cited source	Citation
1870	Arizona	803	DOA, 1892	Sheridan 1995
1880	Arizona	76,524	DOA, 1892	Sheridan 1995
1890	Arizona	698,404	DOA, 1892	Sheridan 1995
1891	Arizona	288,727	Governor's report 1891	Sheridan 1995
1910	Arizona	1,020,000	-	Barnes 1913
1913	Arizona	1,570,000	-	Barnes 1913

A timeline for cattle numbers (1866-1912) is given by Schlegel (1992), Table C-5. A six fold increase in cattle numbers from the late 1870's to early 1880's, followed by a twice fold increase for the next decade. Only about 10-20% of these cattle were raised in northeastern Arizona (Hamilton 1883, Greever 1954). All the given numbers, both for Indian or non-Indian livestock, are not very consistent throughout the literature and should therefore be treated as rough estimates with a large error range of probably 30-50 percent (Schlegel 1992).

Table C-5. Cattle numbers for Arizona (Non-Indian owned)

Year	**Area**	**Estimated # cattle**	**Cited Source**
Late 1870's	Arizona	50,000	Hamilton 1883
Early 1880's	Arizona	300,000	Hamilton 1883
1891	Arizona	720,940	Sheridan 1995
1910	Arizona	651,000	Barnes 1913
1913	Arizona	812,000	Barnes 1913

Although severe grazing impacts were already reported in the 1880's (Iverson 1981, Schlegel 1992, Ferrin-Pare 1965), the extent of the grazing impacts on the grasslands were not fully understood until the next severe drought hit. In 1892 a severe drought hit and 'little or no green grass grew on the range' (Barnes 1941). Nevertheless, the ranges were kept stocked due to the dropping cattle prices. The following winter brought more severe weather conditions, with 18 inches of snow falling in January 1893 west of Holbrook (Barnes 1941). This resulted in 50-70% of the cattle dying; Will C. Barnes for example lost about 5,000 out of 7,000 (Barnes 1941). An eyewitness statement (McClintock 1985) by David E. Adams, an early Mormon settler, describes the dramatic change of the range condition:

> 'When we came to Arizona in 1876, the hills and plains were covered with high grass and the country was not cut up with ravines and gullies as it is now. This has been brought about through the overstocking of the range. On the Little Colorado we could cut hay for miles in every direction. The Aztec Cattle Company brought

> tens of thousand cattle into the country, claimed every other section, overstocked the range and fed out all the grass. Then the water, not being held back, followed the cattle trails and cut the country up. Later, tens of thousand of cattle died because of drought and lack of feed and disease. The river banks were covered with dead carcasses.’

A repetitive pattern during the 1890’s of overgrazing and soil denudation during the drought periods, followed by torrential summer rains in wetter years, generally led to sheet erosion and erosion of topsoil (Sheridan 1995). Erosion of arroyo cutting and channeling of the larger rivers was then followed by a decline of the groundwater level. This ultimately led to drier conditions on the surrounding lands (Abruzzi 1995, Dean 1985 et al. 1985, Sheridan 1995). However, an analysis of historic photographs (taken around 1890) shows no significant changes due to erosion for the Dry Wash area in the southern section of Petrified Forest NP (Wendorf 1953). Channel cutting of the Puerco River in the vicinity of the park was reported (Wendorf 1953).

These extreme and unpredictable environmental conditions led to unstable market conditions (Barnes 1941). As a consequence, both “A-1” and “Hashknife” operations had to liquidate their business in 1899 and 1900 respectively, due to the fluctuating market prices, high operational costs and high animal loss (Schlegel 1992). Most of the land was subsequently sold. The main purchasers were the Babbitt brothers, operating out of Flagstaff, resulting in the largest cattle ranch operation in northern Arizona (Schlegel 1992).

Mormon Settlement

The following is compiled from McClintock (1985) and Abruzzi (1989, 1995) comprehensive studies on the Mormon settlement history of northeastern Arizona.

The first Mormon attempt to colonize Arizona from the north took place in 1873. The Mormon expedition party crossed the Colorado River at Lee’s Ferry and proceeded up the Little Colorado River until they reached Black Falls. It was reported that no green grass was found and they had to dig wells in the dry riverbeds. An exploratory party was then sent out to travel upstream for about 140 miles. They reported that the land was barren, the soils alkaline and the water in the narrow river channel beds was scarce. They also found petrified trees, one of them reported to be 210 feet long. No settlement place was found and therefore, the expedition retreated to Lee’s Ferry. Since reports from the upper Little Colorado River valley sounded promising a scouting expedition was outfitted in 1875. They found early in their expedition open grasslands with enough water to have good farming land, as well as enough good timber sources. Their impressive report quickly spread and in 1876 four parties left Salt Lake City to take up their mission.

These parties established the first settlements in the Little Colorado River valley, namely Sunset (25 miles west of St. Joseph), Allen’s camp (near St. Joseph), Obed (near St. Joseph, abandoned 1878) and Bringham City (Ballenger, near Winslow). Allen’s camp was located about three miles east of today’s St. Joseph city and was moved to the present day St. Joseph city within the first year. Also in the first year at Allen’s camp irrigation ditches were constructed, a fort was built and a weekly mail service was established (Santa Fe - Prescott). Local cottonwood trees and driftwood were used in construction of houses and corrals, as well as for firewood (Barnes 1941). Four additional settlements of Woodruff, Snowflake, Show Low, and St. Johns were founded within the next few years, southeast of the first Mormon settlements.

The settler’s biggest problems were all related to the Little Colorado River which was described as ‘a treacherous stream at best, with a broad channel that wanders at will through the alluvial country that melts like sugar or salt at the touch of water’. It was also described as ‘a mighty rushing torrent when the rains commence in summer, with the appearance of being 25 miles broad’. They encountered frequent floods (the first one with a 12 feet rise), and had to evacuate Sunset in 1888. They were forced to evacuate due to loss of fields that were located too close to the river and they had to constantly rebuild irrigation dams washed out in flooding. Beside agricultural efforts, the Mormons also started ranching sheep and cattle in the valley (Lockwood 1932).

Park Period (1906 - present)

Although the park was formally established in 1906, vast tracts of land within the park boundaries remained as private property. The Atlantic and Pacific Railroad Company and other private landowners owned some of the park lands. To consolidate the park, the National Park Service requested a land exchange act and was passed by Congress on May 14, 1930 (Lubick 1981). It allowed the Federal Government to obtain the title to privately owned land within the park through exchanges for public land in the County. The first exchanges included not only the railroad’s grant land, but also private property from a settler named Wade (Greever 1954). The company accepted the exchange, and about 12,000 acres of land passed to the National Park Service (Lubick 1996). Another land exchange with the Railroad Company and H. Loll, the owner of the Painted Desert Inn, allowed for increased expansion of the park in 1932 (Lubick 1996). This exchange added vast tracks of land in the Painted Desert section to the park property (Lubick 1996). With these land exchanges, the federal government now owned all but about 8,000 acres of the park (Lubick 1996).

Grazing

With the building of a fence in 1934, grazing was excluded from the southern section of the park (Miller 1977 et al. 1977). Ranching continued in other areas of the park, seen by a map, printed in 1939. It shows that several ranches and wells were located in the Petrified Forest area (Harrell 1939). A grazing permit near the Petrified Forest on 6,880 acres was granted as late as 1940 (Lubick 1996). Wendorf states that ‘…cattle are permitted to graze on a small section of the Petrified Forest, but their numbers are closely monitored.’ (Wendorf 1953). He also mentions, that the areas adjacent to the park are ‘…utilized almost exclusively for cattle raising’. In 1963 the entire park boundaries were fenced (Miller 1977 et al. 1977); this eliminated cattle from many parts of the park property. Although, 350 acres of the riparian area along the Puerco River still remained unfenced (Miller 1977 et al 1977) until about 1972 (Miller 1977 et al 1977). In the early 1980's the McCreery Pueblo area was purchased. This purchase was not fenced until 1986 and is the most recently grazed enclosure in the park (Burton 1993). Some areas of the Puerco River corridor still experience intermittent grazing due to problems with maintaining the fences in that area.

Transportation

The transportation history within the park's current boundaries starts with early Euro-Americans in the area. Beale's wagon road that crossed the park in the northern section on Headquarters Mesa was later replaced by the National Old Trail Highway, which later became Route 66 and finally I-40 with some re-routing. Route 66 was the first major transcontinental highway and cross-country road in the first half of the 20th century (Cleeland 1988). It was shorter and easier to travel than the northern routes and was known for its scenic landscapes. It connected major cities and towns such as Santa Fe (Wurtz 1987). Due to the increasing volume of travelers in the late 1940's, traffic congestion on the highway became a major problem (Cleeland 1988). In the southwest a tourism boom occurred (Cleeland 1988), causing the two lane Route 66 to become a major traffic hazard (Wurtz 1987, Cleeland 1988). With Route 66 as new main road, the traffic flow increased dramatically up to 100 cars/day in 1920 (Lubick 1996) and about 100,000 visitors in 1930 (Lubick 1996). Route 66 was widened and improved in 1951 (Lubick 1996). The Interstate Highway bill of 1956 was passed, allowing for the construction of Interstate 40 with the eventual replacement of Route 66 in the 1960's, which subsequently led to the disappearance of the privately owned curio shops in the area.

The railroad stayed generally closer to the Puerco River and crosses the park on the northern riverbank, approximately 8 miles south of the park road corridor. The close vicinity of Adamana to the petrified wood outcrops of the Rainbow Forest, Jasper Forest and Crystal Forest areas led to the establishment of access roads to Petrified Forest NP for tourist purposes. Later on an additional route to the Black Forests in the northern section of the park were established. Nearly all visitors entered to the park from Adamana (Lubick 1996) or via Hwy 180, which crossed Rainbow Forest. In 1932, Congress approved the construction of a modern highway through the Monument, including a new bridge over the Puerco River (Lubick 1996), erected in the same year.

A long used travel route connects the Holbrook area, Holbrook and Woodruff, with Cocho in the upper Little Colorado River valley. It crosses the Petrified Forest area in the vicinity of Rainbow Forest. This route was replaced by Highway 260 and eventually replaced by Highway 180, which crossed the National Park. It was later rerouted and called the 'new' Highway 180 and changed the route to lie south of the National Park boundaries.

Tourism

The onset of tourism in northeastern Arizona is linked to the coming of the railroad (Lubick 1996). No formal railway station was established until about 1890 in Adamana (Barnes 1988). Adam Hanna's ranch and hotel were the main gathering point for visitors to the Petrified Forest (Lubick 1996). With the construction of the Forest Hotel in Adamana around the turn of the century, more comfortable tourist accommodations were created (Lubick 1996). The hotels and the park were subsequently advertised as tourist destinations by the Santa Fe Railroad, e.g. US Railroad Administration (1919).

There is no historical evidence of the earliest tourism within the park. However, the so-called 'water line road' follows more or less the historic wagon route from Adamana to the Rainbow Forest. The oldest visible tourist structure is the Painted Desert Inn. It was originally a trading post and from 1924 through the early 1960's it was used as restaurant and motel. It was also used as the Visitor Center for the park until the Rainbow Forest Visitor Center was built in 1932. Beginning in 1925, the Fred Harvey Company shuttled visitors in "Harveycars" from the railroad in Adamana to the Petrified Forest (Lubick 1996). Evidence of this operation is seen by one car wreck and a motor block found in the grasslands southeast of Pilot Rock (Ted Bolich, pers. com. 1998). Other tourist operations were conducted in the park with privately owned enterprises found along Route 66 and along the park's main road. A tourist destination called the 'Lions Farm' operated within the park, and was removed in the 1960's (Lubick 1996). The only remains of the 'Lions Farm' are some artifact scatters (Rita Garcia, pers. com. 1998) and planted trees on the roadside (Ted Bolich and Rita Garcia, pers. com. 1998). With the Mission 66 program, a new visitor center and the Painted Desert Oasis was developed (Lubick 1996).

Today, the main areas of tourist impact are the visitor sites within the park. Headquarters area (Painted Desert Oasis), the overlooks in the Painted Desert section of the park, Puerco Ruin, the overlook at Newspaper Rock and the trails and overlooks at the main forests: Blue Mesa, Crystal Forest, Jasper Forest, Agate Bridge, Long Logs and Giant Logs (Rainbow Forest) are most impacted by tourism. Currently, there are six designated trails: on the rim of the Painted Desert, down into the Painted Desert - leaving from the Painted Desert Inn, at Blue Mesa, at Crystal Forest, at Long Logs and at Rainbow Forest. Most of the trails are paved and are short one to two mile walks. There are no overnight accommodations in the park since the closure of the Painted Desert Inn in 1962 (Lubick 1996). However, people are allowed to camp in the wilderness section of the park. The concentration of tourism in the park to visitor sites rather than backcountry areas has reduced the ecological impacts in relative comparison to other National Parks. Nevertheless, the impact on the paleontological resources, 'wood theft', is high and was one of the reasons that the park had been fenced in 1963 (Petrified Forest NP 1976).

Mining

The Atlantic and Pacific RR Company sold petrified wood in 1888 within 1,860 acres for 2 dollars per ton. Nobody knows how much has been actually removed (Greever 1954), and no exact location is known . In 1884 several mining claims were filed to exploit the petrified wood deposits (Lubick 1996). In 1888 eighteen tons of petrified wood were shipped (Lubick 1996) to South Dakota to be cut, polished and sent to the market. Under growing public pressure, (Lubick 1996) a legislative measure was set that led to the withdrawal of settlement in 1895 and stopped other forms of exploitation (Lubick 1996). However, three abandoned mining claims were still reported in 1906 (US-Congress 1906).

A map published with President Taft's proclamation of 1911 shows two collecting grounds at Rainbow Forest and Jasper Forest (US-DOI/NPS 1992). These areas are also shown in another map published in 1919 (US Railroad Admin 1919). Oil prospecting also occurred in the 1920's near the Holbrook area (Wayte 1962, Anonymous B); however, they did not reach the Petrified Forest area. Uranium mining also occurred in the 1950's and 1960's and the remains of these operations are seen in the eastern sector of the Painted Desert (Burton 1993).

CCC-Activities

The Civil Works Administration (CWA, 1933-1934) and the Civilian Conservation Corps (CCC, 1934-1942) were active in the park between 1933 and 1942. Three camps were established, two of them in the Puerco River area and one in the Rainbow Forest area. Other construction efforts relating to the CCC activities are found throughout the park. Two quarries were found southeast of Puerco Ruin (Burton 1993), the construction of a dam was found near Rainbow Forest (Burton 1993) and a spike camp was found. Their main work included trail and road construction, campground development, landscaping (500 cottonwood slips were planted along Puerco River), the construction of the water supply line and fencing and archaeological fieldwork (Burton 1993, Lubick 1996). They also remodeled the Painted Desert Inn in the late 1930's.