Vegetation Ecology in the Bighorn Canyon National Recreation Area

Wyoming and Montana

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Summary

The ecology of terrestrial vegetation in the Bighorn Canyon National Recreation Area (BCNRA) was studied during the period 1984-1986. Seventyfive stands, distributed throughout the BCNRA, were sampled for plant species cover and various environmental characteristics. A vegetation classification and map were developed, the data were analyzed using gradient analysis techniques, and the results were synthesized with those from other relevant studies in the region. In general, the vegetation of the BCNRA is 40% juniper/curlleaf mountain mahogany woodland, 16% riparian vegetation, 15% desert shrubland, 12% sagebrush steppe, 8% grassland, 6% coniferous woodland, 2% agricultural land, 1% marsh, and 0.1% Great Plains shrubland. Some of these general vegetation types were sub-divided, creating 21 types that are included on the black-and-white, 1:24,000 map. All types except marshes and agricultural land are discussed in this report, with the discussion focusing on adaptations of the dominant plant species, environmental factors affecting the distribution of each vegetation type, vegetation changes that have occurred and can be expected to occur in the future, certain aspects of weed ecology, and characteristics of the vegetation mosaic along the north-south axis of the Recreation Area. The riparian vegetation appears to be changing most rapidly, due in large part to flood control on the Shoshone and Bighorn Rivers. The suppression of fires and floods, combined with grazing and the creation of mudflats by fluctuating Bighorn Lake water levels, have produced ideal conditions in the riparian zone for the invasion of various exotic plants, saltcedar in particular. The report concludes with a section on using vegetation data to facilitate management activities.

Introduction

Located between the Bighorn Mountains to the east and the Pryor Mountains to the west, the Bighorn Canyon National Recreation Area (BCNRA) includes a diversity of vegetation that is characteristic of the foothills in northcentral Wyoming and southcentral Montana. A deep canyon carved by the Bighorn River is the main attraction for most visitors, but abrupt changes in topographic and geologic features combine to create a diverse mosaic of vegetation that is a colorful and interesting component of the landscape. The vegetation mosaic includes wetlands, desert shrublands, shifting riparian communities, juniper woodlands, sagebrush steppes, coniferous forests, and mixed-grass prairie; and it provides habitat for the Pryor Mountain wild horse herd as well as bighorn sheep, bear, mule deer, white-tail deer, bald eagles, rattlesnakes, and many other species of plants and animals. Lichvar et al. (1984, 1985) report 656 species of plants in the BCNRA, Patterson (1985) found 212 species of birds and 47 mammals, and Redder et al. (1985) found 28 species of fish, 6 amphibians, and 13 reptiles. While the flora and fauna of the BCNRA are now quite well known, there has been relatively little research on the distribution patterns and environmental relationships of the plant communities. We focus on such relationships in this report and compare our results to those of similar studies done nearby, confident that this information will provide a better basis for the interpretation, management, and preservation of the landscape features that attracted the attention of interested citizens and the National Park Service.

The BCNRA is 113 km (70 miles) long and only a few kilometers across at the widest point. It is bordered on the east almost entirely by the Bighorn Canyon (Fig. 1). The total land area is 22,499 ha (55,595 acres). The confluence of the Big Horn and Shoshone Rivers is located on the south end, just east of Lovell, Wyoming, with the current flowing northward through a deep canyon into the Missouri River drainage system.

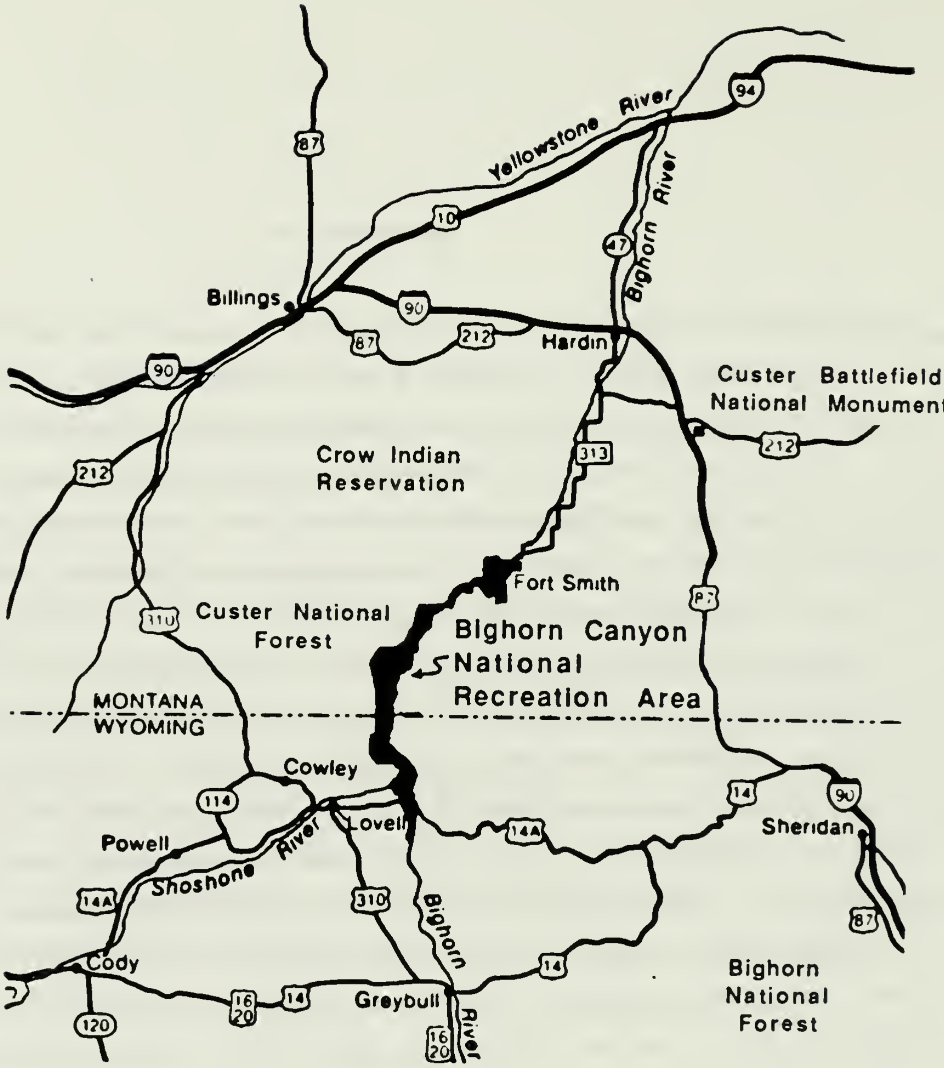

Fig. 1. Location of the Bighorn Canyon National Recreation Area. A visitor center is located in Lovell, and the headquarters are in Fort Smith. The Bighorn Mountains are on the east and the Pryor Mountains are on the west.

The entire Bighorn Canyon is now the site of a reservoir known as Bighorn Lake (Yellowtail Reservoir), but cliffs still rise more than 200 m (760 feet) above water level at several locations. The dam is located near the north end of the BCNRA, at Fort Smith, Montana, and was completed in 1965 for flood control, irrigation, power generation, and recreation. The water level of the reservoir fluctuates considerably, with a mean elevation of 1108 m (3,657 ft).

From a scientific perspective, the BCNRA presents several interesting opportunities for ecological research. First, there is great geologic and topographic diversity in the area and these features are important in determining vegetation patterns. Various studies have focused on the nearby mountain and basin vegetation, but rather little has been published on the foothill vegetation that is so well represented in the Recreation Area. Furthermore, the geology of the Area has been studied in considerable detail (Richards 1955) and there is an elevational gradient of about 1500 m (4950 ft) from the reservoir to the top of East Pryor Mountain. Thus, an opportunity is provided for learning more about geologic, edaphic, and topographic controls on plant distribution in Rocky Mountain foothill vegetation. Secondly, despite the rather small change in elevation from north to south, there is a distinct north-south precipitation gradient. This gradient occurs because the south end is on the northeastern edge of the arid Big Horn Basin, with a mean annual precipitation of 18 cm (7.07 inches; Western Sugar Company records at Lovell, 1920-1985), and the north end is on the western edge of the more humid Great Plains, with a mean annual precipitation of 49 cm (19.3 inches; U.S. Weather Bureau, 1961-1985). Vegetation distribution along this climatic gradient had not been studied. Finally, the BCNRA provided an opportunity to study an entire foothill mosaic in a relatively undisturbed state and in an area being managed to a large extent for its natural values. While one part of our study focuses on the causes of the vegetation mosaic, another part focuses on the nature of the mosaic itself, i.e., the percentage of the land area in each vegetation type, how the relative importance of each type changes from north to south, and how the mosaic inside the BCNRA compares to the mosaic outside. Administrative boundaries must be recognized by resource managers, but the nature of the mosaic beyond a boundary could influence a management plan.

An overview of previous research on vegetation ecology

Though relatively little ecological research has been conducted in the BCNRA per se, a number of relevant studies have been done nearby. The results of these studies will be noted in our results and discussion sections, but an overview seems appropriate here.

The largest group of studies has been centered near Worland, Wyoming, about 121 km (75 miles) south of the BCNRA but still in the Big Horn Basin, where Professor Herbert G. Fisser and his students from the Division of Range Management at the University of Wyoming have studied various aspects of plant ecology since the 1960's. Their early research was motivated by concerns over the invasion of *Halogeton glomeratus,* a common weed in the intermountain west (Fisser and Joyce 1984). Thinking that heavy livestock grazing was a major cause, they based their work on a series of exclosures, some of which are located near the BCNRA. In collaboration with the Bureau of Land Management, Fisser and his associates have provided a large amount of information on soil/vegetation relationships (Fisser 1962, Vosler 1962, Hamner 1964, Nichols 1964, Steger 1970, Trueblood 1980), range condition and trend (Fisser 1964, Garland 1972, Uhlich 1982), phenology (Fisser 1986b), the effects of grazing and sagebrush control (Fisser 1986a), predicting primary productivity (Noller 1968, Whysong 1973, Joyce 1981, Fisser and Joyce 1984, Wight et al. 1986, Hanson et al. 1986), and various aspects of mountain mahogany and juniper ecology (Miller 1964, King 1967, Wight and Fisser 1968, Robinson 1966, Spaeth 1981, Waugh 1986). Additional studies by this group have been done in the Wind River Basin further south.

Studies relevant to the BCNRA also have been done to the north in Montana, to the east in the nearby Big Horn Mountains, and in the Owl Creek Mountains to the south. Wright and Wright (1948) described the grasslands of southcentral Montana, with one study area being located about 72 km (45 miles) north of Fort Smith, and Duncan (1975) conducted a study on curlleaf mountain mahogany in southwestern and southcentral

Montana. The grasslands of the Bighorn Mountains have been studied by Beetle (1956), Hurd (1961), and others, and a detailed study of the forests of the Big Horns was done by Despain (1973). Hoffman and Alexander (1976) provided a habitat type classification for the forests of the Bighorn Mountains, and South (1980) identified the habitat types found in the Pryor Mountains. Williams (1961, 1963) studied bluebunch wheatgrass and vegetation distribution in the Wind River Canyon to the south, making various observations relevant to the whole Bighorn Basin.

Planning documents prepared by the National Park Service, Bureau of Land Management, U.S. Forest Service, and Wyoming Game and Fish Department have been helpful also. In particular, South (1980) prepared an ecological overview of the Pryor Mountains for the Forest Service, describing the vegetation, soils, wildlife (including insects), and management concerns of ten ecosystem types: subalpine plateau, subalpine forest and meadow, Douglas fir woodland, mountain grassland, riparian woodland, juniper shrubland, sagebrush grasslands, desert shrubland, aquatic ecosystems, and areas of rock outcrop. The BCNRA staff reviewed concerns about grazing, exotic plants, fire management, the riparian zone, and other natural resources in their management plan (Peters 1986), and the Wyoming Game and Fish Department reviewed management concerns for the Bighorn River from Thermopolis to Lovell (Weynand et al. 1979). A concern for all agencies has been the management and ecological impact of the Pryor Mountain wild horse herd. The Bureau of Land Management coordinated the preparation of a herd management plan that includes further information on the vegetation and environment of the BCNRA (Jack 1984), where part of the wild horse range is located.

Objectives

A large amount of information has been collected on the plants that dominate the BCNRA landscape, but there is little information on the vegetation patterns that exist there. Furthermore, there have been no attempts, of which we are aware, to examine the causes of the distribution patterns over such a large area of foothill vegetation and to determine the nature of the vegetation mosaic. With this in mind, we established the following objectives for our BCNRA study:

1. Conduct a floristic survey and add plant specimens to the BCNRA herbarium.

2. Classify the vegetation into various types and prepare a vegetation map at the scale of 1:24,000.

3. Examine plant distribution patterns and their relationships to various environmental factors.

4. Describe and discuss the vegetation mosaic from an ecological and management perspective.

The first two objectives have been accomplished. Over 500 plant specimens have been added to the BCNRA Herbarium at Lovell and a flora for the Area has been published (Lichvar, Collins, and Knight 1984, 1985). A total of 73 families, 320 genera, and 656 taxa have been reported, with most being represented by specimens in the Herbarium. Additional species have been found since the flora was published and an update is anticipated. The vegetation map also is completed and available for distribution (Myers, Knight, Jones, and Frey 1986). It shows the distribution of 21 vegetation types plus agricultural land and other human developments.

Our goal in this final report is to accomplish the third and fourth objectives, i.e., provide an analysis of vegetation ecology in the BCNRA. As such, this document should clarify the information included on the vegetation map and provide a better basis for making management decisions, prioritizing research needs, and evaluating opportunities for interpretation. Introduced weedy species are discussed as well as the native species.

The Bighorn Canyon National Recreation Area

Geologic history

Canyons, mountains, hogback ridges, escarpments, and high plateaus are conspicuous features of the BCNRA that have provided geologists a basis for interpreting the historical development of Rocky Mountain landscapes (Blackstone 1971). The geologic record suggests that the BCNRA, and most of the region, was below sea level and covered with saltwater about 350 million years ago. The climate was tropical. As time passed, the seas receded and advanced several times, depositing sand in some places and finer material elsewhere. Thick beds of limestone were formed during one submergence, beds that are now known as Madison Limestone and which form much of the Bighorn River canyon. Millions of years passed, with the appearance on the landscape of dinosaurs about 200 million years ago. Various episodes of volcanism occurred in western North America, depositing fine ash over the Big Horn Basin that was altered to form the deposits of bentonite that are ecologically and economically important in the region today. Gradually the Wyoming-Montana region was lifted well above sea level, sometimes by buckling or faulting in the earth's surface. The sharp, east-facing escarpment of East Pryor Mountain in the BCNRA is a fault, as evidenced by exposures of the same Madison limestone on the escarpment and in the canyon below.

The Bighorn and Pryor Mountains were being formed in the BCNRA about 40-50 million years ago, with the result being increased stream gradients and more rapid erosion. Mountain peaks were lowered as weathering and erosion took place, and the basin floors became higher with sedimentation. Volcanic activity to the west contributed to the slow but sure process of basin filling. Some of the nearby mountains were buried in sediment. A slow meandering river, the ancestral Bighorn River, flowed across the relatively flat region that now is known as the Bighorn Basin. The climate was warm temperate; redwood, ginkgo, cypress, tree fern, and giant horsetails were common, with sycamore, alder, hickory, poplar, and willow becoming common somewhat later (Wing 1981). Of these species, only alder, poplar, and willow are found in the region today.

A general uplifting of the region occurred about 10 million years ago, raising the landscape to near its present elevation above sea level. Erosion again occurred more rapidly, exhuming those parts of the mountains that had been buried. However, uplift occurred slowly and some of the rivers cut canyons through older rocks. The Big Horn Canyon, the Wind River Canyon, and others like them were formed in this way. Sandstones, limestones, shales, siltstones, granites, and other rock types were exposed throughout the BCNRA. The diversity of exposed rock types and abrupt relief provide the variable edaphic and topographic conditions that play such an important role in determining the vegetation mosaic that exists today. Glaciation, which in some areas obscures the direct effect of *in situ* rock types, did not occur in the BCNRA (Richards 1955).

Climate

Cooling continued and today the climate of the Big Horn Basin is referred to as cool temperate and semi-arid. Daily temperatures are lowest in January, averaging -4 C (16.8 F), and are highest in July, averaging 22 C (71.8 F) (Western Sugar Company records, 1920-1985; Martner 1986). The frost-free period begins on about May 16 and lasts an average of 125 days at the lower elevations (Martner 1986). As noted previously, average annual precipitation at the lower elevations ranges from 18 cm at the south end of the BCNRA, near Lovell, to 49 cm in the north at Fort Smith. Spring and early summer rainfall accounts for two-thirds of the precipitation, with the balance coming as snow. Snow cover often is of short duration, as lengthy periods of mild weather are common in the winter. At higher elevations the climate is cooler and somewhat more moist, depending on topographic position and aspect. While rather dry, the Big Horn Basin is viewed as having a relatively mild climate, an attribute that can be explained partially by the comparatively low elevation for the western part of Wyoming.

Flora, fauna, and human history

Three floristic elements are well represented in the BCNRA, with the Great Basin element being most common toward the drier southern portion. Greasewood (*Sarcobatus vermiculatus*), various species of saltbush (e.g., *Atriplex confertifolia* and *A. gardneri*), curlleaf mountain mahogany (*Cercocarpus ledifolius*), and Utah juniper (*Juniperus osteosperma*) are good representatives of the Great Basin flora. The Great Plains element is more common on the north end, represented by sideoats grama (*Bouteloua* *curtipendula*), big bluestem (*Andropogon gerardii*), blazing star (*Liatris punctata*), and purple prairie-clover (*Petalostemom purpureum*); and the Rocky Mountain floristic element is common at higher elevations and toward the north end with species such as Douglas fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilis*), ponderosa pine (*P. ponderosa*), Engelmann spruce (*Picea engelmannii*), and subalpine fir (*Abies lasiocarpa*). A tentative list of rare and endangered plant species is given in Lichvar et al. (1984), and additional information on specific species can be obtained from Clark and Dorn (1979), the Montana Rare Plant Project (Department of Botany, University of Montana, Missoula), and the Rocky Mountain Herbarium (Department of Botany, University of Wyoming, Laramie).

With regard to fauna, a major feature of the BCNRA is the Pryor Mountain Wild Horse Range. While the Range has been subjected to heavy grazing by the feral horses, the herd is now maintained at 121 adults (Jack 1984). Other animals include bighorn sheep, deer, elk, bear, beaver, and a diverse group of upland birds and waterfowl. Patterson (1985) and Redder et al. (1985) report a total of 306 vertebrate species.

Human occupation of the Bighorn Canyon region can be dated back to about 10,000 years ago, when the first native Americans migrated into the area from the north. For thousands of years they lived by hunting and gathering. The first Europeans arrived less than 200 hundred years ago, led by fur traders and explorers like Charles Larocque, William Clark, Jim Bridger, Nathaniel Wyeth, William Hamilton, Benjamin Bonneville, Osborne Russell, and James Stuart (BCNRA literature, Jack 1984, Dorn 1986). The Mason-Lovell Ranch, now a historic landmark in the BCNRA, was established in 1883 at about the time that cattle were being trailed into the Big Horn Basin from the south. Heavy grazing probably occurred in some parts of the BCNRA, especially near water. Cattle grazing is still allowed in the BCNRA, though on a much reduced level, and there are still a few agricultural fields. The Bureau of Land Management, U. S. Forest Service, Crow Indian Tribe, Wyoming Game and Fish Department, and various private land holders now have jurisdiction over land adjacent to the Recreation Area; and the Wyoming Game and Fish Department collaborates with the National Park Service in managing the Yellowtail Wildlife Unit at the confluence of the Bighorn and Shoshone Rivers near the south end.

Methods

Our goal at the outset of this study was to obtain data on species composition and various environmental factors from stands representing each of the different kinds of vegetation found within the BCNRA. This approach requires an initial, subjective classification of the vegetation, a task made fairly simple by the distinct boundaries that often occur in the area due to sharp environmental discontinuities. Nevertheless, most vegetation types were sampled in various locations (stands) so that the original classification could be refined prior to developing the vegetation map. Also, studying several stands in each vegetation type enabled a better understanding of the environmental factors controlling species composition -- one of the major goals of our study.

By the end of two summers we had sampled 75 stands distributed among the following general vegetation types:

Vegetation type sampled	Number of stands
Desert shrubland	16
Sagebrush steppe	15
Juniper/mountain mahogany woodland	31
Grasslands	13

Time did not permit a detailed analysis of the forest, riparian, and wetland vegetation. However, we do discuss the history and environmental relationships of the forests and a more comprehensive study of the BCNRA riparian vegetation is in progress (Akashi, in preparation). As most of the upland vegetation within BCNRA boundaries occurs in the southern half of the BCNRA, all but 5 stands were located there. Our species cover data for each stand are shown in Appendix A, and the precise location of each stand is shown in Appendix B.

Each stand was approximately 1-2 ha in size and appeared homogeneous in terms of species composition, topography, and soils. The percent cover for each shrub species was determined using the line intercept method (ten 40 m lines in each stand), and the percent cover of herbaceous species (grasses, sedges, and forbs) was determined using a modification of the quadrat method known as the Daubenmire canopy-coverage method (Daubenmire 1959). A total of 100 quadrats were sampled in each stand, each quadrat being 20 x 50 cm. Specimens were collected when species could not be easily identified in the field, with subsequent identification being done using the Rocky Mountain Herbarium at the University of Wyoming. Taxonomic nomenclature is that adopted by Lichvar et al. (1985). Common names are listed in Appendix C.

Certain habitat information also was noted for each stand, in particular, elevation, slope, position on slope, aspect, and geologic substrate. Also, one or two soil pits were dug to approximately 1 m or until altered bedrock material was reached. Soil samples were collected from two depths (0-10 and 10-40 cm) in each pit. Each sample was sifted through a 2 mm sieve. Soil pH and conductivity were determined for the surface 10 cm from a paste, and soil texture was determined using the hydrometer method. Geologic formations were identified using Richards (1955) as the primary reference.

Data analysis. Our approach to data analysis involved several techniques for stand comparison. The first was simply to study the tables that showed percent cover for each species in each stand. This simple procedure was adequate, in combination with field observations and the literature, for expanding our preliminary vegetation classification to the 21 types included on the vegetation map. We felt sufficiently confident with this classification that more sophisticated techniques such as cluster analysis were not used.

Another approach for stand comparison is known as direct gradient analysis (Gauch 1982). This method usually involves selecting two environmental factors thought to be important in differentiating the stands. We used elevation and soil depth, but other factors such as percent clay, soil conductivity, or nutrient availability could have been used. The two factors are used as axes for a two-dimensional figure, with a dot representing the location of each stand. After locating each stand on the figure, the similarity of any pair or group of stands, with regard to the two factors, can be quickly ascertained by noting their proximity in the figure (commonly referred to as an ordination). Stands are similar if they are close together, different if they are far apart. As shown in the results section, this approach is useful for determining the environmental factors that are important in causing variation in species composition.

While direct gradient analysis can be helpful, it requires some preconceived notion of what environmental factors will be most useful in causing species differences. An alternative is to use indirect gradient analysis (Gauch 1982), where stands are again positioned in a two-dimensional figure according to their similarity. However, in this case similarity is determined strictly on the basis of species composition, not by similarity in environmental factors. The technique for indirect gradient analysis that we used is known as Detrended Correspondence Analysis (DECORANA), and is used commonly for determining ecological relationships (Gauch 1982). As shown in the results, DECORANA ordinations can help determine which species and environmental factors are most important in causing stand differences. The data used with the DECORANA analysis are included in Appendix A, though we used data only for species that occurred in more than one stand and with relatively high cover values. Separate DECORANA ordinations were derived for desert shrublands, sagebrush steppe, and juniper/mountain mahogany woodlands.

Fire history in the coniferous forests. As is apparent from historical records and visual examination of the forest vegetation, fires have played an important role in the forest ecology of the BCNRA. In some areas the fires have simply maintained open communities, as in the case of the ponderosa pine savannas (or woodlands) on the north end of the Recreation Area. Surface fires sweep through such forests, perhaps every few years, but usually do not kill the trees.

In other areas, such as on East Pryor Mountain and along the southern riparian zones, crown fires may kill the dominant trees, whether Douglas fir or cottonwood. The mosaics created by such fires are easily visible, with patches of younger forest usually interspersed in a matrix of older forest. Aging the trees that dominate the younger forest patches can provide a good estimate of when fires created the patches, and in some cases the fire-free interval can be determined (Romme 1982). Time did not permit the analysis of fire scars to determine the frequency or return interval of fires in this area.

Working in the forested stands of East Pryor Mountain was difficult because of very steep topography, but we did obtain wood cores from 100 trees that were used to gain some indication of fire history there. Also, our riparian study involves the collection of many comparable tree-ring records (Akashi, in preparation). Tree ages were estimated by extracting wood cores from near the base of the tree with an increment corer, and then counting annual rings.

Map preparation and analysis. Our 1:24,000 vegetation map has been published separately (Myers, Knight, Jones, and Frey 1986), but it is an important component of this report. A limited number of copies are available from the authors or from the BCNRA administration, and a copy has been sent to college and university libraries in the region.

Vegetation mapping was initiated in the second summer of our study (1984) after reaching a concensus with BCNRA personnel on the vegetation types that should be included. Orthophotoquads were purchased from the U.S. Geological Survey and fixed-wing aerial photos were obtained from the Soil Conservation Service. Boundaries of the different vegetation types were drawn on the orthophotoquads after close examination of the aerial photos, with field checks being made to the extent that time permitted during the summer. The vegetation boundaries were then traced onto greenline mylars, also obtained from USGS, and appropriate Chartpak symbols were selected to represent the different vegetation types. The map was photographed and printed in six sections by the Wyoming State Printing Office in Cheyenne.

Vegetation maps provide the opportunity for several kinds of analysis, including the determination of the area occupied by each of the mapped units. To estimate the proportion of the BCNRA occupied by each vegetation type, we used a modification of the point-quadrat method. A transparency with a known number of dots was laid over the map in many random locations, with the number of dots on each vegetation type being tallied. The number tallied for each vegetation type was divided by the total number of dots observed to estimate percent of area covered.

Results and Literature Synthesis on BCNRA Vegetation Types

Our analysis suggests that the BCNRA vegetation can be usefully divided into the following plant communities or vegetation types:

1. Marsh
2. Riparian vegetation
   a. Floodplain meadow
   b. Floodplain shrubland
   c. Floodplain woodland
   d. Creek woodland
3. Desert shrubland
   a. Saltbush desert shrubland
   b. Sagebrush desert shrubland
   c. Greasewood desert shrubland
   d. Mixed desert shrubland
4. Grassland
   a. Mixed-grass prairie
   b. Basin grassland
   c. Windswept plateau
5. Great Plains shrubland
6. Sagebrush steppe
7. Juniper and mountain mahogany woodlands
   a. Juniper woodland
   b. Juniper/mountain mahogany woodland
   c. Mountain mahogany shrubland
8. Coniferous woodlands or forests
   a. Limber pine woodland
   b. Douglas fir woodland
   c. Ponderosa pine woodland
   d. Spruce-fir woodland

Each of these vegetation types is included on our 1:24,000 map.

The six most common vegetation types in the BCNRA are (with percent of land area in parentheses): Juniper and mountain mahogany woodlands (40%), riparian vegetation (16%), desert shrubland (15%), sagebrush steppe (12%), grasslands (8%), and coniferous woodlands (6%) (Table 1).

TABLE 1. The proportion of land area within the BCNRA boundary covered by the different vegetation types, expressed in hectares and as a percentage of the total land area. The estimates are based on the vegetation map by Myers et al. (1986). Land area is calculated as the product of the percentage and 22,499 hectares, which is the total land area within the BCNRA (67,595 acres - 12,000 acres water = 55,595 acres or 22,499 ha). One hectare = 2.471 acres = 0.01 square kilometers = 0.003861 square miles. Patterson (1985) made similar calculations, with somewhat different results, but worked from a preliminary copy of the same map.

Vegetation type	Land area (ha)		% of total	
1. Marsh		293		1.3
2. Riparian vegetation		3667		16.3
a. Floodplain meadow	1665		7.4	
b. Floodplain shrubland	1125		5.0	
c. Floodplain woodland	607		2.7	
d. Creek woodland	270		1.2	
3. Desert shrubland		3330		14.8
a. Saltbush	968		4.3	
b. Sagebrush	968		4.3	
c. Greasewood	742		3.3	
d. Mixed desert	652		2.9	
4. Sagebrush steppe		2633		11.7
5. Grassland		1912		8.5
a. Mixed-grass prairie	472		2.1	
b. Basin grassland	1283		5.7	
c. Windswept plateau	157		0.7	
6. Great Plains shrubland		23		0.1
7. Juniper/mtn mahogany woodl'd		8909		39.6
a. Juniper woodland	6502		28.9	
b. Juniper/mtn mahogany woodl'd	1755		7.8	
c. Mountain mahogany shrubl'd	652		2.9	
8. Coniferous woodlands or forests		1350		6.0
a. Limber pine	788		3.5	
b. Douglas fir	450		2.0	
c. Ponderosa pine	45		0.2	
d. Spruce-fir	67		0.3	
9. Agricultural land		382		1.7
TOTALS		22499		100.0

While such values are of interest, the elongate nature of the BCNRA and environmental changes lead to considerable differences in the vegetation mosaic from south to north (Fig. 2). Desert shrubland and riparian vegetation are far more common in the southern one-third, mixed-grass prairie and Douglas fir/ponderosa pine woodlands are more common in the northern third, and the center one-third is characterized by juniper/mountain mahogany woodland and sagebrush steppe.

Desert shrubland

Desert shrublands are restricted to the southern part of the BCNRA, where the climate is comparatively dry with only 18 cm of precipitation during the year. Most stands occur below 1200 m. We identified and mapped four different kinds of desert shrubland, i.e., Saltbush, Sagebrush, Greasewood, and Mixed (Table 2). Except for our mixed desert shrubland, this classification is similar to that developed in the southern part of the Big Horn Basin by Nichols (1964) and Fisser (1964).

Saltbush desert shrubland covers approximately 968 ha in the BCNRA and appears to be the most arid vegetation type. It is characterized by low cover and the prevalence of Gardner saltbush (*Atriplex gardneri*), a short, evergreen half-shrub also known as saltsage or Nuttall's saltbush (Fig. 3). Associated but less common species include bud sagewort (*Artemisia spinescens*), big sagebrush (*A. tridentata*), Indian ricegrass (*Oryzopsis hymenoides*), bottlebrush squirreltail (*Sitanion hystrix*), and plains pricklypear (*Opuntia polyacantha*) (Table 2). Other species known to occur in this type are birdfoot sagewort (*Artemisia pedatifida*), western wheatgrass (*Agropyron smithii*), Sandberg bluegrass (*Poa sandbergii*), halogeton (*Halogeton glomeratus*), fireweed summercypress (*Kochia scoparia*), and seepweed (*Suaeda depressa*) (Vosler 1962, South 1980). Geologically, saltbush desert shrubland occurs on the Embar, Mowry, Frontier, Thermopolis, and Cloverly formations, with the substrate often being shale or alluvium. Often this plant community is disturbed by bentonite mining.

Several investigators have studied the soil characteristics of other

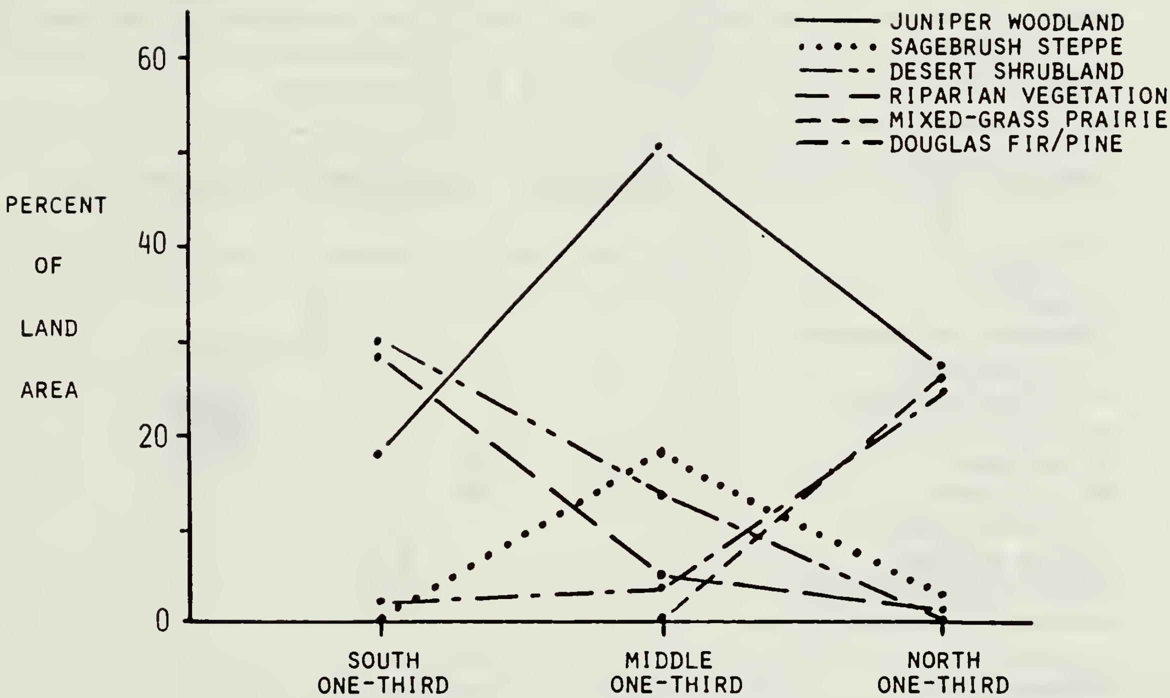

Fig. 2. The percent land area in different vegetation types in the southern, middle, and northern thirds of the BCNRA. The changes can be attributed to topographic differences, the somewhat higher elevations in the middle third, and the change in annual precipitation from 18 cm in the south to 49 cm in the north.

TABLE 2. Common plant species in the desert shrubland vegetation of the Bighorn Canyon National Recreation Area. Sixteen stands were sampled and were divided into four types of desert shrubland: saltbush, sagebrush, greasewood, and mixed (see text). Table 4 summarizes the species composition for sagebrush steppe, another vegetation type. Mean percent cover values are presented for the stands sampled in each type. A more complete list of species and the actual data for each stand are presented in Appendix A, and common names are given in Appendix C. The number of stands sampled for each type of desert shrubland is indicated in parentheses.

Species	Saltbush (5)	Sagebrush (7)	Greasewood (1)	Mixed (3)
Shrubs				
Artemisia spinescens	1	1		
A. tridentata	1	7	2	8
Atriplex canescens		<1	<1	
A. confertifolia		<1	1	<1
A. gardneri	12		<1	
Chyrsothamnus nauseosus		1		1
C. viscidiflorus		<1	1	
Grayia spinosa			<1	
Gutierrezia sarothrae		<1		1
Sarcobatus vermiculatus	<1		21	
Grasses				
Agropyron spicatum				2
Aristida fendleriana		1		1
Distichlis stricta		<1		
Oryzopsis hymenoides	1	1		<1
Stipa comata		2		2
Sitanion hystrix	<1	<1		
Sporobolus airoides	<1	<1		
Forbs and low shrubs				
Arenaria hookeri				1
Astragalus oreganus		<1		
Descurainia pinnata			<1	
Eriogonum brevicaule				<1
Halogeton glomeratus			8	
Opuntia polyacantha	1	<1		<1
Sphaeralcea coccinea	<1	<1	4	
Sueda fruticosa	<1			
Sueda torreyana	<1			

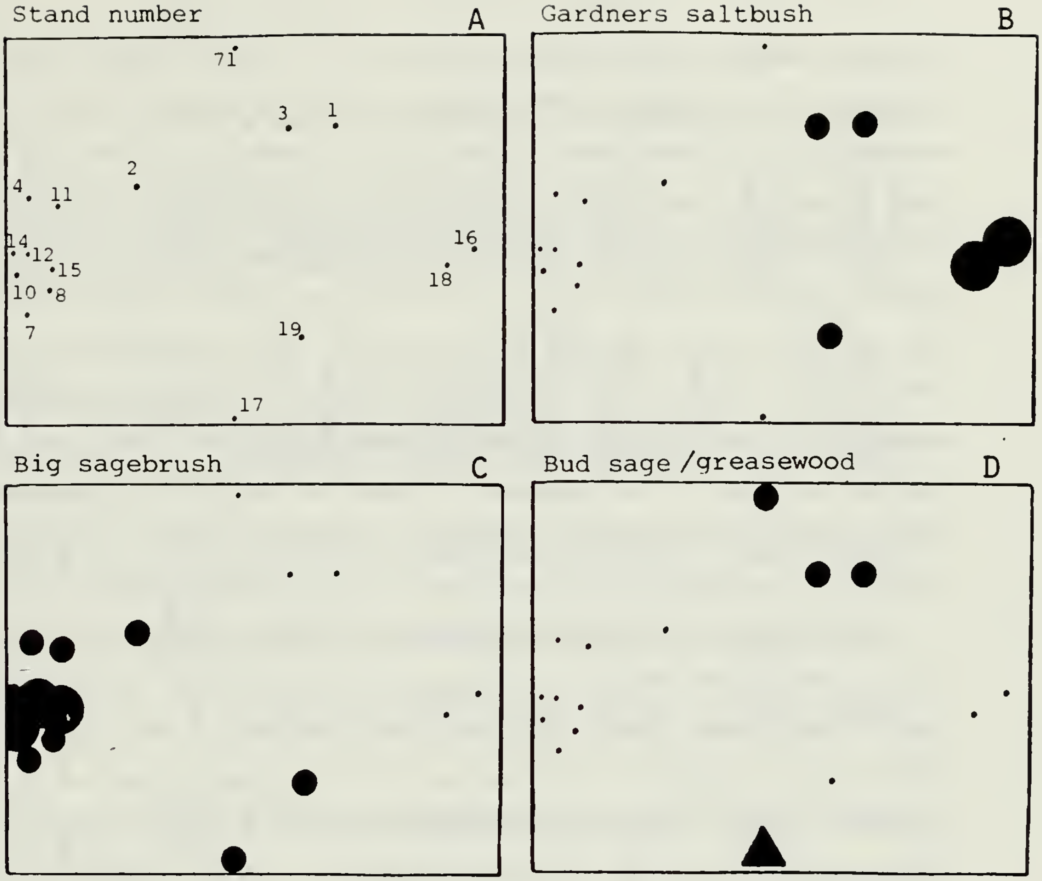

Fig. 3. A DECORANA ordination of 16 desert shrubland stands. Stands are identified by number in part A. Stands located close together are very similar in species composition; those located far apart are very different. The percent cover of individual species is shown in parts B, C, and D, with a small dot indicating a cover of 0-1%, a medium dot indicating 1-10%, and large dot (or triangle) indicating greater than 10% cover. The stands on the right are dominated by Gardner saltbush (B), those on the left by big sagebrush (C). Other species with the same pattern as big sagebrush are Fendler three-awn, Douglas rabbitbrush, rubber rabbitbrush, shadscale, winterfat, and needle-and-thread. On the vertical axis stands were differentiated by bud sagewort and greasewood (D). The triangle represents stand 17, which was dominated by greasewood. Stands 1, 3, and 71 had the largest amounts of bud sagewort and bottlebrush squirrel-tail. No clear patterns became apparent when environmental data were plotted on the ordination. See text for additional information on desert shrublands in the BCNRA.

saltbush desert shrublands (Gates et al. 1956, Vosler 1962, Nichols 1964, Blaisdell and Holmgren 1984), with variable results. Our highest soil conductivity values were found in this vegetation type (13 dS/m), but they were not consistently high (Table 3). Nichols (1964), working in the southern part of the Big Horn Basin, had similar results, and Vosler (1962) could not find a good correlation between Gardner saltbush cover and conductivity, percent clay, or soil pH. Gates et al. (1965) noted that desert shrubs may not be good indicators of soil conditions. On the other hand, ecologists may not be measuring the right soil characteristics. For example, it may be helpful to characterize the deeper part of the profile as well as the surface soil when studying soil/plant relationships in desert shrublands (Gates et al. 1956).

Our results and those of Nichols (1964) indicate that saltbush desert shrubland exists on various soil textures, including sandy loam, sandy clay loam, loam, and clay loam (Table 3). Nichols (1964) found much lower infiltration rates for saltbush desert soils in the southern Big Horn Basin, compared to sagebrush- and bluegrama-dominated communities (Fig. 4), an observation that could be due to a relatively high clay content or to the dispersing effect of sodium on the surface soil particles. Gardner saltbush, like some other species of the Chenopodiaceae, is known to concentrate sodium on the soil surface through leaf fall and salt secretion from salt glands on the leaves, thereby creating saline soils. A soil pH of 8 or above is common, but the soils are not always alkaline and the electrical conductivity commonly is 1.5 dS/m or less (Vosler 1962), which is not particulary high. The saltbush desert shrubland soils that we studied had a pH range of 8.0 to 8.6 and a conductivity range from 0.5 to 13.0 dS/m (Table 3).

Gardner saltbush is a valuable forage species on winter range and is sometimes planted for reclamation purposes, especially where a halophyte might have some advantage over other species. The roots spread laterally to a distance of 2 m, with tap roots penetrating to 1 m or more (Russey 1967). The major form of reproduction is by root sprouts (Russey 1967, Nord et al. 1969) or layering, i.e., the development of adventitious roots and new plants from decumbent branches pressed to the ground (Blaisdell and Holmgren 1984). Young et al. (1984) summarized current knowledge about seed reproduction by noting 1) a high degree of seed

TABLE 3. Various environmental characteristics of the 75 stands sampled in the Bighorn Canyon National Recreation Area, listed by vegetation type. The units for soil conductivity, in the far right column, are deci-Siemens per meter (1 dS/m = 1 mmho/cm). The location of each stand is shown on the maps in Appendix B, and the plant species composition of each stand is given in Appendix A.

Stand No.	Vegetation type	Elevation m	Elevation ft	Aspect	Topographic position	Soil depth	Percent sand	Percent silt	Percent clay	Texture class	Geologic substrate	pH	Conductivity
1	Saltbush desert shrubland	1121	3700	sw	terrace	50 cm	46	24	30	sandy loam	alluvium	8.6	0.9
3		1136	3750	n	terrace	50	46	22	32	sandy clay lm	alluvium	8.1	0.5
16		1182	3900	ne	level	75	38	39	23	loam	shale	8.3	13.0
18		1167	3850	w	level	90	51	24	25	sandy clay lm	shale	8.0	3.7
19		1167	3850	ne	level	100	28	45	27	clay loam	shale	8.4	11.0
2	Sagebrush desert shrubland	1133	3740	w	lower slope	50	65	18	17	sandy loam	alluvium	8.5	0.5
4		1127	3720	n	level	35	55	22	23	sandy loam	alluvium	8.0	0.4
7		1115	3680	ne	level	90	44	16	40	sandy clay	siltstone	8.3	0.4
12		1115	3680	n	terrace	100	74	10	16	sandy loam	alluvium	8.3	0.5
14		1139	3760	e	level	50	42	27	31	clay loam	alluvium	7.8	2.6
15		1133	3740	e	level	70	51	26	23	sandy clay lm	shale	7.8	1.6
71		1121	3700	w	lower slope	10	58	12	30	sandy clay lm	alluvium	8.3	0.5
8	Mixed desert shrubland	1182	3900	n	level	30	48	11	41	sandy clay	siltstone	8.0	2.1
10		1258	4150	nw	entire slope	6	55	15	30	sandy clay lm	colluvium	8.0	0.6
11		1197	3950	nw	entire slope	50	44	30	26	loam	shale	8.1	0.6
17	Greasewood desert shrubland	1176	3880	e	lower slope	65	64	18	18	sandy loam	shale	8.0	2.8
72	Mixed-grass prairie	1061	3500	ne	level	25	33	31	36	clay	sandstone	7.5	0.5
73		1024	3380	w	upper slope	20	39	25	36	clay	sandstone	7.7	0.6
75		1182	3900	ne	lower slope	20	48	26	26	sandy clay lm	sandstone	7.8	0.5
5	Windswept plateau	1139	3760	sw	level	15	46	22	32	sandy clay lm	siltstone	8.1	0.5
6		1164	3840	sw	level	5	45	24	31	sandy loam	colluvium	8.0	0.6
36		1333	4400	e	level	15	44	32	24	loam	colluvium	8.2	0.5

TABLE 3 (continued)

Stand No.	Vegetation type	Elevation m	Elevation ft	Aspect	Topographic position	Soil depth	Percent sand	Percent silt	Percent clay	Texture class	Geologic substrate	pH	Conductivity
38	Basin grassland	1273	4200	ne	level	5	46	22	32	sandy clay lm	colluvium	8.1	0.5
39		1261	4160	w	level	60	43	19	38	clay loam	limestone	8.3	0.6
42		1188	3920	ne	level	70	60	19	21	sandy clay lm	sandstone	8.1	0.4
45		1333	4400	ne	lower slope	15	44	21	35	clay loam	colluvium	8.0	0.4
47		1491	4920	ne	level	15	33	29	38	clay loam	colluvium	7.9	0.4
58		1152	3800	n	lower slope	20	55	14	31	sandy clay lm	colluvium	8.3	0.5
60		1339	4420	n	upper slope	45	33	26	40	clay	colluvium	8.0	0.4
70		1582	5220	nw	lower slope	19	39	25	36	clay	siltstone	7.8	0.5
35	Sagebrush steppe	1273	4200	ne	level	35	68	10	22	sandy clay lm	sandstone	8.1	0.5
37		1248	4120	n	entire slope	10	43	16	41	clay	colluvium	8.3	0.7
43		1200	3960	se	level	65	58	16	25	sandy clay lm	colluvium	8.0	0.4
51		1224	4040	se	level	60	55	17	27	sandy clay lm	alluvium	8.1	0.5
52		1594	5260	e	upper slope	40	42	24	34	clay loam	colluvium	6.5	0.3
53		1424	4700	se	level	55	38	24	38	clay loam	colluvium	7.9	0.5
54		1348	4450	e	level	35	43	22	35	clay loam	colluvium	7.7	0.6
55		1342	4430	sw	level	35	68	14	18	sandy loam	sandstone	7.7	0.3
56		1348	4450	sw	level	50	55	21	24	sandy clay lm	sandstone	7.8	0.4
59		1355	4470	n	lower slope	50	41	16	43	clay	colluvium	8.1	0.5
62		1355	4470	e	level	40	47	21	32	sandy clay lm	sandstone	8.0	0.5
63		1348	4450	se	level	32	34	18	48	clay	sandstone	8.0	0.5
64		1339	4420	w	level	45	47	27	26	sandy clay lm	sandstone	7.4	0.4
65		1333	4400	nw	level	65	38	31	31	clay	sandstone	7.5	0.4
13	Juniper woodland	1152	3800	sw	upper slope	20	62	17	21	sandy clay lm	dolomite	8.0	0.9
20		1152	3800	n	entire slope	40	60	12	28	sandy clay lm	dolomite	8.2	0.6
21		1158	3820	s	entire slope	30	57	15	28	sandy clay lm	limestone	8.1	1.3
22		1127	3720	s	lower slope	40	55	21	24	sandy clay lm	limestone	8.1	0.4
23		1164	3840	ne	upper slope	20	77	6	17	sandy loam	limestone	8.5	0.7
25		1297	4280	ne	level	70	83	4	13	loamy sand	sandstone	8.2	0.6
29		1345	4440	sw	level	50	65	16	19	sandy loam	sandstone	8.0	1.0
34		1321	4360	n	level	10	73	9	18	sandy loam	sandstone	8.0	0.5
40		1212	4000	w	lower slope	45	42	33	25	loam	colluvium	7.9	0.5
41		1394	4600	se	upper slope	20	37	25	37	clay loam	colluvium	7.8	0.6

TABLE 3 (continued)

Stand No.	Vegetation type	Elevation m	Elevation ft	Aspect	Topographic position	Soil depth	Percent sand	Percent silt	Percent clay	Texture class	Geologic substrate	pH	Conductivity
44	Juniper woodland (cont.'d)	1257	4150	n	level	30	83	7	10	loamy sand	sandstone	8.2	0.3
46		1455	4800	ne	upper slope	30	47	19	34	clay loam	colluvium	8.0	1.6
48		1158	3820	sw	upper slope	3	82	6	12	sandy loam	sandstone	8.3	0.3
49		1394	4600	n	entire slope	25	51	15	34	sandy clay lm	colluvium	8.1	0.5
50		1379	4550	s	entire slope	60	50	23	27	sandy clay lm	limestone	8.0	0.7
57		1136	3750	se	upper slope	5	67	10	23	sandy clay lm	colluvium	8.1	0.5
61		1379	4550	s	entire slope	30	25	19	56	clay	siltstone	8.1	0.4
66		1303	4300	sw	upper slope	20	67	10	23	sandy clay lm	sandstone	8.2	0.5
67		1303	4300	ne	entire slope	50	28	25	47	clay	sandstone	8.4	2.7
74		1212	4000	e	entire slope	40	48	24	28	sandy clay lm	colluvium	7.9	0.5
9	Juniper/mountain mahogany	1352	4460	w	upper slope	50	72	13	15	sandy loam	sandstone	8.1	0.6
24		1285	4240	s	upper slope	15	67	12	21	sandy clay lm	sandstone	8.2	0.5
30		1352	4460	sw	lower slope	30	60	12	28	sandy clay lm	sandstone	8.1	0.6
68		1318	4350	sw	upper slope	20	60	11	29	sandy clay lm	sandstone	7.8	0.5
27	Juniper/limber pine woodland	1358	4480	sw	ridge top	2	78	10	12	sandy loam	sandstone	8.0	0.5
69		1348	4450	ne	upper slope	1	70	15	15	sandy loam	sandstone	8.3	0.4
26	Mountain mahogany	1315	4340	sw	upper slope	25	62	15	22	sandy clay lm	sandstone	8.5	0.7
28		1309	4320	n	upper slope	40	67	13	20	sandy clay lm	sandstone	8.0	0.5
31		1406	4640	sw	upper slope	5	69	11	20	sandy loam	sandstone	8.0	0.4
32		1545	5100	se	upper slope	1	47	15	38	sandy clay	limestone	8.2	0.5
33		1485	4900	e	lower slope	1	42	26	32	clay loam	limestone	7.8	0.4

polymorphism; 2) rapid germination under ideal conditions; 3) poor emergence from burial in seedbeds, with surface seeding the most desirable; and 4) short and highly variable seed storage half-life. Ansley and Abernethy (1984) reported on various factors that apparently cause the high seedling mortality often observed when seeding Gardner saltbush for reclamation.

Greasewood desert shrubland. Dominated by greasewood (*Sarcobatus vermiculatus*), another halophyte in the Chenopodiaceae, this community covers about 742 ha in the BCNRA (Table 1) and occurs where soil moisture is more abundant, for example, in ravines, depressions, or where the water table is closer to the surface such as along the Bighorn and Shoshone Rivers. Greasewood grows to a height of 1 m or more and the total plant cover is much higher than for any other type of desert shrubland (Table 2). Associated species include big sagebrush (*Artemisia tridentata*), shadscale (*Atriplex confertifolia*), rubber rabbitbrush (*Chrysothamnus nauseosus*), Douglas rabbitbrush (*Chrysothamnus viscidiflorus*), scarlet globemallow (*Sphaeralcea coccinea*), halogeton (*Halogeton glomeratus*), Gardner saltbush (*Atriplex gardneri*), plains pricklypear (*Opuntia polyacantha*), fireweed summercypress (*Kochia scoparia*), Nuttall monolepis (*Monolepis nuttalliana*), cheatgrass (*Bromus tectorum*), foxtail barley (*Hordeum jubatum*), bottlebrush squirreltail (*Sitanion hystrix*), western wheatgrass (*Agropyron smithii*), Nevada bluegrass (*Poa nevadensis*), and alkali sacaton (*Sporobolus airoides*) (based on our data and Hamner 1964).

Hamner (1964) classified the greasewood-dominated vegetation of the Big Horn Basin into four community types, i.e., greasewood-shadscale, greasewood-big sagebrush, greasewood-grass, and greasewood monoculture. These communities were differentiated in part by edaphic features, with the greasewood-shadscale stands being on heavy clay loams and the greasewood-sagebrush community occurring on loams. While all four communities seemed to have somewhat different edaphic conditions, they were not easily distinguishable and Nichols (1964) found great overlap in the soil texture of greasewood-dominated stands and those dominated by big sagebrush and rabbitbrush. Blaisdell and Holmgren (1984), in a review of intermountain salt desert rangelands, stated that in less saline areas greasewood is associated with shadscale, Gardner saltbush, rabbitbrush, basin big sagebrush, budsage, spiny hopsage, and winterfat. While greasewood can tolerate high levels of salinity and alkalinity, Hamner and various other investigators noted that it is not an infallible indicator of such conditions (Gates et al. 1956); historic disturbances may be as important as current environmental conditions (Blaisdell and Holmgren 1984).

In general, Hamner found that the soil pH of greasewood-dominated stands was commonly 8 or above and that soil conductivity ranged from 2.9 to 8.8 dS/m. Our single stand in this type had a pH of 8.0 and a conductivity of 2.8 dS/m. Nichols (1964) found that the infiltration rate in greasewood-dominated vegetation was much less than in stands dominated by big sagebrush (as was the case for Gardner saltbush; Figs. 4 and 5).

The abundance of several grasses in relation to soil texture was also studied by Hamner in the greasewood vegetation of the Basin, with the interesting observation that blue grama (*Boutelous gracilis)* was more common on the somewhat sandier soils, alkali sacaton (*Sporobolus airoides*) and saltgrass (*Distichlis stricta*) more common on siltier soils, and western wheatgrass (*Agropyron smithii*) more common on the more clayey soils.

Greasewood is a deciduous shrub that can be poisonous to livestock if eaten in sufficient quantities, due to the presence of soluble oxalates. Like various other species in the Chenopodiaceae, it has salt glands that help in tolerating the osmotic problems created by saline conditions and which facilitate, together with leaf fall, the development of more saline conditions directly under the shrub. Some have suggested that this autogenic salt accumulation may be a form of allelopathy, i.e., the production of a chemical by a plant that inhibits the growth of other plants, thereby minimizing competition. Like Gardner saltbush, greasewood is known to produce root sprouts. However, the roots of greasewood penetrate much deeper, down to 3 m according to Nichols (1964).

In addition to increasing the salt content of surface soil, the deciduous nature of greasewood accounts for very little transpiration during the fall, winter, and spring. This could increase the amount of

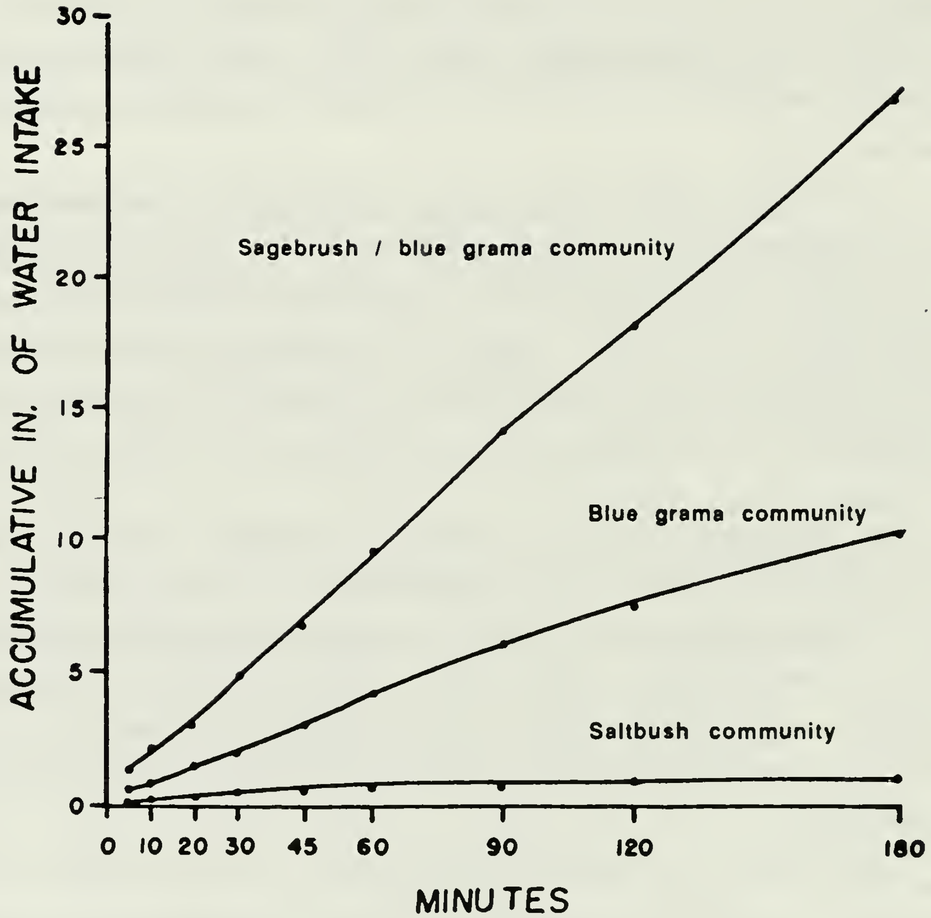

Fig. 4. Data which show how the soil infiltration capacity of saltbush desert shrubland is much lower than a grassland dominated by blue grama, which similarily has a lower infiltration capacity than a community dominated by big sagebrush. The vertical axis is accumulative inches of water intake (1 inch = 2.54 cm). From a study by Nichols (1964a) done near Worland in the Big Horn Basin.

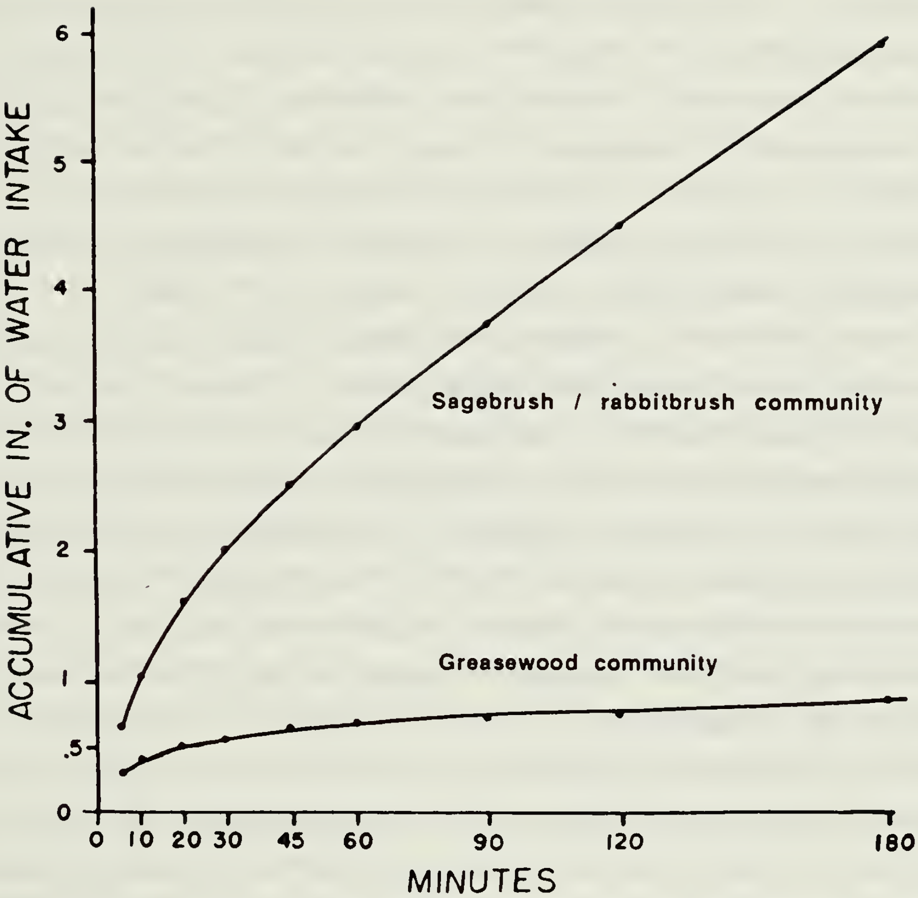

Fig. 5. Data which show how greasewood desert shrubland in the Big Horn Basin has a lower soil infiltration capacity than a stand dominated by big sagebrush and rabbitbrush. The vertical axis is accumulative inches of water intake (1 inch = 2.54 cm). From a study by Nichols (1964a) done near Worland. See Fig. 4 also.

water available in the soil when growth resumes, compared to soils dominated by the evergreen big sagebrush. Rickard (1967) discusses this possibility, noting that indeed there was a more luxuriant growth of herbaceous plants in a stand of greasewood than in an adjacent big sagebrush community. However, the topographic position usually occupied by greasewood, in drainages or nearer the water table, may be as important or more so in causing the greater availability of spring soil moisture. Greasewood appears to require considerable soil moisture, but it simply tolerates high salinity (Gates et al. 1956).

The notion that greasewood-dominated stands occur lower in the landscape is certainly true in many areas. However, Nichols (1964) found greasewood more common on the second terrace of the 15-mile Creek drainage near Worland, with a Basin big sagebrush-rabbitbrush community more common on the first terrace. The sagebrush soils on the first terrace were more permeable (Fig. 5), which could indicate different conditions during deposition or terrace formation, but there is also the possibility that more frequent flooding on the first terrace causes more leaching of accumulated salts. Big sagebrush, which appears to be less tolerant of salts than greasewood, may thus have a competitive advantage on the first terrace, thereby excluding greasewood which can tolerate the more saline conditions that have developed on the second terrace. More research is needed to determine which factors are involved in causing this distribution pattern.

Sagebrush desert shrubland. We identified two kinds of BCNRA vegetation characterized by Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), i.e., sagebrush desert shrubland and sagebrush steppe. The desert shrubland is found at lower elevations (usually less than 1150 m) where big sagebrush is commonly associated with bud sagewort (*Artemisia spinescens*), shadscale (*Atriplex confertifolia*), Indian ricegrass (*Oryzopsis hymenoides*), needleandthread (*Stipa comata*), and most of the other species found in desert shrublands, including greasewood and Gardner saltbush (Table 2). Some of the research done on sagebrush in the Big Horn Basin has occurred where bluebunch wheatgrass (*Agropyron spicatum*) is common (e.g. Fisser 1964, Uhlich 1982), which is more characteristic of our sagebrush steppe type. We found sagebrush desert shrublands on various geologic formations, including the Cloverly, Morrison, and Chugwater.

While big sagebrush often is thought to be intolerant of saline or alkaline soils, Hamner (1964) found it associated with greasewood on soils with a pH of 8.4 and a conductivity of 3.4 dS/m in the Big Horn Basin. The pH and conductivity of our seven stands ranged from 7.8 to 8.5 and 0.4 to 2.6 dS/m, respectively (Table 3). Gates et al.(1956) concluded that big sagebrush could not be used as an indicator of soil conditions, but noted that it tended to grow on soils with relatively low salt content. Nichols (1964) found that sagebrush soils had higher infiltration rates than other desert shrublands near Worland (Figs. 4 and 5), but his study was done on a lower stream terrace where Basin big sagebrush (*A. tridentata* spp. *tridentata)* was the dominant subspecies instead of Wyoming big sagebrush. In contrast, Gates et al. (1956) found big sagebrush on "the heaviest textured soils of any species studied" in western Utah. The great diversity of edaphic conditions on which sagebrush is found could be explained by genetic or ecotypic variation, as noted by Blaisdell and Holmgren (1984), or the fact that plant species composition and growth is a function of climatic conditions as well as soil characteristics. The indicator value of a species undoubtedly varies from one region to another.

Historical factors also must be considered and have been the subject of considerable debate in the case of big sagebrush. While there seems to be little doubt that big sagebrush was a conspicuous feature of the intermountain region prior to the mid-1800's, there is some evidence to suggest that it has increased in abundance with livestock grazing pressure in the Bighorn Basin (Cooper 1953, Fisser 1964). Uhlich (1982) studied a series of exclosures in the Bighorn Basin that had been protected from livestock grazing for 20 years or more, finding that successional development in the absence of grazing varied considerably from one exclosure to the next. Uhlich's results could be explained by different environmental conditions at his exclosures, different land use histories prior to establishing the exclosures, and the observation that different assemblages of species can be quite stable on a given site even though environmental conditions may be similar. Chance plays a significant role in determining which species invade a disturbed site initially, and those species may develop into a very stable community.

Fire is another factor that can have a signficant effect on sagebrush-dominated vegetation, especially under more moist conditions that allow sufficient productivity for the formation of a continuous and substantial fuel. Unlike Gardner saltbush and greasewood, big sagebrush is not capable of producing root or crown sprouts and is easily killed by fire. Reinvasion of sagebrush must be accomplished by seed, with the seedlings subject to intense competition from grasses (Robertson 1947), forbs, and other shrubs that simply resprout and easily increase in importance when the sagebrush shrubs are killed. However, the semi-arid environment of desert shrublands restricts the level of fuel development to such a low level that fires probably are infrequent.

A large volume of literature exists on vegetation dominated by sagebrush. Beetle and Johnson (1982) provide an overview of the distribution, ecology, and taxonomy of the 13 Wyoming species in the Tridentatae section of *Artemisia*, and two other documents provide useful information on the biology and ecology of sagebrush (Utah State University 1979, McArthur and Welch 1986).

Mixed desert shrubland. This vegetation type is found primarily on upland sites in the vicinity of Horseshoe Bend and Sykes Mountain where soils have developed from the Gypsum Springs, Sundance, and the red Chugwater Formations. Total vegetation cover is very low, with rubber rabbitbrush, shadscale, big sagebrush, broom snakeweed (*Gutierrezia sarothrae*), bluebunch wheatgrass (*Agropyron spicatum*), Fendler threeawn (*Aristida fendleriana*), and needleandthread being among the characteristic species (Table 2). Of the four types of desert shrubland, it occupies the smallest area (Table 1) and could have been combined with the sagebrush desert shrubland. However, where it occurs big sagebrush often is more restricted to ravines or depressions. Soil pH and conductivity are similar to sagebrush desert shrubland, but the mixed desert shrubland tended to occur at somewhat higher elevations (Table 3).

We distinguished sagebrush steppe from sagebrush desert shrubland by the higher plant cover and the rarity of shrubs in the Chenopodiaceae (especially greasewood and species of *Atriplex*). The environment probably is somewhat cooler and more mesic because of the higher elevation at which the sagebrush steppe occurs (1200-1600 m or 3960-5280 ft). While this vegetation type has been referred to as sagebrush grassland, sagebrush/grass, or sagebrush steppe, we use the latter term because it implies broad expanses of shrubland or grassland such as occur in the BCNRA and throughout the intermountain west. This type occupies 2633 ha in the BCNRA (Table 1) and is dominated by two species of sagebrush, i.e., Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and black sagebrush (*A. nova*). Characteristic associates of these low shrubs include broom snakeweed, bluebunch wheatgrass, blue grama (*Bouteloua gracilis*), threadleaf sedge (*Carex filifolia*), junegrass (*Koeleria macrantha*), Sandberg bluegrass (*Poa sandbergii*), needleandthread, Hooker sandwort (*Arenaria hookeri*), fringed sage (*Artemisia frigida*), plains pricklypear, and Hoods phlox (*Phlox hoodii*) (Table 4).

Two kinds of sagebrush steppe can be distinguished in the BCNRA, namely, **black sagebrush steppe** where *A. nova* predominates and **big sagebrush steppe** where *A. tridentata* ssp. *wyomingensis* predominates (Fig. 6). The two types were not mapped separately because we could not distinguish them with confidence on the aerial photographs. However, our observations lead us to conclude that black sagebrush steppe covers a larger area. Studies done elsewhere suggest that black sagebrush usually occurs on somewhat drier sites than big sagebrush (West 1979), and Fig. 7A suggests that, in the BCNRA, black sagebrush steppe occurs at somewhat higher elevations than big sagebrush steppe and sagebrush desert shrubland. However, this pattern may be coincidental with other edaphic conditions that are more important. June grass (*Koeleria macrantha*) is more common on sites with black sagebrush in the BCNRA, whereas blue grama (*Bouteloua gracilis*) and needle grass (*Stipa comata*) are more abundant on sites with big sagebrush (Table 4). Although the literature suggests that big sagebrush can tolerate a wide range of salinity, the

TABLE 4. Common plant species in two kinds of sagebrush steppe in the Bighorn Canyon National Recreation Area. Note that Table 2 includes data for big sagebrush (Artemisia tridentata) desert shrubland. Mean percent cover values are presented for the stands sampled in each type, and the number of stands sampled for each is in parentheses. A more complete list of species and the actual data for each stand are presented in Appendix A, and common names are given in Appendix C.

Species	Black Sagebrush Steppe (8)	Big Sagebrush Steppe (6)
Shrubs		
Artemisia nova	28	<1
A. tridentata	4	15
Gutierrezia sarothrae	2	2
Grasses and sedges		
Agropyron spicatum	3	4
Bouteloua gracilis	1	9
Carex filifolia	4	2
Koeleria macrantha	5	1
Poa sandbergii	<1	<1
Stipa comata	<1	3
Forbs and low shrubs		
Arenaria hookeri	1	<1
Artemisia frigida	<1	<1
Opuntia polyacantha	<1	<1
Phlox hoodii	1	1
Lichen	2	2

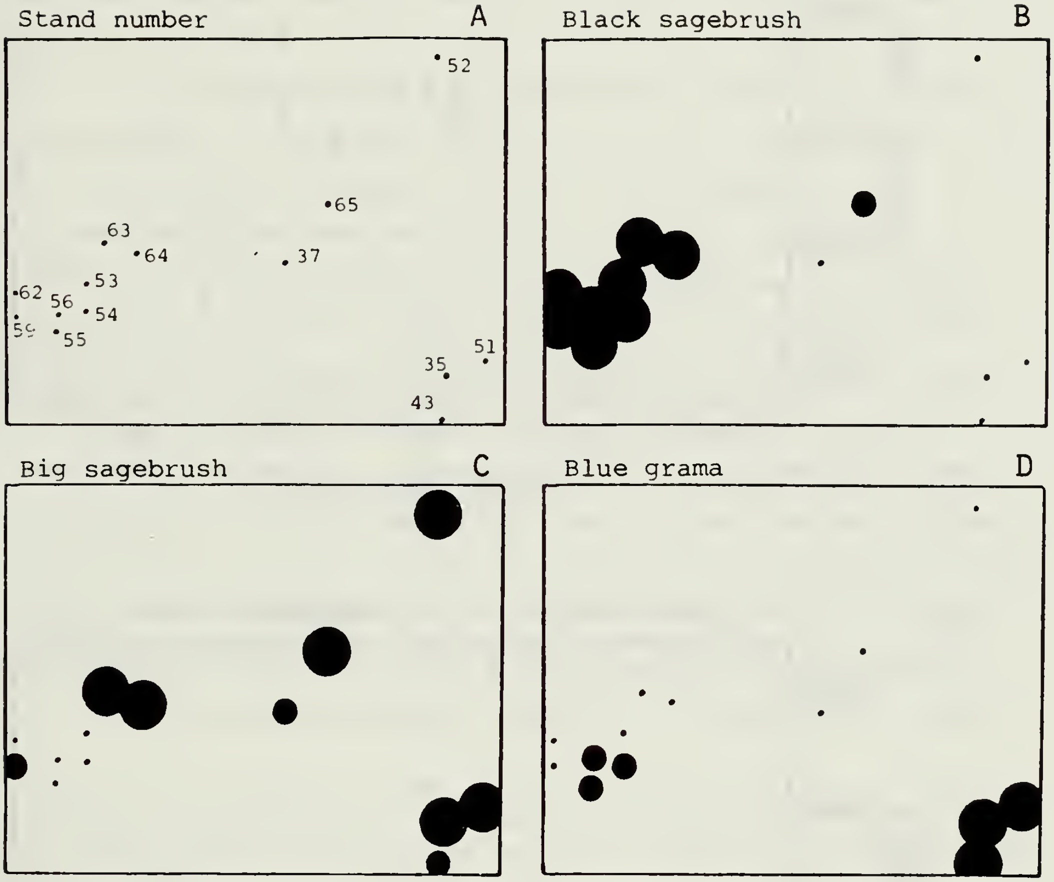

Fig. 6. A DECORANA ordination of 14 stands of sagebrush steppe. Stands are identified by number in part A. Stands located close together are very similar in species composition, those located far apart are very different. The percent cover of individual species is shown in parts B, C, and D, with a small dot indicating a cover of 0-1%, a medium dot indicating 1-10%, and a large dot indicating greater than 10% cover. The stands on the left are dominated by black sagebrush (B), with other species associated with black sagebrush being june grass and threadleaf sedge. Stands in the middle and toward the right of the ordination are dominated by big sagebrush (C), and blue grama was more important in the stands near the bottom of the ordination (D). See text for additional information on the sagebrush steppes of the BCNRA.

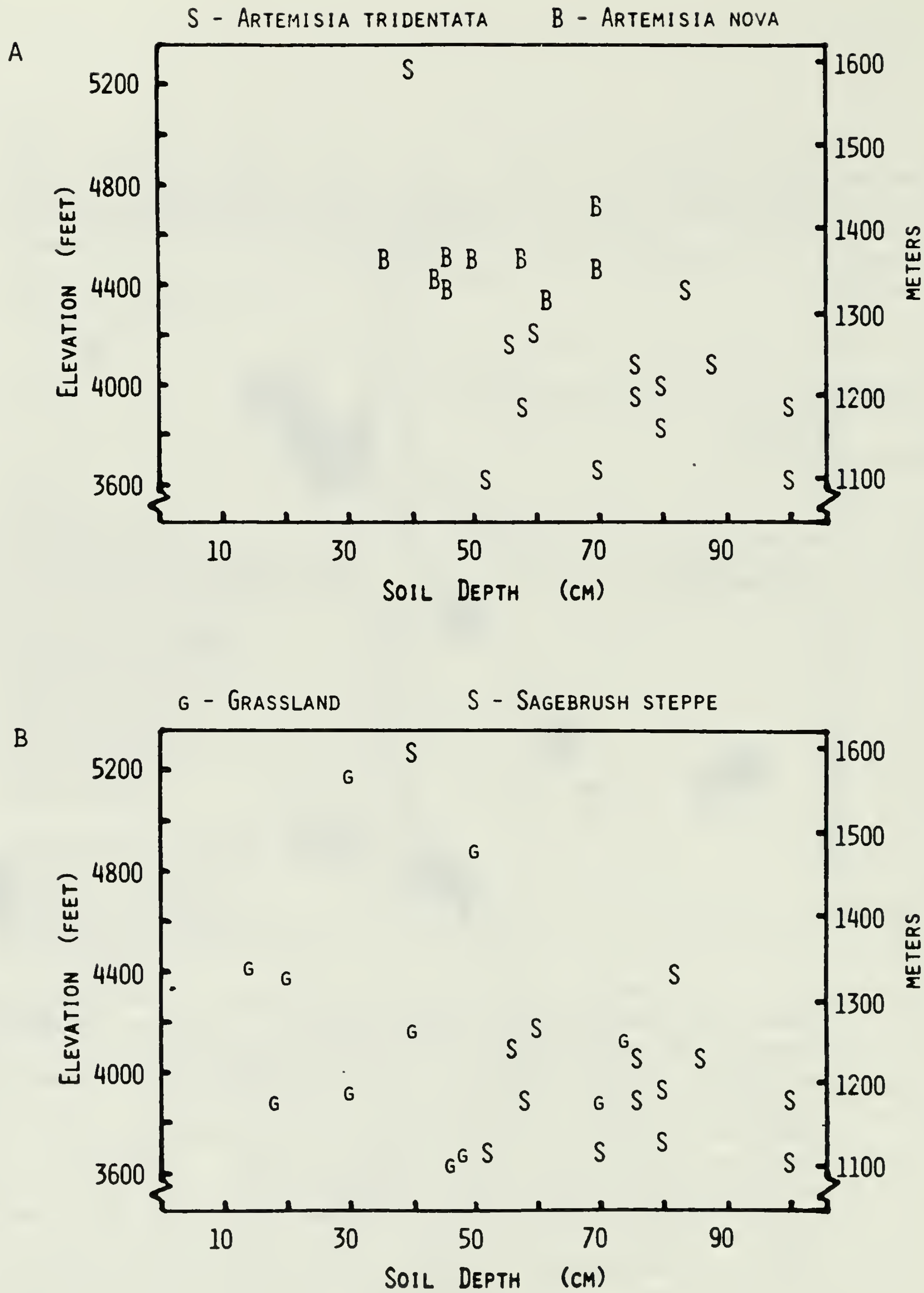

Fig. 7. Two ordinations resulting from direct gradient analysis that show stand distribution in relation to soil depth and elevation. Letter location indicates stand location in relation to the two axes. Different vegetation types or characteristic species are symbolized by different letters. Part A suggests that stands dominated by black sagebrush are located at somewhat higher elevations than stands dominated by big sagebrush in the BCNRA. Part B suggests that grasslands have a wider elevational distribution and shallower soils than sagebrush steppe.

surface soil conductivity in our stands was low (<1 dS/m, Table 3). Soil pH ranged from 6.5 to 8.3.

A large amount of research has been done on sagebrush, particularly the *A. tridentata* complex (McArthur and Welch 1986). The literature is too voluminous to summarize in this report, but note should be made of the inability of big sagebrush and black sagebrush to sprout following fire and the abundance of seedlings that can occur during some years. In some respects both species are like pioneer plants, producing an abundance of seed and sometimes becoming more common in disturbed habitats. Such traits might be advantageous for a species that cannot sprout. The productivity of the steppe ecosystem is sufficiently high that fires could have occurred regularly, especially in the fall after a favorable growing season and relatively light grazing by bison, elk, antelope, and other herbivores. Once established big sagebrush is very competitive and persists in the community like a climax species, probably until the next fire. Historical records indicate that sagebrush has been a conspicuous feature of the Wyoming and Montana landscape for hundreds of years and that its abundance should not be considered solely as an artifact of livestock grazing pressure (Houston 1961, Vale 1975, Johnson 1986).

Both species of sagebrush are evergreen and capable of transpiration and photosynthesis during warm days in the fall, winter, and spring when most other species are leafless (Caldwell 1979), an adaptation that may contribute significantly to their competitive ability. Also, the root system occupies the surface soil as well as the deeper soil (Tabler 1968), which may allow the plant to utilize water from brief summer rains in addition to the deeper water resulting from percolation following spring snowmelt. The distribution of sagebrush is closely correlated with climates where a relatively large proportion of the annual precipitation comes as snow (West 1979). Whereas rain water evaporates rapidly after each event, snow accumulates before melting and the meltwater therefore percolates in larger volumes deeper into the soil where evaporation is slower. The deeper soil water then provides a more reliable source for the growing season. This contention seems to be supported by the observation that sagebrush distribution appears to be correlated with soils that have a high infiltration capacity (Figs. 4 and

5) or "good drainage". In fact, drainage may be less important than percolation to a depth where the water can be stored and used by the shrubs during the drier parts of the summer.

Grasslands

Grasslands with very low shrub cover occur on both sides of the mountains through which the Bighorn Canyon passes, but the northern grasslands are quite different from those to the south. The importance of little bluestem (*Andropogon scoparius,* also known as *Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), and Kentucky bluegrass (*Poa pratensis*) on the north side led us to classify the grasslands there as **mixed-grass prairie**, a term commonly used for grasslands in the nearby northern Great Plains. Other associated grass species included western wheatgrass, bluebunch wheatgrass, blue grama, junegrass, Idaho fescue (*Festuca idahoensis*), needleandthread (*Stipa comata*), green needlegrass (*S. viridula*), and Japanese brome (*Bromus japonicus*) (Table 5). Common forbs include soapweed (*Yucca glauca*), hairy goldenaster (*Heterotheca villosa*), arrowleaf balsamroot (*Balsamorrhiza sagittata*), lupine (*Lupinus* sp.), spikemoss selaginella (*Selaginella densa*), and Lewis flax (*Linum lewisii*). The presence of species such as bluebunch wheatgrass, Idaho fescue, and arrowleaf balsamroot led Branson (1985) to refer to some grasslands near Fort Smith as Palouse prairie, though many ecologists think of Palouse prairie as being restricted to Washington, Oregon and western Idaho. Ross and Hunter (1976) prepared a map of climax vegetation for Montana and referred to the grasslands south of Fort Smith as foothills grasslands (SCS silty range site, 15-19 inch precipitation zone). They did not use the term mixed-grass prairie, referring instead to a diversity of range sites found across the northern Great Plains (including most of central and eastern Montana). Foothills grassland, Palouse prairie, and mixed-grass prairie are all terms that could be used for the northern BCNRA grasslands. We selected mixed-grass prairie based on BCNRA proximity to the western Great Plains and the presence of little bluestem and sideoats grama, but recognizing that the presence of bluebunch

TABLE 5. Plant species common in grasslands of the Bighorn Canyon National Recreation Area. Mean percent cover values are presented for the stands sampled in each type, and the number of stands sampled for each is in parentheses. A more complete list of species and the actual data for each stand are presented in Appendix A, and common names are given in Appendix C.

Species	Mixed-grass Prairie (3)	Basin Grassland (7)
Shrubs		
Artemisia nova	<1	<1
A. tridentata		<1
Gutierrezia sarothrae	<1	4
Grasses and sedges		
Agropyron smithii	1	
A. spicatum	4	8
Andropogon scoparius	5	
Bouteloua curtipendula	2	
B. gracilis	<1	3
Bromus japonicus	2	
Carex filifolia		<1
Festuca idahoensis	<1	
Koeleria macrantha	1	<1
Poa pratensis	6	
Poa sandbergii		<1
Stipa comata	<1	1
Stipa viridula	<1	
Forbs and low shrubs		
Achillea millefolium	<1	
Arenaria hookeri		2
Artemisia frigida	<1	1
A. longifolia	<1	
A. ludoviciana		<1
Comandra umbellata	<1	
Gaura coccinea	<1	<1
Heterotheca villosa	1	
Lesquerella alpina		<1
Opuntia polyacantha	<1	<1
Paronychia sessiliflora		1
Phlox hoodii	1	2
Senecio canus		<1
Tragopogon dubius	2	
Yucca glauca	<1	
Lichens		2

wheatgrass and Idaho fescue is more characteristic of grasslands and shrublands to the west (Mueggler and Stewart 1980). A more detailed analysis of the BCNRA grasslands would have led to more specific subdivisions. Despite the presence of big bluestem (*Andropogon gerardii*) in the BCNRA (Lichvar et al. 1985), we found no grasslands that could be classified as tall-grass prairie.

While much of the mixed-grass prairie in the BCNRA occurs as openings in the foothill conifer woodlands, some extensive tracts are found just south of Fort Smith. Total area covered was about 472 ha (Table 1). The elevation is about the same as the desert shrublands of the south end of the BCNRA (<1200 m), but the precipitation is 2.7 times higher. The soils of the three stands that we sampled were quite shallow (ca 25 cm), had developed on a sandstone substrate, and were either clay or sandy clay loams (Table 3). Surface soil conductivity was consistently <1 dS/m and pH ranged from 7.5 to 7.8 (Table 3). Unlike the grasslands of the central Great Plains which occur on deep soils, the grasslands of the intermountain west often occur where the soils are shallow, perhaps too shallow for certain shrubs that might be expected in the area, e.g., big sagebrush.

Shallow soils were also characteristic of grasslands on the south side of the mountains, which we termed **basin grasslands** to imply the drier environment of the Big Horn Basin. The elevation of our eight stands in this vegetation type ranged from 1152 to 1582 m and, on the average, they were somewhat higher than the mixed-grass prairie in the north. Characteristic plant species included bluebunch wheatgrass, blue grama, needleandthread, broom snakeweed, Hooker sandwort, fringed sagewort, and Hoods phlox (Table 5). Again, the very low sagebrush cover (<1%) could be due to shallow soils. The <2 mm fraction of the soil was classified as clay, clay loam, or sandy clay loam; and the substrate types included limestone, sandstone, siltstone, and colluvium (Table 3). Soil conductivity values were all <1 dS/m and soil pH ranged from 7.8 to 8.3.

A third kind of grassland is represented in what we referred to as **windswept plateau**. This term is non-descriptive botanically, but a better term did not emerge for this vegetation type that occurs on the tops of mesas or ridges with very sparse plant cover. The grasses are scattered and small forbs are common, with the forbs often having the "cushion plant" growth form. The species composition is quite similar to basin grasslands and, in retrospect, they could have been classified together. As might be expected, the soils are shallow (Table 3) and the characteristic species include bluebunch wheatgrass, Fendler threeawn, needleandthread, Hooker sandwort, broom snakeweed, fineleaf hymenopappus (*Hymenopappus filifolius*), stemless actinea (*Hymenoxys acaulis*), squarestem phlox (*Phlox bryoides*), and Hoods phlox (*P. hoodii;* see Appendix B for a complete species list).

Grasslands have been well-studied in many parts of the Great Plains, and in fact they may be one of the best understood ecosystems of the world. The ecological literature is voluminous, including papers on species composition, physiological adaptations, nutrient cycling, effects of climate on productivity, biomass distribution above and below ground, and the importance of bacteria, fungi and other microbes in the soil. A few attempts at synthesizing this information include Daubenmire (1968), Sims et al. (1978a,b,c,d), Breymeyer and Van Dyne (1979), French (1979), and Risser et al. (1981). While much is known that is relevant to the grasslands of the BCNRA, rather little has been published specifically on grasslands of the type that occur within it. Wright and Wright (1948) studied a series of grassland relics in Montana, including one in the Hardin cemetery about 72 km (45 miles) north of Fort Smith. The characteristic species at the Hardin relic included blue grama, green needlegrass, needleandthread, junegrass, western wheatgrass, Sandberg bluegrass, Hoods phlox, broom snakeweed, and plains pricklypear. Wright and Wright concluded that the grasslands near Bozeman were characterized by having most of the precipitation early in the spring, whereas those toward the east had a larger proportion of the annual precipitation during the warm summer, the latter being more characteristic of the Great Plains. In agreement with an earlier study by Morris (1946), they arranged the grassland types from more mesophytic to more xerophytic as follows:

1. Idaho fescue type in mesic locations near Bozeman
2. Bluebunch wheatgrass type near Virginia City, northwest of Yellowstone National Park

3. Bluebunch wheatgrass-threadleaf sedge-blue grama type on sandier soils near Billings
4. Blue grama-needleandthread-junegrass type near Billings and Hardin
5. Blue grama-needleandthread type, the most xeric type and represented in their sample by sites found in the western part of the Gallatin Valley near Three Forks, west of Bozeman.

Our mixed-grass prairie site probably is most similar to their bluebunch wheatgrass-threadleaf sedge-blue grama type, but the presence of sideoats grama (*Bouteloua curtipendula*) and little bluestem (*Andropogon scoparius*) in the foothills near Fort Smith suggests some environmental differences. The BCNRA grasslands near Fort Smith are at a higher elevation, and in some areas Idaho fescue is very common. This species is very abundant in meadows of the nearby Bighorn Mountains (Beetle 1956, Hurd 1961). Big sagebrush was relatively uncommon in the relics studied by Wright and Wright, if it occurred at all, but their observations suggested that it increased with livestock grazing on some sites.

Another study of relics was done by Fisser (1964) in the southeastern part of the Big Horn Basin in Wyoming, south and east of Worland. He located seven relics, most of which were characterized by the presence of bluebunch wheatgrass, big sagebrush, threadleaf sedge, Sandberg bluegrass, and needleandthread. Fisser was able to identify some species that increased with grazing pressure and others that decreased. While sagebrush may be more common in the Bighorn Basin than in the western Great Plains, for example where Wright and Wright (1948) did their study, Fisser considered it to be an increaser along with Sandberg bluegrass, blue grama, and various other species. Cooper (1953) observed the same tendency for big sagebrush in the Nowood River valley south of Tensleep, Wyoming -- also in the Big Horn Basin. The basin grasslands that we identified in the BCNRA appear to be similar to those studied by Fisser and Cooper, except that the soils may be too shallow to support big sagebrush.

Perhaps the most common and widespread species in the BCNRA grasslands is bluebunch wheatgrass (*Agropyron spicatum*). Williams (1963) surveyed the distribution of this species in the Big Horn Basin and found it to be characteristic of the 25-50 cm (10-20 inch) precipitation zone in the foothills or on Basin slopes. At lower elevations it was usually found on north slopes, if it occurred at all, and Idaho fescue became more common at higher elevations (> 2121 m or 7,000 ft). In general, he did not find bluebunch wheatgrass on the saline soils characteristic of the greasewood and saltbush desert shrublands, nor did we, and he concurred with others in classifying it as a decreaser under heavy grazing pressure. Williams (1961, 1963) also observed that fires could kill bluebunch wheatgrass, with cheatgrass (*Bromus tectorum*) being a common invader.

Great Plains shrubland

Restricted to the north end of the BCNRA, Great Plains shrubland is found in more mesic depressions or ravines. Though somewhat similar to creek woodlands, this shrubland usually is not found along streams. The additional moisture apparently comes from more snow accumulation due to drifting and runoff from the slopes above. Great Plains shrubland often occurs as part of a mosaic comprised of mixed-grass prairie, creek woodland, and ponderosa pine woodland, for example just south of Fort Smith. The characteristic species include American plum (*Prunus americana*), chokecherry (*P. virginiana*), wild rose (*Rosa* sp.), and snowberry (*Symphoricarpos* sp.), with occassional boxelder (*Acer negundo*), Rocky Mountain maple (*Acer glabrum*), hawthorn (*Crataegus* spp.), saskatoon serviceberry (*Amelanchier alnifolia*), water birch (*Betula occidentalis*), poison ivy (*Toxicodendron rydbergii*), and the introduced Siberian elm (*Ulmus pumila*). Cottonwoods and other typically riparian species are absent. The name for this vegetation type is tentative, but emerged from the observation that similar shrublands are found in ravines or coulees along drainages in the Great Plains to the east.

Juniper woodland and mountain mahogany shrublands

One of the most characteristic features of the BCNRA and the foothills of the Big Horn Basin are extensive tracts of picturesque shrublands or woodlands dominated by Utah juniper (*Juniperus osteosperma*), curlleaf mountain mahogany (*Cercocarpus ledifolius*), or both. Together they occupy 8909 ha in the BCNRA, 40 percent of the land area (Table 1). Associated species included black sagebrush, broom snakeweed, bluebunch wheatgrass, Fendler threeawn, and an occasional limber pine (*Pinus flexilis*) (Table 6). Rocky Mountain juniper (*J. scopulorum*) may occur at higher elevations, in ravines, or toward the north end where annual precipitation is higher. Total vegetation cover usually is low, especially on the steep canyon walls. Our stands were found from 1127-1545 m (3719-5099 ft) elevation.

Juniper/mountain mahogany woodlands in the Big Horn Basin usually are found on very shallow soils or, perhaps more importantly, fractured bedrock (Wight and Fisser 1968). While such habitats appear very dry, they may be more mesic than some adjacent areas because the little rainfall that does occur is funneled into reservoirs created by the fractures and into which the roots of juniper and mountain mahogany can penetrate. Associated plant species apparently have the same ability. Such reservoirs probably are a more reliable source of water than typical surface soils, from which the relatively small amount of water could be easily evaporated before being used by plants. This phenomenon appears to be an expression of the inverse texture effect (Noy-Meir 1973, Sala et al. (in press)), which implies that coarse soils (possibly including fractured bedrock) become the more mesic habitat when annual precipitation is less than a certain amount (<370 mm in a Great Plains study by Sala et al., in press). More rapid and deeper infiltration minimizes evaporation, thereby preserving more of the water for plants that have deep root systems. Rapid infiltration is thought to be important for the distribution of other conifers and big sagebrush as well. As noted previously, big sagebrush tends to occur on soils with a higher infiltration rate (Figs. 4 and 5).

We divided the juniper/mountain mahogany woodlands into three types -- **mountain mahogany shrubland, juniper woodland,** and **juniper/mountain mahogany woodland.** This division was based solely on the abundance of the dominant species, with mountain mahogany shrubland having very little juniper and juniper woodland having very

TABLE 6. Plant species common in juniper woodland, juniper/mountain mahogany woodland, and mountain mahogany shrubland in the Bighorn Canyon National Recreation Area. Mean percent cover values are presented for the stands sampled in each type, and the number of stands sampled for each is in parentheses. A more complete list of species and the actual data for each stand are presented in Appendix A, and common names are given in Appendix C.

Species	Juniper Woodland (20)	Juniper/MM Woodland (4)	Mountain Mahogany Shrubland (7)
Trees			
Pinus flexilis	<1	<1	<1
Shrubs			
Artemisia nova	2	<1	<1
A. tridentata	<1		
Cercocarpus ledifolius	<1	16	18
Gutierrezia sarothrae	2	<1	<1
Juniperus osteosperma	16	11	3
J. scopulorum	<1	<1	<1
Rhus trilobata		<1	
Grasses			
Agropyron spicatum	2		3
Aristida fendleriana	1	<1	<1
Bouteloua gracilis	<1		
Oryzopsis hymenoides	<1		
Stipa comata	<1		<1
Forbs and low shrubs			
Arenaria hookeri	<1		
Artemisia frigida	<1		<1
Ceratoides lanata	<1		<1
Cryptantha flavoculata	<1		<1
Erigeron spp.	<1	<1	<1
Eriogonum spp.	<1	<1	<1
Hymenoxys acaulis	<1		
Lappula redowskii	<1		
Lepidium densiflorum	<1		
Opuntia polyacantha	<1		<1
Paronychia sessiliflora	<1		
Tanacetum capitatum		<1	<1

little mountain mahogany (Fig. 8, Table 6). Unfortunately, we are still unable to say what environmental factors are important in determining the relative abundance of the two species in the BCNRA. Both occur on a diversity of bedrock types and geologic formations, including sandstones and limestones, and no consistent pattern was apparent in elevation, topography, or soil depth. Greenwood and Brotherson (1978) suggested that true mountain mahogany (*Cercocarpus montanus*) is found on more shallow soils than pinyon-juniper woodlands in Utah, but our data for curlleaf mountain mahongany are inconclusive in this regard (Table 3). Similarily, no distinctions could be made in soil pH (7.8-8.5) or conductivity (with one exception, all <1.6 dS/m, Table 3). Some have suggested that juniper on the upper or northerly edge of its range occurs only in warmer thermal belts, where frosts are less frequent at night due to patterns of cold air drainage and the development of temperature inversions (Billings 1954, Waugh 1986). Indeed, the distribution pattern of juniper is rather discontinuous, as would be the development of thermal belts (Waugh 1986). Also, juniper is more capable than mountain mahogany of invading adjacent rangelands on deeper soils. Thus, the observed differences in juniper and mountain mahogany distribution may be due to differences in microclimate, relative ability to invade adjacent habitats, or soil/bedrock features that we did not study.

The juniper woodlands of the Big Horn Basin have been the subject of several studies under the direction of H. G. Fisser (Robinson 1966, Wamboldt 1973, Wight and Fisser 1968, Hanson 1974, Spaeth 1981, Waugh 1986). Wight and Fisser (1968) mapped juniper woodland distribution in the Basin, noting that it occurred from 1364-1909 m (4500-6300 ft) elevation. Our elevational range in the BCNRA was a little lower, from about 1127-1545 m (3720-5100 ft). Wight and Fisser noted that the lower boundary seemed to be at the juncture with deeper alluvial or colluvial soils, and that the upper limit probably was determined by some climatic factor. Soils were shallow in all of their 45 study areas (10-91 cm, mean 40 cm), with 30-87 percent sand and a pH ranging from 6.8 to 8.1. As with our study, electrical conductivity of the soil was low, from 0.45 to 1.5 dS/m. Mountain mahogany was rather uncommon in their study areas, with big sagebrush, black sagebrush, and broom snakeweed accounting for most shrub cover, but they noted that curlleaf mountain mahogany was

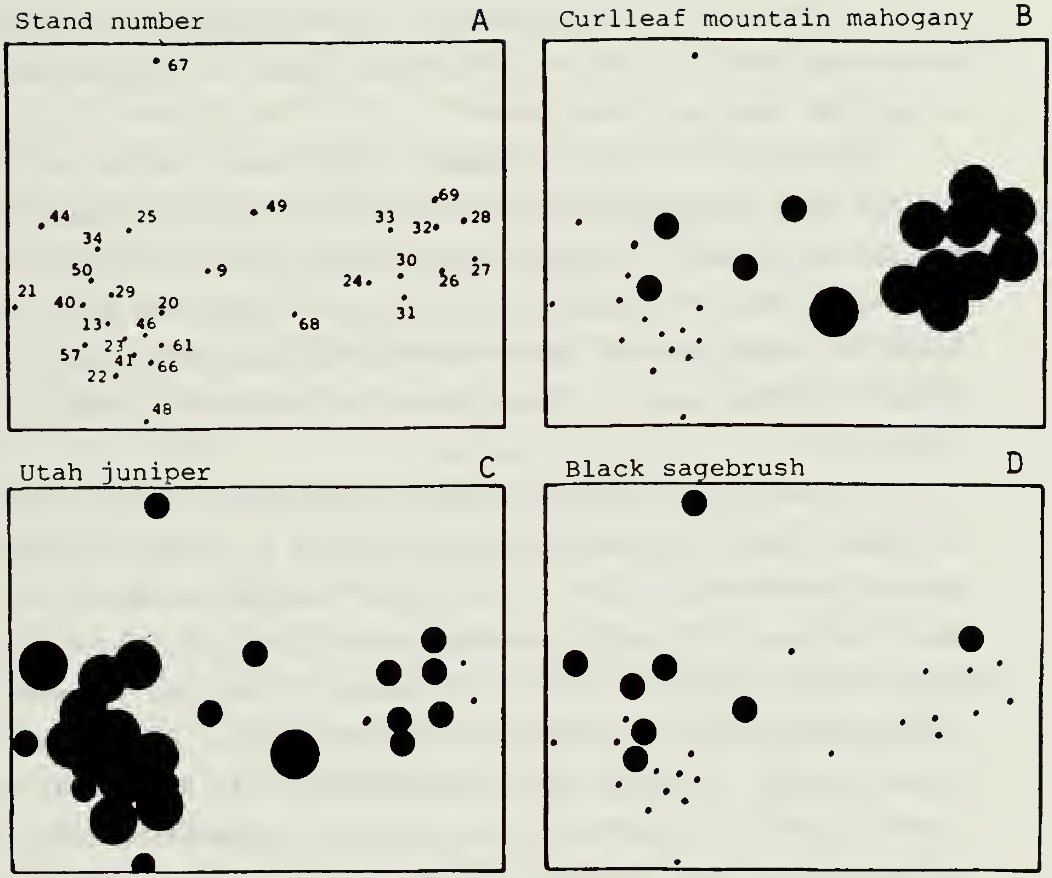

Fig. 8. An ordination of 30 stands of woodlands dominated by Utah juniper and/or curlleaf mountain mahogany. Stands are identified by number in part A. Stands located close together are very similar in species composition, those located far apart are very different. The percent cover of individual species is shown in parts B, C, and D, with a small dot indicating a cover of 0-1%, a medium dot indicating 1-10%, and a large dot indicating greater than 10% cover. The stands on the right are dominated by mountain mahogany (B), those on the left by Utah juniper (C). Fendler three-awn and grass cover were also higher in stands with relatively high juniper cover. The black sagebrush pattern is shown in D. See text for additional information on the juniper/mountain mahogany woodlands of the BCNRA.

found commonly toward the north (between Tensleep and the Montana border) and that it occurred more commonly on the steeper and more barren sites. Consistent with our observations, they found the juniper woodlands on a variety of geologic formations.

One observation made by Waugh (1986) seems particularly noteworthy: whereas many investigators have used the multiple-stemmed nature of Utah juniper as a field taxonomic trait, Waugh found in his study area that often each stem in a cluster is, in fact, a separate plant. Most or all stems of a cluster were about the same age and they probably arose from a group of cached seed, or seeds deposited with bird droppings. Juniper seed is known to be bird dispersed.

Juniper invasion into adjacent grasslands or shrublands is one of the most often discussed ecological topics in the Intermountain West. The most recent summary for the Pinyon-Juniper woodlands of the Great Basin is found in the proceedings of a symposium (Everett 1987), and Waugh (1986) presents data on an example of juniper invasion near Worland in the Big Horn Basin. Using tree ring analysis as a means of studying stand history, he found that the juniper in his study area were restricted to a limestone outcrop prior to expansion, which began about 10 years after the introduction of large cattle herds. He noted that more than 90% of the juniper seedlings were becoming established under sagebrush, which could have been functioning as nurse plants, and he hypothesized that the increase of sagebrush following livestock grazing had created a more favorable environment for juniper invasion. A wide range of juniper ages have been reported in the Big Horn Basin, ranging from very young stands to stands with trees over 500 years old (Wight and Fisser 1968, Waugh 1986).

The importance of nurse plants for shade has been noted by others in arid and semi-arid environments, but other factors could be important as well (as reviewed by Waugh 1986). In particular, livestock grazing could have reduced the fuels available for fire. Tausch and Tueller (1977) concluded that fires at 50-60 yr intervals in the Great Basin could prevent juniper invasion, and others have noted that burning can restrict the abundance of sagebrush (Wright et al. 1979). Fire suppression by any means could have accelerated the change of grasslands to sagebrush and then to juniper woodland. Old-age juniper woodlands often are restricted to rocky ridges where fires are less frequent (Burkhardt and Tisdale 1976). On the other hand, Waugh (1986) discussed the possibility that heavy livestock grazing could have reduced the rate of evapotranspiration from the soil by reducing leaf area, thereby creating a more mesic environment that could have favored sagebrush and juniper invasion. Reduced evapotranspiration in combination with an unusually wet period could have triggered the invasion episode observed by Waugh, which ended after about 50 years (in 1940). Others have suggested that drought, in combination with grazing and fire suppression, favors juniper invasion. More research seems necessary, but a combination of interacting factors undoubtedly is involved.

Herbaceous plant production is greatly reduced with the establishment of juniper in a grassland or shrubland, probably due to 1) competition for water, light, and nutrients, and 2) the production of phytotoxic chemicals by the juniper (Jameson 1966, 1970). The lack of fine fuels and the spacing of the junipers often creates a community that is not easily ignited. Fires become less frequent, which perpetuates conditions favorable to the non-sprouting Utah juniper. While fire has been used to kill junipers in order to provide more livestock forage, it is often necessary to ignite each tree individually with a torch (Wes Hyatt, personal communication). Spaeth (1981) studied succession following juniper control in the Big Horn Basin, including one stand 15 miles east of Lovell, and recommended against juniper control if the potential existed for the rapid expansion of introduced annuals such as cheatgrass (*Bromus tectorum*). Another caution comes from wildlife managers who have noted that the elimination of juniper could have an adverse effect on deer and other wildlife by reducing the amount of "thermal cover" that is important for winter survival. Shade during the summer may be important as well.

Are juniper woodlands expanding in the BCNRA? Our research was not designed to answer this question, but juniper expansion is occurring elsewhere in the Big Horn Basin and fire has been used for control.

There is a voluminous literature on the ecology of pinyon-juniper woodlands, some of which is relevant to the BCNRA. Perhaps the best introduction to this literature is the recent symposium proceedings edited by Everett (1987), where papers can be found on succession, rooting patterns, paleoecology, the effects of fire, juniper control, economics, classification, nutrient cycling, plant-water relations, hydrology, and wildlife. Another helpful collection of papers was edited by Gifford and Busby (1975).

Mountain mahogany shrublands. Two species of mountain mahogany occur in Wyoming, the deciduous *Cercocarpus montanus* in the Black Hills and across the southern half of the State, and the evergreen *Cercocarpus ledifolius* in the foothills of the Bighorn Mountains and to the west and south. Both species occur together on the west side of Flaming Gorge Reservoir (though Miller (1964) suggests that this population of *C. ledifoliuus* is ssp. *typicus*, not ssp. *intercedens*). The Big Horn Mountain stands apparently are a northeastern disjunct of *C. ledifolius* ssp. *intercedens*, with the closest population being 233 km (145 miles) to the southwest in the Snake River Canyon (Miller 1964).

Both species of *Cercocarpus* are characteristic of shallow, rocky soils on foothill slopes near lower tree line, and both occur on a variety of bedrock types (Johnson 1950, Medin 1960, Brooks 1962, Miller 1964, Dealy 1978). Miller (1964) noted that the curlleaf mountain mahogany community in the foothills of the Bighorn Mountains was most common on dolomite in the Amsden formation, red shale in the Chugwater formation, and sandstone in the Tensleep formation. Soil pH was slightly basic, with an average of 7.7 in Miller's stands and a range of 7.8 to 8.5 in our stands (Table 3). Because of shallow soil and abundant rock, the mountain mahogany shrubland has been characterized as being dry. However, the inverse texture effect may enable these sites to be more mesic than adjacent grasslands or shrublands, as discussed previously.

Two studies have been done on the curlleaf mountain mahogany shrubland in the vicinity of the Big Horn Canyon (Miller 1964, Duncan 1975). Duncan (1975) studied 22 stands in southwestern Montana, one of which was located in the Pryor Mountains. Associated species included bluebunch wheatgrass, Indian ricegrass, needleandthread, broom snakeweed, and an occassional juniper, ponderosa pine, Douglas fir, or limber pine. Our species composition data (Table 6) and those of Miller (1964) are very similar to Duncan's. Duncan also found that mountain mahogany ages varied from 5 to 85 years in her stands, but she cited other studies reporting ages of over 150 years (Scheldt 1969, Claar 1973).

In a similar study, Miller (1964) sampled eight stands in the foothills of the Bighorn Mountains in Wyoming, six being located on the western side. Small mammal and bird data were collected as well as vegetation data. Miller found stands of mountain mahogany between 1212 and 2485 m (4000 and 8200 ft) on the western slopes of the Bighorn Mountains, and between 1152 and 2182 m (3800 and 7200 ft) on the east slopes. Miller noted that the shrub was found on all exposures from about 1515 to 1970 m (5000 to 6500 ft), and that stands in the higher Tensleep and Shell Canyons had a greater amount of cover and different associated species than those on more exposed slopes. In the canyons skunkbush (*Rhus trilobata*), chokecherry (*Prunus virginiana*), ninebark (*Physocarpus monogynus*), pricklygilia (*Leptodactylon pungens*), clubmoss (*Lycopodium annotinum*), wax currant (*Ribes cereum*), and chickweed (*Cerastium arvense*) were common associates, whereas black sagebrush, Hoods phlox, and goldenweed (*Haplopappus acaulis*) were more common associates on the drier slopes. Bluebunch wheatgrass was the most common grass species in all of Miller's stands, with Sandberg bluegrass, junegrass, cheatgrass, and Japanese brome being common associates.

Both species of mountain mahogany are browsed frequently by deer in the winter (Medin 1960, Duncan 1975, South 1980, Austin and Urness 1980), responding with the growth of lateral branches or buds. However, sprouting from the base following a fire usually does not occur. Miller (1964) did note some potential for layering, and large seed crops are common (though often on a 2 to 10 year cycle; Phelps 1968 cited in Duncan 1975). Stands of curlleaf mountain mahogany in the Big Horn Basin may become re-established by seedlings. Some have observed the invasion of adjacent communities by curlleaf mountain mahogany following the suppression of fires, suggesting that frequent fires have restricted mountain mahogany to rocky sites (Dealy 1978, Arno and Wilson 1986).

Coniferous forests and woodlands

Coniferous forests and woodlands cover approximately 1350 ha or 6 percent of the BCNRA (Table 1), occurring primarily in the cooler and/or more mesic habitats found on East Pryor Mountain (up to an elevation of about 2600 m) and toward the northern end where rainfall is higher. At lower elevations the coniferous woodlands are restricted to north slopes or deep ravines. The distinguishing feature is the abundance of limber pine (*Pinus flexilis*), Douglas fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), Engelmann spruce (*Picea engelmanii*), or subalpine fir (*Abies lasiocarpa*). While juniper woodland is a coniferous woodland as well, it was sufficiently distinctive to be treated separately. We use the term "woodland" to imply the usual patchy or savanna nature of the tree-dominated vegetation, but some areas toward the north end of East Pryor Mountain can be referred to as forests. Sampling for tree density, basal area, and size class structure was not necessary for our objectives, but Patterson (1985) provided such data for several stands in the BCNRA.

Limber pine woodlands usually are located at lower elevations. Frequently they are found on rocky ridges dispersed through the juniper woodland type, or on the fringes of the **Douglas fir woodland** which is commonly found in the more mesic ravines of East Pryor Mountain or the northern end of the Big Horn Canyon. Limber pine and Douglas fir often occur together in the southern half of the BCNRA, with commonly associated species being spiraea (*Spiraea betulifolia*), buffaloberry (*Shepherdia canadensis*), ground juniper (*Juniperus communis*), snowberry (*Symphoricarpos oreophilus*), ninebark (*Physocarpus monogynus*), kings fescue (*Leucopoa kingii*), Rocky Mountain maple (*Acer glabrum*), and others (South 1980). Much of the Douglas fir woodland on East Pryor Mountain is growing on Madison limestone.

Toward the north Douglas fir is commonly associated with ponderosa pine, a tree that seems to require a somewhat warmer environment with more dependable summer precipitation. **Ponderosa pine woodland** is characteristic of the area near Fort Smith and Bull Elk Basin, where it occurs commonly on south slopes. Associated species include Douglas fir, little bluestem, bluebunch wheatgrass, needleandthread grass, Idaho fescue, lupine, arrowleaf balsamroot, golden aster (*Heterotheca villosa*), soapweed (*Yucca glauca*), prickly pear cactus (*Opuntia polyacantha*), Lewis flax (*Linum lewisii*), yarrow (*Achillea millefolium*), harebell (*Campanula rotundifolia*), bastard toadflax (*Comandra umbellata*), fringed sagewort

(*Artemisia frigida*), owl clover (*Orthocarpus* sp.), and Indian paintbrush (*Castilleja* spp.). The ponderosa pine woodland often merges with mixed-grass prairie, forming a ponderosa pine savanna.

Spruce-fir woodland occurs primarily on the north and northeast sides of East Pryor Mountain, probably in the coolest habitat of the BCNRA. Associated species include huckleberry (*Vaccinium scoparium*), clematis (*Clematis pseudoalpina*), heart-leaf arnica (*Arnica cordifolia*), gooseberry (*Ribes* spp.), and others (South 1980). As shown on the vegetation map (Myers et al. 1986), the spruce-fir woodland occurs at a higher elevation than the Douglas fir woodland, which generally is higher than the limber pine woodland and juniper woodland. Notably absent or rare in the BCNRA forest mosaic are aspen (*Populus tremuloides*) and lodgepole pine (*Pinus contorta*), both of which are common in the mountains to the east and west.

Fire has modified the woodland mosaics of the BCNRA. This is apparent from fire scars at the bases of tree trunks and from the sharp boundaries between young and old Douglas fir forest on the east face of East Pryor Mountain (visible from the highway north of Layout Creek). While occurring on very steep terrain that is difficult to study, we were able to determine that the older forest on East Pryor Mountain has not been burned for at least 150 years. Of the 60 trees that we aged in the older forest, 28 percent were 150 years old or older. As can be expected in Douglas fir forests, the stand was uneven-aged with the ages of our 60 trees ranging from 22 to 196 years. In contrast, the two burned stands that we sampled, and which are visible from the highway, had a maximum age of 54 and 53 years, respectively. The fire that initiated the conspicuous patches of young forest on East Pryor Mountain probably occurred in about 1930, or a few years before. Newspaper records could provide a more precise date.

Fires undoubtedly will occur again in the BCNRA, as they have for millenia. Prescribed burns are a feasible management alternative that should be considered, but our data are inadequate to recommend when and where such burns might be advisable. Additional data on fuel accumulation would be necessary along with a review of management objectives. Outbreaks of the native spruce budworm and bark beetles may occur in the region also.

Riparian vegetation

Three major categories of riparian vegetation exist in the BCNRA: **marsh** vegetation in oxbows and diked areas where waterflow is minimal and emergent plants such as cattails (*Typha angustifolia* and *T. latifolia*) are common; **floodplain** vegetation along the Bighorn and Shoshone Rivers where ground water is near the surface; and **creek** woodlands on the tributaries of the two major rivers. Combined, such habitats occupy 16 percent of the land area (Table 1) and they are extremely important for many animal species. Patterson (1985) provides information on the riparian fauna as well as some data on tree size-class structure, tree density, and shrub density.

Creek woodlands. The major rivers of the BCNRA are fed by a series of perennial and ephemeral streams that derive their water from nearby mountain ranges, either directly as surface flow or through springs. Layout Creek, Trail Creek, and Davis Creek are examples. Such streams have carved fairly steep valleys or even small canyons, along which a species-rich woodland dominated by plains cottonwood (*Populus deltoides*) and narrowleaf cottonwood (*P. angustifolium*) has developed. Other trees found with the cottonwoods include boxelder (*Acer negundo*), water birch (*Betula occidentalis*), peach-leaf willow (*Salix amygdaloides*), Russian olive (*Elaeagnus angustifolia*), Rocky Mountain juniper (*J. scopulorum*), Douglas fir, and hackberry (*Celtis occidentalis*).

Common shrubs found in the Creek woodlands include rose (*Rosa woodsii* and *R. sayi*), skunkbush (*Rhus trilobata*), Rocky Mountain maple (*Acer glabrum*), snowberry (*Symphoricarpos* spp.), silver sage (*Artemisia cana*), Basin big sagebrush (*A. tridentata* ssp. *tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), chokecherry (*Prunus virginiana*), and poison ivy (*Toxicodendron rydbergii*); and common herbaceous plants include rock clematis (*Clematis columbiana*), horsetail (*Equisetum* sp.), dogbane (*Apocynum androsaemifolium*), smooth brome (*Bromus inermis*), tall wheatgrass (*Agropyron elongatum*), poison hemlock (*Conium maculatum*), common yarrow (*Achillea millefolium*), harebell (*Campanula rotundifolia*), and phacelia (*Phacelia* spp.). Ephemeral streams toward the more arid south may have basin big sagebrush, greasewood, and Utah juniper along the margins.

Floodplain Meadows and Mudflats. Some sites on the Bighorn River floodplain are best classified as meadows because trees and shrubs are absent or rare. Often this vegetation type occurs on mudflats caused by the pronounced fluctuations in water level, whether due to low snowfall in the mountains or storage/release decisions at Boysen and Yellowtail Dams. The temporary nature of the mudflats creates an ideal environment for the invasion of native and introduced weedy species, e.g., *Artemisia biennis, Chenopodium berlandieri, Halogeton glomeratus, Kochia scoparia, Rumex maritimus*, and *Tamarix chinensis* (Table 7). Perhaps the best place to observe this community is on either side of the causeway where U.S. Alternate 14 crosses Bighorn Lake.

Floodplain meadows occur elsewhere along the Bighorn and Shoshone Rivers, often in areas that appear to have been flooded recently and where trees and shrubs, for whatever reason, have not yet become established. Many of the species are the same as found on the mudflats, but grasses and sedges are more common (Table 7).

Floodplain woodland. As is characteristic of many floodplains throughout the Great Plains and intermountain west, groves of cottonwoods occur commonly along the Bighorn and Shoshone Rivers. Plains cottonwood (*Populus deltoides*) is the characteristic tree throughout the Bighorn Basin, with associated tree species including peach-leaf willow (*Salix amygdaloides*), silver buffaloberry (*Shepherdia argentea*), and the introduced Russian olive (*Elaeagnus angustifolia*). A variety of shrubs, forbs and grasses are found as well (Table 7), including some that are introduced weeds, e.g., Russian knapweed (*Centaurea repens*) and saltcedar (*Tamarix chinensis*). Shrub and herbaceous plant cover is comparatively low when tree density is high, probably due to inadequate light. As discussed later, cottonwood regeneration is very rare along the Bighorn River, probably due to flow regulation at Boysen Reservoir (especially the suppression of spring floods).

TABLE 7. Some plant species found in the mudflat and riparian vegetation of the Bighorn River at the south end of the BCNRA. See Akashi (in preparation) for a more detailed analysis of the riparian vegetation along the Bighorn and Shoshone Rivers. Common names are given in Appendix C.

Mudflats

Artemisia biennis
Chenopodium berlandieri
C. glaucum
C. rubrum var. rubrum
Conyza canadensis
Halogeton glomeratus
Hordeum jubatum
Iva xanthifolia
Kochia scoparia
Melilotus sp.
Polygonum aviculare
P. lapathifolium
Potentilla paradoxa
Rorippa sinuata
Rumex maritimus
R. stenophyllus
Sonchus asper
Spergularia marina
Suckleya suckleyana
Tamarix chinensis

Floodplain shrubland

Shrubs
Artemisia tridentata
Chrysothamnus nauseosus
Ribes aureum
Rhus trilobata
Rosa woodsii
Salix exigua
Sarcobatus vermiculatus
Symphoricarpos occidentalis
Tamarix chinensis

Grasses and forbs
(See woodlands list)

Floodplain woodland

Trees
Populus deltoides
Salix amygdaloides
Elaeagnus angustifolia

Shrubs
Artemisia tridentata
Chrysothamnus nauseosus
Rhus trilobata
Salix exigua
Symphoricarpos occidentalis

Forbs
Artemisia ludoviciana var. latiloba
Asclepia speciosa
Apocynum cannabinum
Cardaria pubescens
Centaurea repens
Chenopodium berlandieri
C. fremontii
Cirsium arvense
Clematis ligusticifolia
Equisetum laevigatum
Glycyrrhiza lepidota
Halogeton glomeratus
Iva axillaris
Kochia scoparia
Medicago sativa
Psoralea lanceolata
Salsola kali

Grasses and sedges
Agropyron repens
A. spicatum
Bromus inermis
Hordeum jubatum
Oryzopsis hymenoides

TABLE 7 (continued).

Floodplain meadow

Forbs
Artemisia biennis
Atriplex heterosperma
Chenopodium album
C. glaucum
C. rubrum
Cirsium arvense
Clematis ligusticifolia
Halogeton glomeratus
Helianthus annus
Kochia scoparia
Medicago sativa
Plantago major
Potentilla paradoxa
Rorippa sinuata
R. triangulivalvis
Xanthium strumarium

Grasses and sedges
Agropyron elongatum
Beckmannia syzigachne
Hordeum jubatum
Muhlenbergia asperifolia
Phalaris arundinacea
Puccinellia nuttalliana
Scirpus acutus
S. maritimus
S. pungens
Sporobolus airoides

Shoreline and riverbank

Forbs
Artemisia biennis
Asclepias speciosa
Bidens cernua
Chenopodium berlandieri
C. glaucum
Cirsium arvense
Cleome lutea
Conyza canadensis
Euphorbia glyptosperma
Glycyrrhiza lepidota

Shoreline and riverbank (cont'd)

Forbs (cont'd)
Gnaphalium palustre
Helianthus annus
Lycopus asper
Melilotus sp.
Oenothera depressa
Plantago major
Polanisia trachysperma
Polygonum aviculare
P. spathifolium
Potentilla paradoxa
Ranunculus cymbalaria
Rumex maritimus
Rorippa curvipes
Salsola kali
Sisymbrium loeselii
Sphaerophysa salsula
Trifolium pratense
Verbena bracteata
Veronica anagallis-aquatica
Xanthium strumarium

Grasses, rushes, and sedges
Agropyron elongatum
A. repens
Agrostis alba
Carex lanuginosa
Distichlis stricta
Echinochloa muricata
Eleocharis palustris
Elymus canadensis
Hordeum jubatum
Juncus compressus
J. tenuis var. dudleyi
J. torreyi
Phalaris arundinacea
Polypogon monspeliensis
Scirpus maritimus
S. pungens

Floodplain shrubland. Interspersed in the floodplain woodlands are openings dominated by various species of tall shrubs. Two of the most common dominants are skunkbush and saltcedar, but associated species may include rabbitbrush (*Chrysothamnus nauseosus*), greasewood, snowberry (*Symphoricarpos occidentalis*), basin big sagebrush (*Artemesia tridentata* ssp. *tridentata),* wild rose (*Rosa woodsii*), narrow-leaf willow *(Salix exigua*), and a variety of forbs and grasses (Table 7). The abrupt transitions from woodland to shrubland, together with abundant evidence of fire-scarred trees, suggest that fire has played an important role in shaping the floodplain mosaic.

Saltcedar, an introduced shrub that escaped cultivation in the 1870's, forms a prominent type of floodplain shrubland in the southern part of the BCNRA. Viewed as a weed of little value, it is well adapted to the mudflats created by the fluctuating water levels of Bighorn Lake in the relatively warm Big Horn Basin and, like cottonwood and willow, it produces thousands of small, plumed seeds that germinate soon after dispersal. Saltcedar roots grow rapidly, up to 30 inches in the first year (Merkel and Hopkins 1957). Campbell and Dick-Peddie (1964) found that areas in New Mexico that are flooded sometime during the growing season have more saltcedar than those that are flooded only in the spring. Thus, reservoir management creates a favorable environment for saltcedar. The shrub is well-adapted to saline environments and, in fact, it appears to hasten surface soil salinization by salt secretion through salt glands on the leaves. Control is very difficult but may be best accomplished through a combination of burning and herbicides (Evans et al. 1981). Saltcedar eradication is discussed frequently, but managers should determine the plant species that are likely to grow in its place on the reservoir mudflats.

General Discussion

As a summary figure that may be useful in conjunction with our vegetation map, Fig. 9 shows the distribution of the different BCNRA vegetation types in relation to elevation and our current perception of water availability. Elevation is not an environmental factor, but it represents a complex gradient involving changes in various factors including temperature and precipitation. Similarly, water availability is a function of soil characteristics such as depth, texture, and infiltration rate as well as precipitation. Neither elevation nor water availability are expressed quantitatively in Fig. 9, primarily because 1) topographic position or aspect can override the effect of elevation, and 2) estimating actual water availability requires more intensive measurements than we were able to make in the time available, especially considering that the water in fractured bedrock reservoirs probably is impossible to estimate. Our hypothesis that juniper and mountain mahogany occur on fractured bedrock because it is a relatively mesic environment, as discussed previously, led us to consider juniper/mountain mahogany woodlands as having more available water than sagebrush steppe and the grasslands. Further research is necessary to determine if this contention is justified.

Considering vegetation distribution in relation to elevation and estimated water availability is useful, but temperature inversions, the probability of late spring or early fall frosts, snow accumulation patterns, soil salinity, fire frequency, flooding frequency, depth to groundwater, and grazing intensity may be important also. Some factors are more important in certain vegetation types, and further study would identify still others that are important in causing the rich diversity of vegetation in the area.

At the outset we had hoped to observe correlations between geologic substrata and different types of vegetation. Except for the shales, siltstones, and alluvium at the lower elevations toward the south end, which were characterized by desert shrublands, we could not identify any species or community types that were restricted to certain rock types. Of course, the shallow soils that characterize the juniper/mountain mahogany woodlands are a reflection of the resistant nature of certain

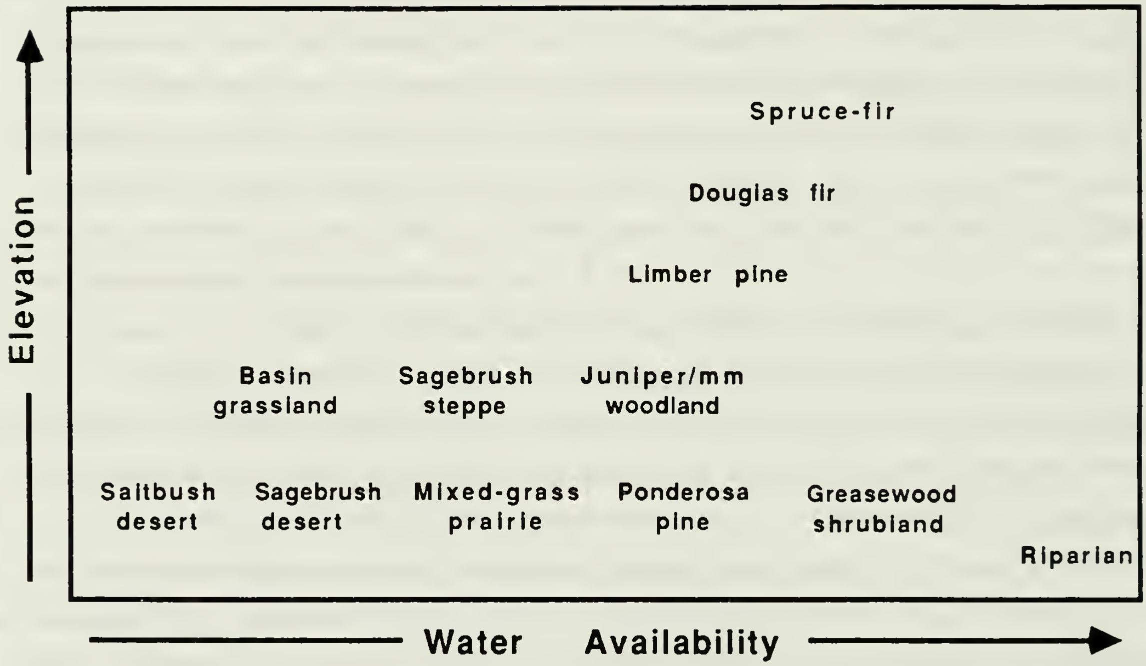

Fig. 9. The hypothesized relationships between water availability, elevation, and the major vegetation types of the BCNRA. The elevation gradient extends from approximately 1100 to 2600 m (3630 to 8580 ft). See text for explanation.

formations, but this community was found on several formations and bedrock types (Table 3). More important seems to be the development of colluvium or a soil more than a few centimeters deep, which depends as much on topographic position and slope as on the weathering and chemical characteristics of the bedrock. We still suspect that certain plant species are restricted to certain bedrock types in the BCNRA, but more field work is necessary to justify this contention.

We anticipated that the saltbush desert shrubland would have soils with a higher pH and conductivity than any of the other vegetation types. While this seems to be true to some extent (Table 3), there was no consistent correlation. Others have had similar results. It should be noted, however, that we determined conductivity only for the surface soil; subsoil characteristics may be more important for differentiating desert shrublands. The arid climate of the Big Horn Basin surely is one factor that accounts for the presence of saltbush desert shrublands, but more detailed soil analyses probably would identify a geologic cause for the high salinity and alkalinity that often exists in such areas. One conclusion from our study is that geologic and edaphic causes for vegetation patterns in the foothills are not as easy to prove as some may think.

Infiltration rate is an edaphic characteristic that we did not measure, but one which seems intuitively important in areas such as the BCNRA. Nichols (1964) found dramatic differences in infiltration rates of several communities in the Big Horn Basin (Figs. 4 and 5), with saltbush desert shrubland having the lowest -- probably due to the bentonite that tends to characterize these soils. Aridity is accentuated by low infiltration rates because the water remains near the surface where it evaporates readily. Low infiltration, more than salinity, may determine the distribution of desert shrublands. In contrast, high infiltration rates allow water to be stored at greater depths where evaporation is much slower. As noted by Noy-Meir (1973) and Sala et al. (in press), coarse-textured soils may provide more water to plants in semi-arid climates than finer-textured soils with a higher water-holding capacity but a lower infiltration rate. Of course, the volume of soil for water storage is important also.

Groundwater availability creates special circumstances that diversify the vegetation mosaic in semi-arid regions. In particular, riparian vegetation and greasewood shrubland are more common. Productivity is higher due to less plant water stress during the year, which enhances the possibility of fuel accumulation for fires as well as heavy grazing. More water leads to more evaporation and salt accumulation, which becomes especially important in greasewood shrublands that do not benefit as often from the periodic flushing of salts by floodwaters, such as occurs in the riparian zones. Soils can become very saline in greasewood shrublands located in depressions. Interestingly, greasewood also occurs in upland situations that appear to be well above groundwater, often growing with sagebrush. Such situations might be characterized by a perched water table or a subsoil that fringes on an aquifer.

With higher elevation there is the possibility of more frequent rain or snow and less evapotranspiration, due to cooler temperatures. Plant cover increases and tall shrub or tree survival is enhanced. Coniferous woodlands become more frequent, especially in deep ravines or on northerly slopes at the lower elevations. Snow accumulation patterns may play a role, as water input from snow could have a different effect than input by rain; snow accumulates from one storm to the next, with little evaporation between storms. When the snow melts, there potentially is a larger input to the soil so that water percolates deeper and is stored more effectively for plant use. In contrast, rains occur when air and soil are warmer, evaporation begins immediately after the rain stops, and the chances of deep infiltration are less. Thus, snow distribution patterns probably interact with cooler temperatures, higher annual precipitation, and perhaps fractured-bedrock reservoirs in creating conditions favorable for tree growth. Spruce-fir forests are found on the coolest, most mesic sites on the north side of East Pryor Mountain, but at about the same elevation as, or slightly higher than, Douglas fir woodlands. Douglas fir and limber pine seem to have a higher tolerance for drier conditions. Ponderosa pine woodlands occur at low elevations, but only on the north end of the BCNRA where spring and summer precipitation is considerably higher than toward the south. All of the coniferous woodlands probably have less water available than the riparian communities.

In sum, our rationale for placing the different vegetation types in Fig. 9 can be stated as follows (in order of hypothesized water availability):

Saltbush desert shrubland	Deep, saline soils with high water-holding capacity, but low infiltration rate and low annual precipitation; no groundwater available.
Basin grassland	Shallow soils and low precipitation; no groundwater available
Sagebrush desert shrubland	Deeper soils than basin grassland and with higher infiltration capacity, but low precipitation and no groundwater available.
Mixed-grass prairie	Shallow soils with low water-holding capacity, but high infiltration rate and relatively high growing season precipitation; no groundwater available.
Sagebrush steppe	Deeper soils, somewhat cooler due to slightly higher elevations, and, perhaps, snow being a larger percentage of the annual precipitation; no groundwater available, but relatively high infiltration rate.
Juniper/mountain mahogany	Soils very shallow or non-existent, but with fractured bedrock into which snowmelt and rainfall is funneled; no

	groundwater. Water availability may be about the same as sagebrush steppe.
Ponderosa pine woodland	Shallow soils, but with relatively high growing-season precipitation; no groundwater available, but roots may benefit by fractured bedrock near the surface, thereby providing more available water than in the adjacent mixed-grass prairie.
Coniferous woodlands	Shallow soils but occur at higher elevations where evaporation stress is lower and where snowmelt may lead to substantial inputs during the spring; no groundwater available, but fractured bedrock may compensate for shallow soils.
Greasewood Shrubland	Deep soils with high water-holding capacity and the availability of groundwater during at least part of the growing season.
Riparian vegetation	Deep soils, though sometimes coarse; groundwater available during much of the growing season.

This rationale must be viewed as a hypothesis or an approximation, but it is supported to some degree by our observations and those of others (as discussed previously under the heading of each vegetation type). Regrettably, testing the inverse texture effect for fractured bedrock will be difficult.

Vegetation dynamics. As described in the Introduction, the area now known as the BCNRA was once characterized by forests dominated by trees that no longer occur in the region. Millions of years have passed since then, but change continues. Thinking in terms of millions or thousands of years may not be helpful to resource managers, but the BCNRA vegetation is changing on a shorter time scale as well. The relative abundance of sagebrush steppe and basin grasslands could be increasing or decreasing, depending on livestock grazing, the development of steppe flamability, and the periodicity of fire. Utah juniper could be invading sagebrush steppes or basin grasslands for the same reasons, and ponderosa pine woodlands could be invading the northern grasslands. In the riparian zone, some tracts of floodplain woodlands could change to floodplain shrublands within the next decade, for reasons discussed previously. Insects or disease could change Douglas fir woodland to limber pine woodland. Such changes are natural and can be expected.

However, the vegetation mosaic of any area depends on environmental factors as well as rates of invasion and disturbances. With the exception of the riparian vegetation, the mosaic in the BCNRA seems to be due more to environmental factors than disturbances. For example, most coniferous woodlands occur in special topographic situations, and the desert shrublands generally occur on dry, often saline soils. Disturbances will occur in these types of vegetation, but shifts in their boundaries will be minor because the dominant plants usually cannot survive elsewhere. Changes could be occurring due to invasions by sagebrush, juniper, or coniferous trees, but, on the other hand, these species lack the ability to sprout and their expansion rate could be limited by fires as well as the abrupt environmental gradients that occur over much of the BCNRA. It is our impression that the BCNRA upland mosaic is relatively stable because it is determined primarily by environmental gradients. In contrast, the riparian vegetation mosaic along the Bighorn and Shoshone Rivers is quite dynamic.

The shifting floodplain mosaic. A complex and shifting vegetation mosaic occurs on the floodplains of the BCNRA, caused by flooding, shifting channels, fluctuating water levels, saltcedar invasion, grazing, cultivation, and fire. The rapid change has become apparent through our analysis of aerial photos taken of the Bighorn River in 1938, 1944, 1954, 1961, 1967, 1979, and 1981. Some of the woodlands, shrublands, and meadows are in different locations today than they were 50 years ago, undoubtedley due to a variety of interacting factors. For example, rates of plant growth are higher in the riparian zone than anywhere else in the region, which allows for the rapid accumulation of fuels and an abundant supply of livestock forage. Grazing probably reduces the amount of fine herbaceous fuels, thereby diminishing the probability of the next fire. However, it is conceivable that grazing has led to increased shrub cover. There is also some evidence to suggest that woodlands may be converted to shrublands by fire, with the net effect of both grazing and woodland fire possibly being an increase in the area dominated by shrubs. Shrublands develop large amounts of fine fuel also, but the fuels are more woody and are not affected as much by livestock grazing. Further research is needed to determine if shrublands are becoming more common and if hotter fires can be expected in the riparian zone because of increased aerial coverage of shrublands.

Superimposed on the interactions of fire and grazing is the effect of flood control which has led to much less channel shifting. Our study of the aerial photo sequence suggests that the Bighorn River channel is more static now than it was prior to intensive flow management (Akashi, in preparation). A major consequence may be much less cottonwood regeneration (Johnson et al. 1976, Fenner et al. 1985, Bradley and Smith 1986). The lack of cottonwood seedlings in other areas has been attributed to the lack of spring floodwaters, when the cottonwood seed is dispersed, or, as suggested by Fenner et al. (1985), the occurrence of summer floods that wash away delicate seedlings. Just as fire suppression has led to changes in nearby National Forests, flood suppression could be leading to changes in the BCNRA riparian zone.

Cottonwoods are relatively short-lived trees and the extremely hot fires that seem imminent in the adjacent shrublands could spread into the woodlands, possibly hastening their demise. Beaver kill cottonwoods also, but probably at a rate that would be inconsequential if natural regeneration occurred over a sufficiently large area. The suggestion that cottonwood groves are covering less area is supported by a conclusion reached in the Bighorn River Management Plan, prepared by the Wyoming Game and Fish Department (Weynand et al. 1979). This report states, "A comparison of aerial photographs taken in 1954 with photographs from 1975 shows a definite trend toward a loss of the riparian type, with an even more pronounced decrease in cottonwood overstory." Of course, the utilization of riparian habitats for agricultural purposes is another possible cause.

Interestingly, the situation along the Shoshone River seems to be different than along the Bighorn River. The Shoshone is a braided stream, whereas the Bighorn River is a more gentle meandering stream. Some observers think that cottonwood seedlings are more common along the Shoshone because of the impression that flooding there is more common. Further research is necessary to validate this contention.

Our understanding of vegetation dynamics along the BCNRA floodplains is developing, but the above discussion should be viewed as tentative. One of us, Yoshiko Akashi, is conducting a study on riparian vegetation dynamics in the BCNRA; her report will be available in the spring of 1988 and it should set the stage for new discussions on riparian ecology and management.

Vegetation adjacent to the BCNRA. The boundaries of parks, national forests, and other special use areas are established to a large degree on the basis of social, legal, economic, and political expediency. Resource managers know, however, that features outside the boundary often influence the ecology and management of the area inside. Animals migrate across the boundary and land-use practices on the outside can affect the inside. With this in mind, we included on our vegetation map an area up to a mile or so beyond the BCNRA boundary. Examining three separate sections of our map, we asked, "What is the effect on the vegetation mosaic of including the area mapped outside of the BCNRA?" With one exception, the percentage area occupied by the different vegetation types changed very little, indicating that the mosaic remained about the same (Table 8). The exception was near the south end, where much of the BCNRA boundary occurs in the riparian zone. Adjacent land area is mostly desert shrubland. Therefore, including the adjacent land reduced the proportion of riparian vegetation and increased the proportion of desert shrubland (Table 8).

TABLE 8. An illustration of the effect on the vegetation mosaic of including land area up to one mile outside of the BCNRA boundary. The numbers are percent of land area occupied by the vegetation types listed, and the names at the top are for the three sections (USGS topographic quads) used for the analysis. The term "inside only" refers to the vegetation mosaic within the BCNRA boundary; and "with buffer" refers to the vegetation mosaic of the BCNRA plus the adjacent land area. The numbers do not add to 100 percent because not all of the less common vegetation types are included.

	Kane		**Natural Trap Cave**		**Dead Indian Hill**	
Vegetation type	Inside only	With buffer	Inside only	With buffer	Inside only	With buffer
Marsh	10	2				
Riparian vegetation	68	30				
Desert shrubland	8	50				
Juniper woodland			42	52		
Desert shrubland			25	26		
Riparian vegetation			24	7		
Sagebrush steppe					51	56
Juniper woodland					27	27

The implications of inside/outside differences in vegetation patterns are not fully understood, but they surely extend beyond the common observation that the animals of adjacent semi-arid uplands depend to a large extent on more mesic riparian lowlands. Further study on the significance of adjacent land areas may be especially important for long, narrow management units such as the BCNRA, where the ratio between boundary length and inside area is very high. The ecological implications of "edge effects" and different mosaics is one of the unifying themes of "landscape ecology", a somewhat new discipline that could be helpful in managing the units of the National Park System where mosaics are changing for whatever reason (Forman and Godron 1986, Knight 1987, Urban et al. 1987).

Weed distribution. Preventing weed invasion is a common but difficult goal in the National Park System. Vectors for seed dispersal from nearby weed patches include people, domestic and native animals, water flow, and wind. Though parks, monuments, and recreation areas are usually managed for their natural values, suitable sites for weed establishment still exist, especially along roads and reservoirs where human-caused disturbances seem unavoidable. The BCNRA has both, with the mudflats created by fluctuating reservoir levels providing an extensive environment for the invasion of many species. Furthermore, because a variety of upland birds and mammals spend part of their time near these mudflats, they are providing a ready means for seed dispersal into the surrounding area.

Of the weedy species that have been found or reported in the BCNRA, the following have been designated in Wyoming as noxious weeds (Steve Miller, personal communication):

Field bindweed (*Convolvulus arvense*)
Canada thistle (*Cirsium arvense*)
Leafy spurge (*Euphorbia esula*)
Russian knapweed (*Centaurea repens*)
Hoary cress (*Cardaria draba*)

Other weedy species of concern that occur in or near the BCNRA include saltcedar (*Tamarisk chinensis*), spotted knapweed (*Centaurea maculosa*), filago (*Logfia arvensis*), musk thistle (*Carduus nutans*), and halogeton (*Halogeton glomeratus*). Various other introduced species may be problems in some areas, but now they sometimes are considered as naturalized. These include smooth brome (*Bromus inermis*), downy brome (*B. tectorum*), Russian thistle (*Salsola kali*), timothy (*Phleum pratense*), crested wheatgrass (*Agropyron cristatum*), intermediate wheatgrass (*A. intermedium*), sweet clover (*Melilotus* spp.), alfalfa (*Medicago sativa*), salsify (*Tragopogon dubius*), and Russian olive (*Eleagnus angustifolia*).

With the exception of the riparian zone, it is our impression that most weedy species have very restricted, localized distributions in the BCNRA at this time. The special case of saltcedar was discussed previously in the context of floodplain shrublands, and our data (Appendix A) do indicate that *Bromus tectorum* and *B. japonicus* are widespread. Where weeds do occur abundantly, they have the well-known effect of reducing, at least temporarily, the abundance of native species through competition. There is also the possibility that they increase flammability and/or fire frequency.

Using vegetation data for BCNRA management. With this report we have provided a vegetation map and some data on the nature of BCNRA vegetation. Furthermore, we have tried to synthesize our results with the literature that seems relevant to vegetation ecology in the BCNRA, so that teaching, future research, and resource management can be done with greater insight and wisdom. More specifically, the results of our research could be helpful in the following ways:

1. Developing educational programs for the public; the BCNRA is more than a beautiful canyon with good fishing and nearby herds of wild horses and bighorn sheep.

2. Developing or improving management plans for the riparian zone, which is more susceptible to change and more impacted by human activity than any other vegetation type.

3. Monitoring changes in weed distribution, perhaps by noting

periodically the location of current populations on a copy of the vegetation map. Specific weedy species will be found more frequently in certain vegetation types; the potential for their expansion could soon become apparent.

4. The species composition of much of the lowland BCNRA vegetation in 1986 is now known. Such information can be used for comparing BCNRA resources to those elsewhere and for monitoring changes in BCNRA vegetation through time. Determining the relevancy of new literature can be done more easily.

5. There may be reasons for increasing or reducing the population size of certain animals, whether native or domesticated. Each species probably will use a certain group of vegetation types for habitat, each of which is now mapped. The actual habitat available for specific species can be calculated more easily, especially if enough is known about the behavior of the species being considered. Carrying capacity can be estimated with greater confidence. Monitoring and searching for rare and endangered species could be facilitated if their presence is associated with specific vegetation types.

6. As more is learned about the requirements of certain BCNRA animals, or as management objectives are modified, there may be some basis for modifying the existing vegetation mosaic. Understanding the ecology of the plant species will help in deciding what is feasible.

7. In the event of fire, disease outbreaks, or other disturbances, there is a better basis for deciding what the consequences might be and whether control efforts are justified.

8. Establishing future research priorities can be done with greater understanding.

9. New personnel can be informed more quickly and efficiently about BCNRA plant ecology.

The unique mandate of the National Park System and the large size of many of its units provide special opportunities for the emerging discipline of landscape ecology. Traditionally, ecologists have studied small parts of the landscape, such as woodlots, remnant patches of prairie, or a single marsh -- often isolated in a matrix of agricultural land or intensively-managed forests. Studying such areas has been very fruitful in terms of understanding plant and animal adaptations, productivity, nutrient cycling, and population dynamics, but areas such as the BCNRA provide special opportunities for studying the natural mosaic. This is important ecologically because plants and animals evolved in such mosaics, not in an isolated woodlot or prairie remnant. They depend on a mosaic, not an isolated stand of forest or grassland. Questions are being asked about the factors that cause the mosaic, an old theme in ecology, but in addition questions are being asked about the significance of the mosaic to different species and ecological processes. For example, how would animal life and levels of plant productivity change if a fire eliminated sagebrush from 50 percent of the sagebrush steppe in the BCNRA? Such an event could have happened in the past and it may in the future. Would wildlife and rates of erosion be affected if cottonwood densities along the Bighorn River declined by 50 percent? What is the effect of scattered "islands" of limber pine on the animal life of the BCNRA juniper woodlands? Would wildlife populations be affected adversely if a disease killed most of the limber pine? In the vicinity of East Pryor Mountain, is the plant and animal life in the juniper woodland below dependent on the cliffs and coniferous woodlands above?

With the availability of computer-assisted mapping, geographic information systems, and techniques such as radio-telemetry for monitoring animal movements, plus the availability of vegetation maps and a larger store of ecological information, answers to such landscape-scale questions should be possible. The results could be useful to resource managers in more agro-urban settings as well as to the managers of the more natural areas where the research is done. New research and management opportunities should emerge as we learn to think more clearly about the significance of the landscape mosaic and how it changes -- in space and time.

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Appendix A

Species composition for each stand arranged by vegetation type

Species are listed in alphabetical order and the numbers for each species are percent cover. Stand number appears at the top of each column. Specimens for most species are deposited in the herbarium at the Lovell visitor center. See Appendix C for common names of the species listed in these tables.

Greasewood desert shrubland

Species	Stand number 17
Artemisia tridentata	2.0
Atriplex canescens	.1
A. confertifolia	.8
A. gardneri	.4
Chenopodium pratericola	.1
Chrysothamnus viscidiflorus	.7
Descurainia pinnata	.2
Grayia spinosa	.3
Halogeton glomeratus	8.0
Ipomopsis pumila	.1
Iva axillaris	.1
Opuntia polyacantha	.2
Sarcobatus vermiculatus	20.5
Sphaeralcea coccinea	4.3

Saltbush desert shrubland

Species	Stand number 1	3	16	18	19
Abronia fragrans		.1			
Agoseris glauca					.1
Allium textile					.1
Aristida fendleriana	.4				
Artemisia frigida				.4	
A. spinescens	3.1	2.9	.1		.1
A. tridentata	.4	.1	.1		5.1
Astragalus gracilis				.1	
Atriplex gardneri	3.3	2.6	26.9	18.5	6.7
Camissonia scapoidea			.1	.1	
Castilleja sp.	.1				
Chenopodium fremontii			.1		
Chrysothamnus nauseosus			.6		.2
C. viscidiflorus					.1
Cleome serrulata					.1
Cryptantha flavoculata		.1			
Descurainia pinnata					.1
D. richardsonii				.1	
Erysimum inconspicuum				.1	
Gutierrezia sarothrae		1.0			.1
Halogeton glomeratus			.1	.2	
Helianthus petiolaris			.1		.1
Lappula redowskii			.1		.1
Lepidium densiflorum	.1		.2		.2
Lupinus pusillus					.1
Machaeranthera canescens					.1
M. grindelioides		.2			
M. tanacetifolia	.9	.2			
Monolepis nuttalliana			.2		
Opuntia polyacantha	1.6	2.0	.1	.1	.1
Orobanche fasciculata					.1
Oryzopsis hymenoides	1.6	.8	.1	.4	.3
Pediocactus simpsonii					.1
Penstemon nitidus					.1
Phacelia glandulifera					.1
Plantago patagonica	.7	.3			
Sarcobatus vermiculatus					2.7
Sisymbrium linifolium				.1	.1
Sitanion hystrix	1.1	1.1	.1	.2	.6
Sphaeralcea coccinea	1.1	2.3			.1
Sporobolus airoides		1.4			.1
Sporobolus cryptandrus	5.4				
Stipa comata		.4			
Suaeda fruticosa				2.1	.5
S. torreyana			1.9		
Tetradymia spinescens					.2
Xylorhiza glabriuscula					.1
Unknowns (5)	.2	.2		.1	

Sagebrush desert shrubland

Species	Stand number 2	4	7	12	14	15	71
Abronia fragrans			.1				
A. micrantha				.1			
Agropyron spicatum					.3		
Arabis demisa					.1		
Arenaria hookeri		1.3					
Aristida fendleriana	3.1	2.1		.4			2.8
Artemisia frigida				.1			
A. nova					.1		
A. spinescens	.1	.3					4.6
A. tridentata	8.2	7.0	4.2	12.6	7.1	10.3	.1
Astragalus geyeri				.3			
A. gracilis			.				
A. oreganus			.1	1.0	.9	.8	
Atriplex canescens		.2		.2			
A. confertifolia	.1		.2	.1	.8	.2	.9
A. gardneri	.4					.5	
Bouteloua gracilis		.5					1.1
Ceratoides lanata		.3		.3	.4	.1	.1
Chaenactis douglasii			.1			.1	
Chenopodium berlanderi	.1						
C. pratericola				.1			
Chrysothamnus nauseosus			5.0		.7	1.2	
C. viscidiflorus			1.2	.1		.4	
Comandra umbellata			.1			.1	
Cryptantha caespitosa			.1				
C. kelseyana				.1			
Cymopterus acaulis		.1	.1			.1	
Descurainia pinnata	.1				.1		
Distichlis stricta			3.2	.4	.1	.2	
Eriogonum brevicaule		.3	.4		.3	.1	
E. cernuum				.2			
Euphorbia glyptosperma	.1						
E. missurica				1.0			
Gaura coccinea		.3			.1		
Gutierrezia sarothrae	.1	.3		.1	.6	.5	.1
Helianthus petiolaris				.1			
Hymenopappus filifolius	.1	.1		.1	.3	.1	
Hymenoxys acaulis		.4					
Ipomopsis pumila	.1			.1			
Lappula redowskii					.1		
Lepidium densiflorum	.1			.7	.1		
Lesquerella arenosa						.1	
Machaeranthera grindelioides		.3		.1		.1	
M. tanacetifolium	.1						
Oenothera albicaulis				.1			
Opuntia polyacantha	1.1	.3	.1	.2	.1	.2	2.1

continued

Sagebrush desert shrubland (continued)

Species	Stand number 2	4	7	12	14	15	71
continued							
Oryzopsis hymenoides	.8	.4	1.2	.9	.3	1.4	.3
Oxytropis besseyi	.1			.1	.2	.1	
Penstemon nitidus		.1	.1				
P. sp.					.1		
Petalostemum occidentale			.1		.1		
Phlox bryoides						.5	
P. hoodii		.2					
Psoralea lanceolata						.1	
Sisymbrium linifolium					.1		
Sitanion hystrix	.5	.3	.2	.1		.1	2.8
Sphaeralcea coccinea	.8	.9	.2	.2	.1	.1	1.4
Sporobolus airoides	4.2		.1				
Stephanomeria runcinata						.1	
Stipa comata		4.1	1.3	6.2	2.8	1.0	
Streptanthella longirostris			.2	.1			
Thlaspi arvense			.1				
Townsendia incana		.1					
Tragopogon dubius			.1				
Unknowns (8)			.9				

Mixed desert shrubland

Species	Stand number 8	10	11
Agropyron spicatum		5.1	
Arenaria hookeri		.6	2.2
Aristida fendleriana		.6	3.3
Artemisia campestris			.1
A. dracunculus		.1	
A. frigida			.2
A. tridentata	5.4	13.5	5.0
Astragalus oreganus		.5	
Atriplex confertifolia	.2	.5	.1
A. gardneri	.4		
Bouteloua gracilis		.2	
Chaenactis douglassii	.1		
Chrysothamnus nauseosus	1.5	1.2	1.1
C. viscidiflorus	.2	.1	
Comandra umbellata	.2		
Cryptantha caespitosa		.1	
C. celosioides	.1	.1	
C. kelseyana	.2		
Cymopterus acaulis	.1		
Eriogonum annum			.1
E. brevicaule	1.1	.1	
Gutierrezia sarothrae	.4	.6	.9
Halogeton glomeratus		.1	.1
Hymenopappus filifolius		.1	
Hymenoxys acaulis		.1	
Ipomopsis spicata		.1	
Juniperus osteosperma		.1	
Lappula redowskii	.1	.1	
Leptodactylon pungens		.1	
Lesquerella sp.		.2	
Machaeranthera grindelioides			.1
Opuntia polyacantha	.3	.2	.5
Orobanche fasciculata		.1	
Oryzopsis hymenoides	.1		1.0
Penstemon nitidus			.1
Penstemon sp.			.1
Physaria didymocarpa			.1
Platyschkuhria integrifolia			.6
Poa scabrella		.1	
Sarcobatus vermiculatus		.1	
Sitanion hystrix	.1	.1	
Sphaeralcea coccinea			.1
Sporobolus airoides		.1	
Stanleya pinnata		.1	
Stephanomeria runcinata	.1	.1	
Stipa comata	.2	3.5	2.4
Streptanthella longirostris	.1	.1	
Unknowns (1)	.2		

Sagebrush steppe

Species	Stand number 35	37	43	51	52	53	54
Achillea millefolium					.2	.1	
Agoseris glauca							
Agropyron smithii			.1		.2	.1	.1
A. spicatum	4.2	13.6		1.1	3.5	4.2	5.0
Allium geyeri	.1		.1		.1	.1	
A. textile							
Alyssum alyssoides						.1	
Antennaria corymbosa					.2	.2	
Arabis demisa				.1			
Arenaria congesta					.1	.4	
A. hookeri	1.1	1.0		.2	.1	.1	.7
A. sp.							
Aristida fendleriana	.1			.5			
Artemisia cana							.1
A. frigida	.4	1.0		.3	.3	.3	.1
A. ludoviciana					.1	.1	
A. nova					.1	20.1	20.3
A. tridentata	11.8	7.0	10.2	10.7	25.0	.2	.2
Astragalus adsurgens					4.0	.7	
A. gracilis			.1				
A. lagopus							
A. lotiflorus			.1				
A. missouriensis							
A. purshii							
A. spatulatus							
Atriplex confertifolia		.2	.1				
A. gardneri	.1						
Balsamorrhiza sagitata					8.4	.1	
Bouteloua gracilis	18.9		24.0	11.3		.4	3.0
Bromus commutatus					4.5	.8	
B. inermis				.1			1.4
B. japonicus							
B. tectorum					1.1	.1	
Calochortus nuttallii	.1						.1
C. sp.					.1		
Camelina microcarpa					.1		.2
Campanula rotundifolia						.1	
Carex filifolia			11.8		1.2	9.6	6.7
Castilleja angustifolia		.1		.1			
C. chromosa							
C. sessiliflora	.1						
C. sp.		.1	.1			.1	
Cerastium arvense					1.4		
Ceratoides lanata	.1			.2			
Chenopodium berlandieri				.1			
C. leptophyllum		.1					
C. pratericola			.1				

continued

Sagebrush steppe (continued)

Species	35	37	43	51	52	53	54
continued							
Chrysothamnus nauseosus					.1	.1	.1
C. viscidiflorus						.2	
Collinsia parviflora							
Comandra umbellata	.1				.6	.4	.1
Conium maculatum							
Crepis acuminata	.1				.7	.1	
Cryptantha celosioides	.1	.1		.3			
Delphinium bicolor						.1	
Delphinium sp.							
Descurainia pinnata	.1						
D. richardsonii	.1	.3					
Draba reptans		.1					
D. sp.				.1			
Erigeron caespitosus	.1					.7	
E. corymbosus					.1		
E. ochroleucus						.1	
E. pumilus	.1						.1
E. sp.					.1	.1	.1
Eriogonum brevicaule	.1	.1					
E. flavum							
E. pauciflorum							
E. umbellatum						.1	
Erysimum inconspicuum	.1						
Euphorbia sp.							
Festuca idahoensis					2.7		
F. octoflora				.2			
Gaura coccinea					.1	.2	.2
G. sp.							
Geum triflorum					.1	.1	
Glycyrrhiza lepidota							
Gutierrezia sarothrae	1.7	1.9	3.3	.8	.3	2.9	2.0
Hackelia deflexa			.1				
Haplopappus aremerioides							
Hedeoma drummondii							
Heterotheca villosa						.1	
Hymenopappus filifolius	.1			.1			
Hymenoxys acaulis						.3	.3
Ipomopsis spicata	.1						
Juniperus horizontalis					.2		
J. osteosperma		.3				.8	.6
J. scopulorum					.4	1.2	
Koeleria macrantha		.1			4.7	7.2	9.3
Lappula redowskii	.1	.1	.1	.1			
Lepidium densiflorum	.5		.6	.3		.1	
Lesquerella alpina		.3					
L. sp.	.2						.1

Stand number

continued

Species	Stand number 35	37	43	51	52	53	54
continued							
Leucopoa kingii					.2		
Lewisia rediviva							
Liatris punctata					.1	.1	
Linum lewisii					.1	.1	
L. rigidum							
Lithospermum ruderale					.1	.1	
Lomatium sp.		.2		.1			
Lupinus sp.					2.6		
Lygodesmia juncea						.1	
L. runcinata							
Machaeranthera grindelioides				.1			
Mentzelia albicaulis							
Musineon divaricatum						.1	
Opuntia polyacantha	1.0	.3	1.8	2.2		.1	
Orobanche fasciculata	.1						
Oryzopsis hymenoides	.1						
Osmorrhiza lepidota					.1		
Oxytropis campestris						.1	
O. lagopus					3.9	.1	
Paronychia sessiliflora	.1	.4				.1	
Pediocactus simpsonii	.1					.1	
Penstemon eriantherus	.1	.1					.1
P. laricifolius							.1
P. sp.						.1	
Petalostemon occidentale					.1	.1	.1
P. purpureum							.4
Phlox hoodii	.8	3.9		.1	1.4	2.9	1.1
Physaria didymocarpa							
Physocarpus monogynus				.1			
Pinus flexilis					.1		
Plantago patagonica			.2				
Poa cusickii					.2		
P. pratensis							.1
P. sandbergii					3.5	1.6	
P. scabrella		1.0	3.0				
P. sp.	1.7			.8			1.7
Prunus americana					.1	.1	
Ranunculus cymbalaria						.1	
Rhus trilobata					.1	.1	.1
Rosa woodsii							
Sedum lanceolatum							
Selaginella densa					10.5		
Senecio canus	.1	.1				.1	
Senecio sp.	.1	.2				.1	

continued

Sagebrush steppe (continued)

Species	Stand number 35	37	43	51	52	53	54
continued							
Sitanion hystrix	.5		.5	.2			
Solidago missouriensis						.1	
S. sp.							
Sphaeralcea coccinea				.2		.1	.1
Stephanomeria runcinata						.1	.1
S. tenuifolia			.1				.1
Stipa comata	7.3	1.6	1.3	4.6	.4	.5	1.1
S. viridula						.2	
Streptanthella longirostris	.1						
Symphoricarpos albus							.1
Taraxacum laevigatum						.1	
Taraxacum sp.		.1					
Tragopogon dubius	.1				.1	.1	.1
T. sp.							
Viola nuttallii							
Yucca glauca	.1					.1	
Zygadenus venenosus							
Unknowns							

Sagebrush steppe (continued)

Species	Stand number (continued)						
	55	56	59	62	63	64	65
Achillea millefolium							
Agoseris glauca							.1
Agropyron smithii		.1			.1		.4
A. spicatum	1.6	2.8	3.0	1.7	.1	3.1	3.4
Allium geyeri							.1
A. textile	.2						
Alyssum alyssoides							
Antennaria corymbosa	.7		.2				.1
Arabis demisa						.1	
Arenaria congesta							
A. hookeri	1.3		2.0	1.0	.9		.1
A. sp.							
Aristida fendleriana			.6			.1	
Artemisia cana							
A. frigida	.7	1.4	.1	.1	.1	.7	.1
A. ludoviciana							
A. nova	31.4	37.8	26.4	36.1	29.4	21.4	4.1
A. tridentata		.1	2.5		13.7	12.1	27.6
Astragalus adsurgens							
A. gracilis							
A. lagopus						.1	
A. lotiflorus							
A. missouriensis	.1						
A. purshii		.1		.2	.1		
A. spatulatus			.1				
Atriplex confertifolia							
A. gardneri							
Balsamorrhiza sagitata							
Bouteloua gracilis	4.2	3.5				.1	.2
Bromus commutatus							
B. inermis							
B. japonicus	.1				1.0		.1
B. tectorum							
Calochortus nuttallii	.2	.1	.1				
C. sp.							
Camelina microcarpa							
Campanula rotundifolia			.1				
Carex filifolia	5.4	8.6	.4	.2		1.6	
Castilleja angustifolia						.1	
C. chromosa	.2		.2				
C. sessiliflora	.1						
C. sp.				.1			
Cerastium arvense							
Ceratoides lanata							.1
Chenopodium berlandieri							
C. leptophyllum							.1
C. pratericola							

continued

Sagebrush steppe (continued)

Species	Stand number (continued)						
	55	56	59	62	63	64	65
continued							
Chrysothamnus nauseosus		.1					
C. viscidiflorus							
Cirsium sp.							
Collinsia parviflora					.1		
Comandra umbellata	.2	.1	.2			.6	.1
Conium maculatum		.1					
Crepis acuminata		.1	.1	.1			
Cryptantha celosioides		.1					
Delphinium bicolor	.1						
Delphinium sp.	.1						
Descurainia pinnata							
D. richardsonii							
Draba reptans							
D. sp.							
Erigeron caespitosus							
E. corymbosus							
E. ochroleucus	.8	.1	1.3	.3			
E. pumilus						.1	
E. sp.					.1		.1
Eriogonum brevicaule				.1			.1
E. flavum	.1						
E. pauciflorum			.2				
E. umbellatum							
Erysimum inconspicuum		.1					
Euphorbia sp.	.1						
Festuca idahoensis							
F. octoflora	.3						.1
Gaura coccinea	.1			.1	.1		
G. sp.	.1	.1					
Geum triflorum							
Glycyrrhiza lepidota					.1		
Gutierrezia sarothrae	2.1	2.7	2.2	2.7	1.4	2.5	2.4
Hackelia deflexa							
Haplopappus aremerioides			.1				
Hedeoma drummondii							.1
Heterotheca villosa	.1						
Hymenopappus filifolius							
Hymenoxys acaulis			1.0				
Ipomopsis spicata							
Juniperus horizontalis							
J. osteosperma			2.6		.1		.1
J. scopulorum			.1				
Koeleria macrantha	6.3	6.5	.1	7.2	2.1	4.7	2.9
Lappula redowskii							

continued

Species	Stand number (continued) 55	56	59	62	63	64	65
continued							
Lepidium densiflorum							.1
Lesquerella alpina				.6	.1	.1	
L. sp.							
Leucopoa kingii							
Lewisia rediviva	.1					.2	
Liatris punctata							.1
Linum lewisii			.1				
L. rigidum	.1						
Lithospermum ruderale							
Lomatium sp.		.5	.2	.1	.1		.2
Lupinus sp.							
Lygodesmia juncea				.2			
L. runcinata	.1				.2		
Machaeranthera grindelioides							
Mentzelia albicaulis							.1
Musineon divaricatum	.4						
Opuntia polyacantha	.1	.2		.1		.1	.4
Orobanche fasciculata	.1						.1
Oryzopsis hymenoides	.4				.1		
Osmorrhiza lepidota							
Oxytropis campestris							
O. lagopus							
Paronychia sessiliflora	.1		2.9				
Pediocactus simpsonii					.1		
Penstemon eriantherus	.1			.1	.1	.1	
P. laricifolius			1.5			.4	
P. sp.	2.2	.1		.3			.1
Petalostemon occidentale							
P. purpureum							
Phlox hoodii	1.5			2.6	1.9	.8	2.2
Physaria didymocarpa							.1
Physocarpus monogynus							
Pinus flexilis							
Plantago patagonica							.2
Poa cusickii							
P. pratensis							
P. sandbergii							
P. scabrella							
P. sp.	3.1		4.1	.9	1.8		.7
Prunus americana							
Ranunculus cymbalaria							
Rhus trilobata							
Rosa woodsii					.1		
Sedum lanceolatum	.1		.2				
Selaginella densa							
Senecio canus	.3	.1	.1	.1	.1		
Senecio sp.				.3	.1		.2
S. viridula					.1		

continued

Sagebrush steppe (continued)

Species	Stand number (continued) 55	56	59	62	63	64	65
continued							
Sitanion hystrix							
Solidago missouriensis							
S. sp.					.1		
Sphaeralcea coccinea	.1			.1	.1		
Stephanomeria runcinata							
S. tenuifolia		.1		.1			
Stipa comata	.7	.4	.1	.7		.7	1.8
Streptanthella longirostris							.1
Symphoricarpos albus							
Taraxacum laevigatum					.1		.1
Taraxacum sp.					.1		.1
Tragopogon dubius		.1			.1		.1
T. sp.	.1						
Viola nuttallii	.1						
Yucca glauca	.2		.2	.1	.1		.1
Zygadenus venenosus		.1					
Unknowns							

Mixed grass prairie

Species	Stand number 72	73	75
Achillea millefolium	1.1	.3	.1
Agropyron smithii	2.4	1.7	
A. spicatum	.2	7.2	4.6
Andropogon scoparius		.1	15.2
Apocynum sp.		.1	.3
Artemisia cana	.6		
A. frigida		.4	.1
A. longifolia	.8	.3	
A. nova			.1
A. ludoviciana	.2	.2	.1
Asclepias sp.			.1
Aster sp.	.1	.1	
Astragalus sp.	.6		
Bouteloua curtipendula		2.6	3.9
B. gracilis		1.0	.5
Bromus japonicus	3.2	2.6	.1
B. tectorum	.1	.1	
Calamovilfa longifolia		.1	
Calochortus sp.	.1	.1	.1
Camelina microcarpa		.1	
Campanula rotundifolia			.2
Carex sp.			6.2
Castilleja sp.			.7
Cercocarpus ledifolius			.1
Cirsium sp.	.1	.1	
Comandra umbellata	.2	.6	.2
Ratibida columnifera	.1	.2	
Cryptantha sp.		.1	
Descurainia pinnata		.1	
Erigeron sp.			.1
Eriogonum flavum			.1
E. sp.		.1	.3
Festuca idahoensis	.2		
Gaillardia aristata			.1
Gaura coccinea	.8	1.0	.5
Gutierrezia sarothrae		.4	.6
Heterotheca villosa	1.9	.2	.7
Juniperus horizontalis			.1
Koeleria macrantha	.4	1.7	2.2
Lactuca sp.	.1	.1	
Liatris punctata			1.7
Linum lewisii	.1		.3
Lomatium sp.		.1	.2
Lupinus sp.	.2		.1
Lygodesmia juncea	1.3	.1	
Monarda fistulosa	.1		
Oenothera sp.	.3	.1	.5
Opuntia polyacantha	.1	.1	

continued

Mixed grass prairie (continued)

Species	Stand number 72	73	75
continued			
Pediocactus simpsonii		.1	
Petalostemon occidentale		.1	
Phlox hoodii	.1	.9	3.5
Plantago patagonica	.3	.1	
Poa pratensis	18.8	.3	
P. scabrella		.8	.5
Prunus virginiana	.1	.2	
Psoralea sp.	.3	.2	.1
Echinacea pallida	.1	.3	.2
Rhus trilobata	.1	.1	
Rosa sayi	.1	.1'	
R. woodsii		.1	
Selaginella densa			1.9
Senecio canus			.1
S. sp.	.9		
Stipa comata		.9	.1
S. viridula	.6	.1	
Taraxacum sp.	.1		
Thermopsis sp.	.1		
Toxicodendron rydbergii		.3	
Tragopogon dubius	2.4	3.5	.3
Viola nuttallii		3.0	
Yucca glauca	.8		1.6
Zygadenus venenosus	.1		.1
Unknowns (15)	2.5	3.0	3.9

Basin grassland

Species	Stand number 38	39	42	45	47	58	60	70
Agropyron spicatum	8.9	12.3	4.6	7.5	3.4	7.4	7.5	12.2
Allium sp.						.1		
Arenaria hookeri	2.4	2.2		1.7	2.2		6.0	1.7
A. nuttallii	2.5				.1			
Aristida fendleriana	.3			.1				
Artemisia frigida	1.4	2.5		.1	1.2	.2	1.7	2.1
A. nova	1.4	.1	.1	.5	.2	.1	3.3	.2
A. tridentata	.1	.2	.8			1.0		
Astragalus gracilis			.2					
A. hyalinus						.1		
A. spatulatus					.1		1.1	
Atriplex confertifolia						.2		
Bouteloua gracilis	2.4	3.7	15.7	2.5				
Carex filifolia			6.1		.4	.3	4.9	6.2
Castilleja angustifolia								.1
C. chromosa					1.1			
C. sessiliflora	1.4			.3				
Ceratoides lanata		.1		.2	.1		.1	
Cercocarpus ledifolius					.1			
Chenopodium sp.					.1			
Comandra umbellata							.1	.5
Cryptantha caespitosa						1.1		
C. celosioides	.1			.6	.1			.1
C. kelseyana	.1							
C. sp.	.1	.2						
Descurainia sp.						.1		
Draba reptans								.1
Erigeron ochroleucus				.1	.6	.6	5.0	
E. pumilus	.2							1.0
E. strigosus					1.3			2.5
E. sp.		.1				.1		
Eriogonum annum	.1				.3			
E. brevicaule		.1			.7	.1	1.2	
E. caespitosa						.1	.1	
E. flavum								.3
E. sp.				.2				
E. sp.							.8	
Festuca octoflora			.1					
Gaura coccinea	.1			.1				
Gayophytum racemosa						.1		
Gutierrezia sarothrae	1.5	3.9	6.8	7.7	4.2	1.7	1.5	3.9
Heterotheca villosa			.1					
Hymenopappus filifolius	.1	.1				.2	.2	
Hymenoxys acaulis		.4					2.6	1.4
Juniperus osteosperma	.1	.1		.7	.2		1.6	
J. scopulorum							.4	
Koeleria macrantha						.3		2.0
Lappula redowskii				.1				

continued

Basin grassland (continued)

Species	Stand number 38	39	42	45	47	58	60	70
continued								
Lepidium densiflorum			.3	.2				
Lesquerella alpina	.1	1.2			1.7		1.5	.6
L. arenosa						.6		
Linum lewisii					.4	.1	.2	.1
Lithospermum incisum		.1						
Lomatium cous								.1
Machaeranthera canescens								.2
M. grindelioides		.1				.2	1.2	.1
Musineon divaricatum						.7		
Opuntia polyacantha	.6	.2	3.4	1.5		.2		
Oryzopsis hymenoides			.1					
Oxytropis besseyi						.1		
O. campestris						.5		.1
Paronychia sessiliflora	1.4			1.1	2.9		1.0	2.1
Penstemon eriantherus	.1	.1		.3				.1
P. laricifolium					1.4			
P. nitidus						.1		
P. sp.					.2	.3		
Phlox bryoides						.1		
P. hoodii	.6	3.6	.4	1.0	6.6			5.2
Pinus flexilis					.1		.8	.2
Poa sandbergii			2.0	.4				
P. scabrella	.2							
P. sp.						.3		.2
Rhus trilobata						.1		
Senecio canus	.6			.9	1.6		.4	
S. sp.						.7		
Sphaeralcea coccinea			.1	.1				
Stanleya tomentosa				.1	.1			.2
Stephanomeria runcinata						.1		
S. tenuifolia			.1					
Stipa comata		1.3	.1	4.9		1.3		
Tragopogon pratensis			.1					
Yucca glauca				.1				
Unknowns (11)	.3			.1		1.1	.8	

Windswept plateau

Species	Stand number 5	6	36
Agropyron spicatum	3.0	4.7	
Arenaria hookeri	3.1	2.8	5.3
Aristida fendleriana	1.2	.1	
Artemisia frigida		.2	.1
A. nova	.1		
A. tridentata	.8		
Astragalus spatulatus		.1	.3
Atriplex confertifolia	.1	.1	
Carex sp.			.1
Castilleja linear			.2
Ceratoides lanata	.1		
Chenopodium fremontii		.1	
Cleome serrulata	.1		
Cryptantha caespitosa		.1	
C. celosioides	.3	1.8	
C. flavoculata	1.0		
C. sp.			.1
Distichlis stricta		.1	
Erigeron ochroleucus			1.1
Eriogonum annum	.4		
E. brevicaule		.1	.2
Gaura coccinea	.1	.3	
Gutierrezia sarothrae	1.8	1.0	1.9
Hymenopappus filifolius	.5	.3	
Hymenoxys acaulis	1.2	3.9	1.9
Ipomopsis pumila	.1		
Juniperus osteosperma			.6
Lappula redowkii	.1		
Lesquerella alpina			.2
Linum lewisii			.1
Lomatium sp.	.8	.1	.1
Machaeranthera grindelioides	.6		
M. tanacetifolia		.7	
Opuntia polyacantha	.3	.1	
Oxytropus besseyi		.1	
O. sp.	.1		
Paronychia sessiliflora			6.9
Pediocactus simpsonii	.1		
Penstemon eriantherus			.1
Phlox bryoides	1.3	2.1	
P. hoodii	.1		6.4
Poa sandbergii			.1
Sisymbrium linifolium	.1		
Sphaeralcea coccinea	.1	.1	
Stanleya tomentosa			.1
Stipa comata	2.2	.1	
Wyethia scabra	.1	.1	
Unknowns (4)			1.2

Juniper woodland

Species	13	20	21	22	23	25	29	34	40	41
	Stand number									
Abronia fragrans		.1								
Agropyron spicatum		7.7	.3		1.8	.9	1.5	.6	1.3	4.9
Allium geyeri								.1		
A. sp.						.1			.1	
Arabis demisa			.1	.1	.1			.1		2.1
Arenaria hookeri	.4	2.2	.2	.1	.2	.4	1.1	.7	.5	.1
A. nuttallii										.1
Aristida fendleriana	2.8	.6		2.5	.5	.8	1.3	2.0	1.7	
Artemisia campestris										
A. frigida		.3		.1	.1			.6	.1	
A. nova	1.4		.1		.	7.9	2.1	6.9	.7	
A. spinescens										
A. tridentata		1.6	4.2		.1			1.3	.8	
Astragalus hyalinus		.1								
A. oreganus					.8					
A. spatulatus		.4	.1			.1				
A. sp.						.1				
Atriplex canescens										
A. confertifolia			.1		.3					
Bouteloua gracilis						.4		1.0	2.4	
Bromus ciliatus					.1					
B. japonicus										
B. sp.										
Cammissonia scapoidea										
Carex filifolia						3.7				
C. sp.								.6		
Castilleja angustifolia								.1		
Ceratoides lanata							.5	.5		
Cercocarpus ledifolius						1.0	3.1	.5		
Cheilanthes feei										
Chenopodium atrovirens							.1			
C. berlandieri								.1	.1	
C. fremontii				.1		.1				.1
C. leptophyllum						.1				
Chrysothamnus nauseosus			.1							
Clematis ligusticifolia									.1	
Cleome lutea					.2					
Comandra umbellata								.4		
Cryptantha celosioides	.2	.3			.1		.1	.2		
C. flavoculata				.1			.1			
C. kelseyana					.2	.2		.1		
C. sp.		.7	.6							
Cymopteris acaulis								.1		
Descurainia pinnata	.2	.3								
D. richardsonii			.3						.2	
D. sp.						.5				

continued

Juniper woodland (continued)

Species	Stand number 13	20	21	22	23	25	29	34	40	41
continued										
Draba crassifolia								.5		
D. reptans						.9	.1		.5	
Elymus cinereus				.1						
Erigeron caespitosus									.1	
E. corymbosa				.1						
E. ochroleucus		.5	.4			.1				
E. pumilus								.1		
E. strigosus						.1				
E. annum				.2			.1			
E. sp.			.1							
Eriogonum brevicaule		.1	.5	.1			.1			
E. caespitosa								.2		
E. cernuum						.3	.2		.1	
E. flavum		.2								
E. ovalifolium										
E. sp.						.1				
Euphorbia glyptosperma				.1					.1	
Festuca octoflora						.2				
Gaura coccinea	.3			.1	.1				.1	
Gilia leptomeria							.2			
Gutierrezia sarothrae	3.7	1.2	1.4	1.0	1.4	.3	.1	.7	2.3	.2
Hackelia sp.				.1						
Halogeton glomeratus				.2	.1					
Haplopappus aremerioides										
Hedeoma drummondii					.2				.1	
Heterotheca villosa										
Heuchera parvifolia										.1
Hymenopappus filfolius		1.0	.3	.1	.1	.1	.2		.1	
Hymenoxys acaulis										
Ipomopsis pumila					.1			.1		
I. spicata		.1			.1				.1	
Juniperus osteosperma	16.1	29.1	3.7	16.9	17.3	18.3	26.0	20.1	14.8	36.9
J. scopulorum										
Koeleria macrantha										
Lappula redowskii		.1			.1	.2		.1	.1	.1
Lepidium densiflorum				.1	.2	.4	.1	.2	.2	
Lesquerella alpina		.1	.4				.1	.1		
L. arenosa	.3									
L. sp.						.1				
Liatris punctata				.1						
Linum lewisii								.1		
Lithospermum parviflorum					.3	.2				
L. incisum						.1			.1	
Lomatium cous										

continued

Juniper woodland (continued)

Species	Stand number 13	20	21	22	23	25	29	34	40	41
continued										
Lygodesmia runcinata								.1		
Machaeranthera grindelioides				.1			.1		.1	
Mentzelia montana				.1		.2				
M. nuda				.1						
Mirabilis linearis									.1	
Nama densa						.1				
Opuntia polyacantha	.2		.1	.2	.2	.4	.9	1.3	1.5	.3
Orobanche fasciculata						.1				
Oryzopsis hymenoides					.4	.3	.1	.1	.1	
Oxytropis besseyi	.1									
O. campestris		.1	.1							
Paronychia sessiliflora				.1	.1	.2	26.0	1.5	.3	.1
Penstemon eriantherus		.2	.1			.1				
P. laricifolius								.2		
P. nitidus					.2					
Petalostemon occidentale	.5									
Petrophytum caespitosum									.1	
Phacelia glandulifera				.2		.6				
Phlox hoodii						.1			.6	
Physaria didymocarpa									.1	
Pinus flexilis										
Plantago patagonica									.1	
Poa cusickii										
P. sandbergii						.1			.1	
P. sp.								.3		
Psoralea lanceolata										
Rhus trilobata			.1					.1	.1	
Salsola kali				.1					.1	
Sedum lanceolatum										
Senecio canus				.1	.1					
Sisymbrium altissimum	.1						.1			
S. linifolium			.1				.2			
Sitanion hystrix						.1	.1		.1	
Solidago missouriensis								.1		
Sphaeralcea coccinea	.3		.1		.2				.2	
Stanleya pinnata				.1						
S. sp.										
Stephanomeria runcinata				.1						
S. tenuifolia										
Stipa comata				1.1	.8	.1	1.7	.7	.2	.1
Streptanthella longirostris				.1		.2				
Tanacetum capitatum						.2		.5		
Wyethia scabra				1.0						
Yucca glauca										
Zygadenus venenosus						.1			.1	
Unknowns										

Juniper woodland (continued)

Species	Stand number (continued)									
	44	46	48	49	50	57	61	66	67	74
Abronia fragrans	.5									
Agropyron spicatum	.2	2.8		6.8	3.3		3.6	3.6	7.7	2.5
Allium geyeri	.1									
A. sp.										.2
Andropogon scoparius										.1
Arabis demisa									.2	
A. sp.	.8									
Arenaria hookeri	.1	.9		1.4			.2		1.9	
A. nuttallii										
Aristida fendleriana	.4	.9	1.4	.2	1.8	1.7	.4	1.1		.1
Artemisia campestris	.1									
A. frigida		.5		.2	.4		.1		.3	
A. longifolia										.3
A. ludoviciana										.1
A. nova	7.1			.8	.5		.1	.2	10.3	
A. spinescens	.1									
A. tridentata	3.7				.1				.1	
Astragalus crassicarpus								.2		
A. hyalinus								.1		
A. oreganus										
A. spatulatus				.2						
A. sp.		.1								
Atriplex canescens				.1				.1	.1	
A. confertifolia					.8	.3				
Bouteloua curtipendula										8.7
B. gracilis	1.6	.1			4.1					.2
Bromus ciliatus										.1
B. japonicus	.1									
B. tectorum									.1	
B. sp.	.6									
Cammissonia scapoidea			.1							
Campanula rotundifolia										.1
Carex filifolia				1.3			1.3		1.1	
C. sp.										.9
Castilleja angustifolia							.1			
Ceratoides lanata				.2						
Cercocarpus ledifolius			1.0	1.8						.1
Chaenactis douglassii									.1	
Cheilanthes feei			.1							
Chenopodium atrovirens			.2				.1	.1		
. berlandieri	.1									
C. fremontii										
C. leptophyllum										
Chrysothamnus nauseosus									2.1	
Cirsium sp.								.1		
Clematis ligusticifolia										
Cleome lutea			.1							

continued

Juniper woodland (continued)

Species	Stand number (continued) 44	46	48	49	50	57	61	66	67	74
continued										
Comandra umbellata	.3							.1	.7	.1
Cryptantha celosioides	.1	.5		.3		.1	.2	.2		
C. flavoculata				.8	.1			.8		
C. kelseyana									.1	
C. sp.			.1							.1
Cymopteris acaulis										
Descurainia pinnata										
D. richardsonii		.7						.4		
D. sp.			.7				.5			
Draba crassifolia				.1						
D. reptans				.3	.2			.3		
Eleocharis sp.										.1
Elymus cinereus										
Erigeron caespitosus										
E. corymbosa										
E. ochroleucus		.2					.1	.2		
E. pumilus		.3		1.2					.1	
E. strigosus	.1			1.2	.1				.8	
E. annum				.1		.1				
E. sp.										
Eriogonum brevicaule		.2		.1				.1	1.2	
E. caespitosa							.1			
E. cernuum			.2							
E. flavum	.1			.2			.1			.1
E. ovalifolium				.1			.1			
E. pauciflorum							.1			
E. sp.										.1
Euphorbia glyptosperma	.1		1.8							
Festuca octoflora	1.1			.6						
Gaillardia sp.										.1
Gaura coccinea						.1		.2		
Gilia leptomeria			.2							
Glycyrrhiza lepidota									.1	
Gutierrezia sarothrae	1.6	1.2	.4	.9	4.0	2.1	.4	.5	3.5	3.6
Hackelia sp.										
Halogeton glomeratus										
Haplopappus aremerioides			.1				.1			
Hedeoma drummondii	.1	.1	.4					.1		
Hedysarum boreale							1.9			
Heterotheca villosa			.1							.1
Heuchera parvifolia	.1			.1						
Hymenopappus filfolius		.1		.1			.1	.2	.2	

continued

Juniper woodland (continued)

Species	Stand number (continued) 44	46	48	49	50	57	61	66	67	74
continued										
Hymenoxys acaulis				.2	.1			.1		
Ipomopsis pumila								.2		
I. spicata			.1					.1		
Juniperus horizontalis										5.1
J. osteosperma	16.4	30.3	9.6	10.1	14.3	5.4	29.1	24.9	2.7	
J. scopulorum	.9			1.2				.2	2.7	
Koeleria macrantha	1.6			.4	.1				2.7	.3
Lappula redowskii	.1		.1	.1	.1			.1		
Lepidium densiflorum	.4		.4	.1				.1	.1	
Lesquerella alpina	.1	.2		.7			.1		1.0	
L. arenosa							.1			
L. sp.							.1			
Leucopoa kingii										.3
Liatris punctata										.2
Linum lewisii				.1						.1
Lithospermum incisum		.1	.3					.1		
L. parviflorum										
Lomatium cous				.1						
Lomatium sp.									.1	.6
Lygodesmia runcinata										
Machaeranthera grindelioides							.1			
M. nuda										
Mirabilis linearis		.1								
Monotropa uniflora									.1	
O. sp.										.1
Opuntia polyacantha	2.7	.4	.1	.1	.4	.3	.1	.6	.1	
Orobanche fasciculata										
Orthocarpus luteus									.1	
Oryzopsis hymenoides	.3	.2				.6	1.1	.6		
Oxytropis besseyi			.1				.1			
O. campestris					.1	.1				
Paronychia sessiliflora	.1	.9		.1	.2			.1	.4	
Penstemon eriantherus		.1		.1		.1			.1	
P. laricifolius	.1			.1						
P. nitidus								.2		
Petalostemon occidentale							.1			
P. sp.							.1			
Petrophytum caespitosum										
Phacelia glandulifera			2.4							
Phlox hoodii				1.6			.1		.1	.1
Physaria didymocarpa			.1				.1	.1		
Pinus flexilis				.1			.1			

continued

Juniper woodland (continued)

Species	Stand number (continued) 44	46	48	49	50	57	61	66	67	74
continued										
Plantago patagonica										
Poa cusickii		.1								
P. sandbergii								.1		
P. sp.										.1
Psoralea lanceolata			.1							
P. sp.										.1
Rhus trilobata	.1					.1	.2	1.9	.1	
Ribes cereum									.1	
Salsola kali			.7		.1					
Sedum lanceolatum				.1					.2	
Selaginella densa								.1	.1	
Senecio canus		.9					.1		.2	.4
S. sp.							.1			
Sisymbrium altissimum										
S. linifolium										
Sitanion hystrix										
Solidago missouriensis									.2	
Sphaeralcea coccinea		.1				.1		.1		
Sporobolus airoides						.1				
Stanleya pinnata			.1			.1	.1		.1	
S. sp.			.1			.1	.1		.1	
Stephanomeria runcinata								.1	.1	
S. tenuifolia	.1								.1	
Stipa comata	1.8			1.2	2.9				.3	
Streptanthella longirostris			.1							
Taraxacum sp.										.2
Tanacetum capitatum										
Townsendia incana								.3		.1
Tragopogon dubius										.2
T. sp.									.1	
Wyethia scabra							.1			
Yucca glauca		.1				1.5	.1		.2	.4
Zygadenus venenosus										.1
Unknowns										

Juniper/mountain mahogany woodland

Species	Stand number 9	24	30	68
Abronia fragrans		.1		
Agropyron spicatum			.2	1.0
Allium geyeri				.1
Allium sp.				.1
Aristida fendleriana		.1	.8	.1
Artemisia nova	1.8	.1	.1	
A. tridentata	2.4			
Atriplex confertifolia	.2			
Carex filifolia				.1
C. vallicola				.4
Cercocarpus ledifolius	5.5	18.6	19.3	20.0
Chenopodium atrovirens				.1
C. berlandieri				.1
C. leptophyllum	.1			
C. sp.				.1
C. sp.				.1
Cryptantha celosioides				.1
C. flavoculata			1.3	
Cymopterus acaulis		.1		
Descurainia pinnata	.7			.1
D. richardsonii			.1	
D. sp.				.5
Draba reptans				.1
Erigeron ochroleucus		.1	.2	
E. sp.		.1		
Eriogonum cernuum			.1	.2
Euphorbia glyptosperma		.1	.1	
Festuca octoflora				.1
Gaura coccinea				.1
Gilia leptomeria	.1	.1		
Grayia spinosa	.9			
Gutierrezia sarothrae		.7	.6	.4
Halogeton glomeratus	.2			
Haplopappus aremerioides		.1		
Hedeoma drummondii				.1
Hymenopappus filifolius		.1	.1	.1
Hymenoxys sp.				.1
Ipomopsis pumila	.1			
Juniperus osteosperma	5.1	6.9	7.3	24.6
J. scopulorum		.5	.1	
Lapulla redowskii				.2
Lesquerella alpina			.1	
Lithospermum incisum			.2	.1
Machaeranthera canescens				.1
M. grindelioides			.1	

continued

Juniper/mountain mahogany woodland (continued)

Species	**Stand number** 9	24	30	68
continued				
Opuntia polyacantha				.1
Oryzopsis hymenoides				.4
Phacelia glandulifera				.1
Phlox bryoides			.2	
P. hoodii			.1	
Pinus flexilis				.1
Rhus trilobata		.1	.1	.1
Senecio canus				.1
Sitanion hystrix	.1			
Stipa comata	.1			.1
Tanacetum capitatum		.2	.8	
Zygadenus venenosus				.1
unknowns (7)		.4		.2

Species	Stand number 26	28	31	32	33
Agropyron spicatum	.1	6.5	.2	4.9	7.1
Allium geyeri	.2				
Allium sp.		.1			
Amaranthus albus				.1	
Arenaria hookeri				.1	.8
A. sp.		1.0			
Aristida fendleriana	.2		.9	.1	1.1
Artemisia frigida		.6		.1	.1
A. nova	.6				.1
Astragalus spatulatus					.1
Bromus tectorum				.1	
Calochortus				.1	
Carex filifolia	.2	.1			
C. sp.			.1		
Ceratoides lanata	.4	.5		.3	.4
Cercocarpus ledifolius	13.7	28.4	19.2	15.6	14.6
Chaenactis douglasii		.1			
Chenopodium atrovirens		.1			
C. pratericola		.1			
Chrysothamnus viscidiflorus		.2			
Comandra umbellata			.1		
Crepis acuminata		.2			
Cryptantha celosioides	.3	.1		.1	
C. flavoculata	.2		1.2	.5	1.3
Descurainia pinnata				.1	
D. richardsonii		.2			
D. sp.				.2	
Draba crassifolia					.1
D. reptans				.2	
Erigeron compositus		.1		.1	
E. linear		.1		.1	
E. ochroleucus	.1				
E. pumilus					.4
E. strigosus			.1		.6
E. sp.		.1		.1	
Eriogonum annum	.1				
E. brevicaule		.1			
E. flavum		.1			
E. ovalifolium				.1	
E. paucifolium		.1			
E. sp.			.1		
Euphorbia glyptosperma	.1			.1	
Festuca sp.					.1
Gutierrezia sarothrae	.3	.4	.3	1.1	.6
Haplopappus aremerioides			.2		
Hedeoma drummondii	.1			.2	
Heuchera parvifolia		.2			
Hymenoxys acaulis				.1	.3

continued

Mountain mahogany shrubland (continued)

Species	26	28	31	32	33
continued					
Juniperus osteosperma	2.4	.5	7.3	1.2	3.6
J. scopulorum		1.0			
Kelseya uniflora			2.6		
Kochia scoparia	2.4				
Lappula redowskii		.1		.1	
Lesquerella alpina				.1	
L. sp.					.5
Lomatium sp.	.3	.1			.1
Machaeranthera grindelioides			.4		.1
Musineon divaricatum			.1		
Opuntia polyacantha	.1	.1	.2	.1	.1
Oryzopsis hymenoides		.7		.1	
Oxytropis besseyi	.3				
O. camprestris	.5				
Paronychia sessiliflora		.1			.1
Penstemon eriantherus					.1
P. sp.		.1			
Petrophytum caespitosum				.2	
Phacelia glandulifera		.1			
Phlox bryoides			.1		
P. hoodii		.4	.1	.3	.8
Poa sandbergii				.1	
P. sp.		.1			
Rhus trilobata		.1			
Sedum lanceolatum				.1	
Senecio canus		.2			
S. sp.				.1	
Stephanomeria runcinata		.1			
Stipa comata	.5	.8	.1		
Streptanthella longirostris		.1			
Sullivantia hapemanii					.1
Tanacetum capitatum	.6	.1	.2		.5
Taraxacum laevigatum					.1
Zygadenus venenosus				.1	
Unknowns (7)	.1	.7			.2

Limber pine woodland

Species	Stand number 27	69
Agropyron spicatum	.1	1.1
Allium geyeri		.1
Arabis demisa		.1
Aristida fendleriana	.4	.3
Artemisia nova		1.2
Carex filifolia		2.1
Cercocarpus ledifolius	11.6	34.9
Comandra umbellata		.1
Cryptantha caespitosa	.6	
C. flavoculata	.1	
Draba crassifolia		.5
D. reptans		.2
Erigeron caespitosus	.1	
E. pumilus		.6
E. strigosus		.7
Gutierrezia sarothrae	.5	
Heuchera parvifolia		.4
Hymenopappus filifolius	.1	
Ipomopsis pumila		.3
I. spicata	.1	
Juniperus osteosperma	.7	6.7
J. scopulorum	.2	10.8
Koeleria macrantha		.1
Lesquerella alpina		.1
Lomatium sp.	.1	
Lygodesmia runcinata		.4
Machaeranthera grindelioides	.3	
Opuntia polyacantha		.1
Oryzopsis hymenoides		.1
Penstemon laricifolius		.1
Petrophytum caespitosum	.4	
Phlox bryoides	.8	
P. hoodii	.1	
Physocarpus mongynus		.1
Pinus flexilis	.3	.2
Poa sp.		1.5
Rhus trilobata		.1
Ribes cereum		.1
Sedum lanceolatum		.2
Senecio canus	.1	
Solidago missouriensis		.1
Stephanomeria runcinata	.1	
Stipa comata	.2	.7
Sullivantia hapemanii		.3
Toxicodendron rydbergii		.1
Unknown (1)	.1	

Appendix B

Maps showing stand location

(Not included in this copy of the report, but available from the authors or from BCNRA offices in Lovell and Fort Smith)

Appendix C

Common names for the Latin nomenclature used in this report

Most common names were obtained from the following reference: A. A. Beetle. 1970. Recommended plant names. Research Journal 31, Agricultural Experiment Station, University of Wyoming, Laramie, WY 82071.

Scientific name	Common name
Abies lasiocarpa	subalpine fir
Acer glabrum	Rocky Mountain maple
A. negundo	boxelder
Achillea millefolium	yarrow
Agropyron cristatum	crested wheatgrass
A. elongatum	tall wheatgrass
A. intermedium	intermediate wheatgrass
A. repens	quackgrass
A. smithii	western wheatgrass
A. spicatum	bluebunch wheatgrass
Agrostis alba	redtop bent
Amelanchier alnifolia	saskatoon serviceberry
Andropogon gerardii	big bluestem
A. scoparius	little bluestem
Apocynum androsaemifolium	dogbane
A. cannabinum	Indianhemp dogbane
Arenaria hookeri	Hooker sandwort
Aristida fendleriana	Fendler threeawn
Artemisia biennis	biennial wormwood
A. cana	silver sagebrush
A. frigida	fringed sagebrush
A. longifolia	longleaf sagewort
A. ludoviciana	Louisiana sagewort
A. nova	black sagebrush
A. pedatifida	birdfoot sagewort
A. spinescens	bud sagewort
A. tridentata	big sagebrush
Asclepias speciosa	showy milkweek
Astragalus oreganus	windriver milkvetch
Atriplex canescens	fourwing saltbush
A. confertifolia	shadscale saltbush
A. heterosperma	saltbush
A. gardneri (A. nuttallii)	Gardner saltbush

Beckmania syzigachne	American sloughgrass
Betula occidentalis	water birch
Bidens cernua	nodding beggarticks
Bouteloua curtipendula	sideoats grama
B. gracilis	blue grama
Bromus inermis	smooth brome
B. japonicus	Japanese brome
B. tectorum	cheatgrass
Campanula rotundifolia	harebell
Cardaria draba	hoary cress
C. pubescens	hairy whitetop
Carex filifolia	threadleaf sedge
C. lanuginosa	woolly sedge
Castilleja spp.	Indian paintbrush
Celtis occidentalis	hackberry
Centaurea maculosa	spotted knapweed
C. repens	Russian knapweed
Cerastium arvense	chickweed
Ceratoides lanata	winterfat
Cercocarpus ledifolius	curlleaf mountain mahogany
C. montanus	true mountain mahogany
Chenopodium album	lambsquarters/common goosefoot
C. berlandieri	pitseed goosefoot
C. fremontii	Freemont goosefoot
C. glaucum	oakleaf goosefoot
C. rubrum	red goosefoot
Chrysothamnus nauseosus	rubber rabbitbrush
C. viscidiflorus	Douglas rabbitbrush
Cirsium arvense	Canadian thistle
Clematis columbiana	rock clematis
C. ligusticifolia	virginsbower
Cleome lutea	yellow beeplant
Comandra umbellata	bastard toadflax
Conium maculatum	poison hemlock
Convolvulus arvense	field bindweed
Conyza canadensis	Canada horseweed
Crataegus sp.	hawthorn
Cryptantha flavoculata	miners candle
Descurainia pinnata	pinnate tansymustard
Distichlis stricta	saltgrass
Echinochloa muricata	barnyard grass
Elaeagnus angustifolium	Russian olive
Eleocharis palustris	creeping spikerush
Elymus canadensis	Canada wildrye
Equisetum laevigatum	smooth horsetail
Erigeron spp.	fleabane
Eriogonum brevicaule	shortstem wildbuckwheat
Eriogonum spp.	wildbuckwheat
Euphorbia esula	leafy spurge
E. glyptosperma	ridgeseed spurge
Festuca idahoensis	Idaho fescue

Gaura coccinea	scarlet gaura
Glycyrrhiza lepidota	American licorice
Gnaphalium palustre	cudweed
Grayia spinosa	spiny hopsage
Gutierrezia sarothrae	broom snakeweed
Halogeton glomeratus	halogeton
Helianthus annuus	common sunflower
Heterotheca villosa	hairy goldenaster
Hordeum jubatum	foxtail barley
Hymenopappus filifolius	fineleaf hymenopappus
Hymenoxys acaulis	stemless actinea
Iva axillaris	poverty sumpweed
I. xanthifolia	sumpweed
Juncus compressus	rush
J. tenuis	poverty rush
J. torreyi	Torrey rush
Juniperus communis	ground juniper
J. osteosperma	Utah juniper
J. scopulorum	Rocky Mountain juniper
Kochia scoparia	fireweed summercypress
Koeleria macrantha	junegrass
Lappula redowskii	bluebur stickseed
Lepidium densiflorum	prairie pepperweed
Leptodactylon pungens	granite pricklygilia
Liatris punctata	blazing star
Linum lewisii	Lewis flax
Logfia arvensis	filago
Lycopodium annotinum	clubmoss
Lycopus asper	rough bugleweed
Medicago sativa	alfalfa
Melilotus sp.	sweet clover
Monolepis nuttalliana	Nuttall monolepis
Muhlenbergia asperifolia	alkali muhly
Oenothera depressa	evening primrose
Opuntia polyacantha	plains pricklypear
Orthocarpus sp.	owlclover
Oryzopsis hymenoides	Indian ricegrass
Paronychia serpylifolia	creeping nailwort
Petalostemon purpureum	purple prairieclover
Phacelia spp.	phacelia
Phalaris arundinacea	reed canarygrass
Phleum pratense	timothy
Phlox bryoides	squarestem phlox
P. hoodii	Hoods phlox
Physocarpus monogynus	ninebark
Picea engelmannii	Engelmann spruce

Pinus contorta	lodgepole pine
P. flexilis	limber pine
P. ponderosa	ponderosa pine
Plantago major	common plantain
Poa nevadensis	Nevada bluegrass
P. pratensis	Kentucky bluegrass
P. sandbergii (secunda)	Sandberg bluegrass
Polanisia trachysperma	roughseed clammyweed
Polygonum aviculare	prostrate knotweed
P. lapathifolium	curlthumb knotweed
P. spathifolium	knotweed
Polypogon monspeliensis	rabbitfoot beargrass
Populus angustifolium	narrowleaf cottonwood
P. deltoides	plains cottonwood
P. tremuloides	aspen
Potentilla paradoxa	cinquefoil
Prunus americana	American plum
P. virginiana	chokecherry
Pseudotsuga menziesii	Douglas fir
Psoralea lanceolata	scurfpea
Puccinellia nuttalliana	alkaligrass
Ranunculus cymbalaria	shore buttercup
Ribes aureum	golden currant
R. cereum	wax currant
Rhus trilobata	skunkbush
Rorippa curvipes	watercress
R. sinuata	spreading yellow watercress
R. trinagulivalvis	watercress
Rosa sayi	wildrose
R. woodsii	wildrose
Rumex maritima	dock
R. stenophyllus	narrowleaf dock
Salix amygdaloides	peachleaf willow
S. exigua	willow
Salsola kali	Russian thistle/coyote willow
Sarcobatus vermiculatus	greasewood
Schizachyrium scoparium	little bluestem
Scirpus acutus	tule bulrush
S. maritimus	bulrush
S. pungens	bulrush
Senecio canus	woolly groundsel
Shepherdia argentea	silver buffaloberry
S. canadensis	buffaloberry
Sisymbrium loeselii	tall hedgemustard
Sitanion hystrix	bottlebrush squirreltail
Sonchus asper	prickly sowthistle
S. arvensis	perennial sowthistle
Spergularia marina	saltmarsh sandspurry
Sphaeralcea coccinea	scarlet globemallow
Sphaerophysa salsula	salt globepea
Sporobolus airoides	alkali sacaton
Stipa comata	needleandthread
S. viridula	green needlegrass

Suckleya suckleyana	poison suckleya
Suaeda depressa	Pursh seepweed
S. fruticosa	alkali seepweed
S. torreyana	Torrey seepweed
Symphoricarpos spp.	snowberry
Tamarix chinensis	saltcedar
Tanacetum capitatum	rock tansy
Toxicodendron rydbergii	poison ivy
Tragopogon dubius	salsify
Trifolium pratense	red clover
Typha latifolia	cattail
T. angustifolium	narrowleaf cattail [redacted]
Ulmus pumila	Siberian elm
Verbena bracteata	bigbract verbena
Veronica anagallis-aquatica	water speedwell
Xanthium strumarium	cocklebur
Yucca glauca	soapweed