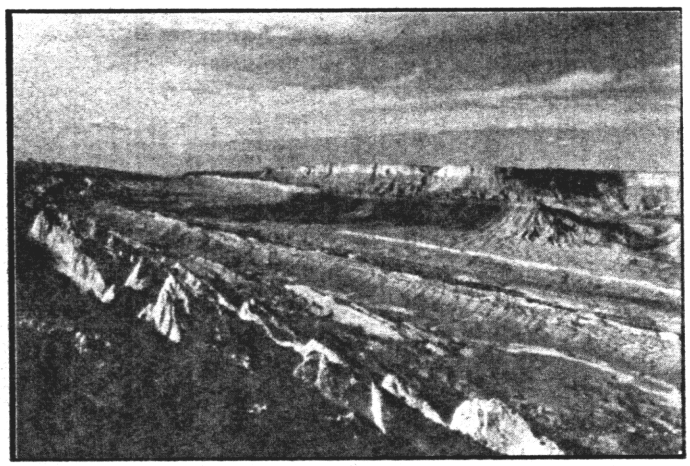
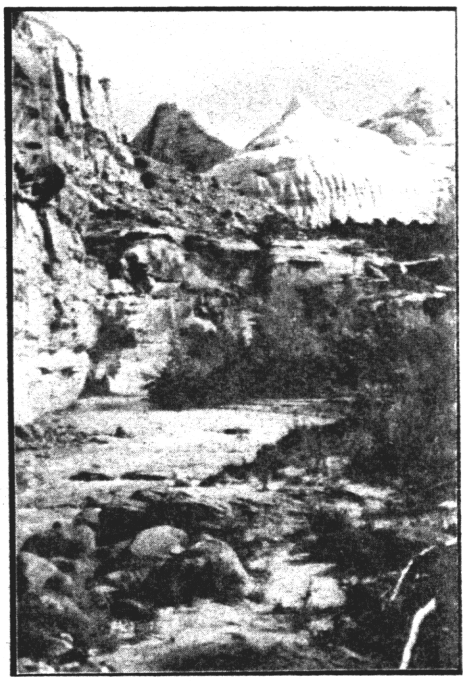
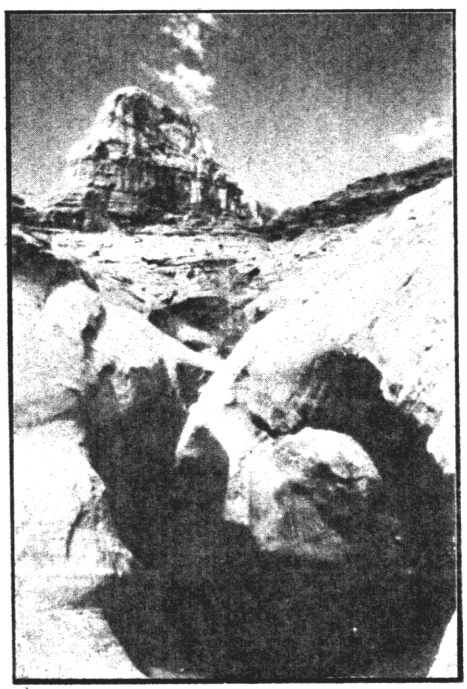
Plant Communities of Capitol Reef National Park, Utah

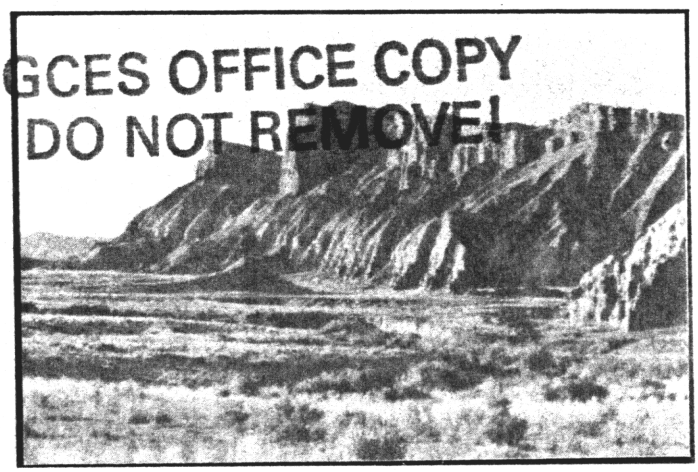
William H. Romme, Kenneth D. Heil, J. Mark Porter, and Rich Fleming

Technical Report NPS/NAUCARE/NRTR-93/02









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Plant Communities of Capitol Reef National Park, Utah

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Cooperative Park Studies Unit
at Northern Arizona University

Capitol Reef National Park was established in 1971 as a 241,000 acre park in the heart of the Colorado Plateau. The law creating the park called for the immediate phase-out of livestock grazing. In 1982, controversy surrounding the required phase-out precipitated the passage of a second law which called for an extension of grazing activities. This law also called for the establishment of a comprehensive grazing research program, initially overseen by the National Academy of Sciences, to determine the effects of the activity on the park's natural and cultural resources. By 1991, with NPS funding, the Division of Resource Management and Science at Capitol Reef National Park eventually shepherded to completion 11 separate studies as part of this effort. This document is the second report to be published as part of this grazing research series.

Norman R. Henderson
Chief, Resource Management and Science
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Abstract

Thirty-four community types and thirteen phases were identified and described in Capitol Reef National Park (CARE). A community was defined as a more or less unique and repeated assemblage of plant species occupying sites characterized by a more or less unique combination of elevation and soil texture conditions. A phase is a recognizable subunit of a community type, characterized by a somewhat unusual assemblage of species and occupying a portion of the usual habitat for that community type with no recognizably unique environmental conditions. Phases may reflect subtle, unrecognized patterns in underlying environmental gradients; or unique historical events of dispersal, establishment, or disturbance; or both. They cannot be mapped reliably, but they contribute to the park's biological diversity. A dichotomous key is provided for field identification of communities and phases in CARE.

The system of communities and phases developed for CARE was compared with other classification systems developed elsewhere on the Colorado Plateau, and with the Brown-Lowe-Pase (BLP) system being adopted in all National Park units in the region. Of the 34 community types in CARE, 23 comparable types have been described in surrounding areas, and the remaining 11 either are unique to CARE or simply have not been described elsewhere. Those communities that to date have been described only from CARE include the hopsage badlands, sagebrush-bitterbrush, bristlecone pine-cushion plant, mesic montane woodland, cottonwood-rabbitbrush woodland, waterpocket, alder-birch, dogwood-spruce, hornbeam-boxelder-oak woodland, cultivated orchards and settlements, and perennial wetland communities. Several of the community types in CARE do not readily fit any of the units in the original BLP system, suggesting that some new subassociations, associations, series, and formations may be needed to accommodate the distinctive plant communities of the Colorado Plateau.

A map of CARE vegetation can be produced by overlaying existing data layers using a geographic information system (GIS). Detailed instructions are provided for making a map based on the combinations of elevation, substrate, slope aspect, and physiognomic vegetation class associated with each community type.

Introduction

The vegetation of Capitol Reef National Park (CARE) is complex and diverse. Heil et al. (1993) provide an overview of the plant communities and vegetation patterns in CARE, as well as the vascular flora and general environmental conditions in the park. The objectives of this companion paper are to: (1) describe each plant community in greater detail; (2) compare the plant communities and classification system developed in CARE with communities and classifications elsewhere on the Colorado Plateau—in particular, with the Brown-Lowe-Pase system being adopted throughout the region; and (3) present the rationale and methodolgy for producing a vegetation map of CARE by use of information on geology, elevation, and physiognomic vegetation types that already exists in the park's geographic information system (GIS).

Plant species distribution in CARE is controlled primarily by gradients in elevation and soil texture, the latter being determined mainly by geologic substrate. In many areas, plant species abundance has been altered greatly by heavy livestock grazing. Topographic position and aspect influence species distribution and abundance in a few places, but are not major controlling factors in plant distribution (unlike many other regions). See Heil et al. (1993) for gradient analyses of CARE vegetation and an analysis of grazing effects.

The vegetation in Capitol Reef National Park appears to be a continuum rather than a

series of discrete units, except where underlying physical factors, such as soil texture or moisture, change abruptly. The communities that we describe below are not the communities of Clements and Daubenmire; rather they are recognizable assemblages of plant species that tend to be consistently associated with particular combinations of environmental conditions.

We define a *community* as a more or less unique and repeated assemblage of plant species occupying sites characterized by a more or less unique combination of elevation and soil texture conditions. A *phase* is a recognizable subunit of a community type, characterized by a somewhat unusual assemblage of species and occupying a portion of the usual habitat for that community type with no recognizably unique environmental conditions. Phases may reflect subtle, unrecognized patterns in underlying environmental gradients; or unique historical events of dispersal, establishmnt, or disturbance; or both. They cannot be mapped reliably, but they contribute to the park's biological diversity, and so are included in this classification. The 47 communities and phases that we identified in CARE are listed in Table 1 and described below. A dichotomous key for identification of plant communities in CARE is provided in Appendix 1.

Table 1. Summary of community types and phases in Capitol Reef National Park. See text for definitions and descriptions.

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- F5. Dogwood-Spruce Riparian Woodland Community
- F6. Hanging Garden Community
- F7. Hornbeam-Box Elder-Oak Woodland Community
- F8. Cultivated Orchards and Settlements
- F9. Perennial Wetland Community

Part I: Descriptions of the Plant Communities and Phases

A. BADLANDS COMMUNITIES

These communities are found on the most severe sites in the park, at lower elevations on clay-rich substrates such as the Mancos Formation and the Brushy Basin member of the Morrison Formation, and on gypsiferous substrates of the Carmel and Moenkopi Formations. These sites are characterized generally by low precipitation, low soil water holding capacity, and high temperatures. Some sites, especially those developing in marine shales or evaporites, also have unfavorable soil nutrient and pH conditions for plant growth.

These kinds of communities in the intermountain region have been described as salt-desert shrublands (West 1983b). Total annual precipitation in most areas is less than 200 mm (West 1983b), and soil surface temperatures over 60° C have been recorded in July in a salt-desert near Cisco, Utah (Wein and West 1972). Soil characteristics have a powerful influence on plant community characteristics. Generally plant cover and biomass are higher on more coarse-textured soils, which provide greater effective soil moisture than extremely fine-textured soils in this climate (Everitt 1970; Loope 1977; West 1983a, 1983b). Most of the plant biomass is below-ground (Moore and West 1973), and intermountain salt-deserts have some of the highest root-shoot ratios for any type of vegetation in the world (West 1983b).

Individual plants tend to be widely spaced, but the bare soil surface between plants supports a well-developed microphytic crust containing a variety of mosses, lichens, algae, and fungi (West 1983a). Where undamaged by livestock trampling or vehicles, this microphytic crust plays an important ecological role by reducing wind and water erosion and fixing nitrogen (West 1983a, 1988; also see the special issue of *Great Basin Naturalist* [volume 53, number 1, 1993] devoted to soil crusts).

Although these communities sometimes appear monotonous and homogeneous, there are pronounced vertical and horizontal patterns of soil chemistry and biological activity (Charley and West 1975). Soil fertility tends to be greatest and decomposition fastest in the immediate vicinity of the shrubs (Charley and West 1975; West 1982, 1983b). Alkalinity and salinity also are highest beneath *Atriplex* and *Artemisia* species (Charley and West 1975, West 1982).

The badlands communities usually support low plant cover and biomass, and low species richness. However, several of the dominant shrub species in the family Chenopodiaceae have rapid rates of evolution and presumably of ecotypic differentiation (Stutz 1978, West 1983b). Thus the low diversity of species may be compensated to some extent by high genetic and physiological diversity within species. Moreover, despite the low species richness, some of the most interesting plants in the park are found in these badlands communities, including various endemics, endangered, and threatened species (see Heil et al. 1993).

A1. BENTONITE BADLANDS COMMUNITY

This community is restricted to bentonite clays of the Brushy Basin member of the Morrison Formation (Jmb) at elevations near 1500 m (5000 ft).

It is characterized by a very sparse cover (<25%) of low shrubs and forbs. Species composition is variable from site to site. In the vicinity of the Oyster Shell Reef and elsewhere, the dominant species are native annuals, such as *Atriplex rossii* , *Phacelia demissa*, and *Eriogonum flexum*. In other areas, such as the Bentonite Hills area north of the Fremont River, plant cover is almost zero.

This community is uncommon and localized in the park and elsewhere on the Colorado Plateau. It does not correspond to any of Tuhy and MacMahon's (1988) community types, but Everitt (1970) described similar communities and habitats near the Henry Mountains several kilometers east of CARE.

A2. HOPSAGE BADLANDS COMMUNITY

This community is found on heavy clays of the Chinle (JTc) and Moenkopi (JTm) Formations at 1545-1730 m (5100-5700 ft) near

Fruita, and of the Curtis Formation (Jcu) at 5800 ft in the South and Middle Deserts.

The dominant species are *Grayia brandegii* and other low shrubs including *Atriplex confertifolia* and *Atriplex cuneata*. *G. brandegii* is predominantly a tetraploid from near Fruita, and is predominantly diploid in the South and Middle Desert areas. Total plant cover is typically low (<50%).

This community is common but localized in the park, especially in the northern portion, and elsewhere on the Colorado Plateau. It does not correspond to any of Tuhy and MacMahon's (1988) community types.

A3. MAT SALTBUSH COMMUNITY

The mat saltbush community is found on heavy clay soils, derived from the Mancos Formation (Kmb, Kmm, and Kmt) at 1510-1820 m (5000-6000 ft) in the vicinity of the Post, and from the Moenkopi (JTm) and Chinle (JTc) Formations at 1510-2000 m (5000-6600 ft) near Fruita.

The dominant species in this community are low, commonly matlike shrubs including *Atriplex cuneata*, *A. corrugata*, *A. confertifolia*, and *Eriogonum corymbosum*. Grasses and forbs also are important on some sites, but are nearly absent on others. Total plant cover is generally low, from 1-50%.

This community is common but localized in the park, especially in the southern portion, and is common and extensive elsewhere on the Colorado Plateau. It corresponds to Tuhy and MacMahon's (1988) *Atriplex gardneri* var. *cuneata* and *Atriplex corrugata* cover types in Glen Canyon National Recreation Area (NRA). Similar communities have been described near the Henry Mountains (Everitt 1970, Neese 1981), in the Book Cliffs area (Ibrahim and West 1972), and in the Kaiparowits region (Wood et al. 1974, Harper and Jaynes 1986; cited in Tuhy and MacMahon 1988).

Species composition is variable from site to site, and three phases can be identified within CARE. These phases are recognizable and contribute to the park's biological diversity, but they are not distinctive enough in either floristic composition or habitat to warrant classification as separate community types.

A3a. Shrub Phase

This phase consists of nearly pure stands of *A. corrugata*, or of mixed stands of *A. corrugata*, *A. cuneata*, and/or *A. confertifolia*. A few forbs and cacti may be present, but grasses are scarce or absent. This phase may represent severe soil conditions, severe overgrazing, or a combination of both. Tuhy and MacMahon (1988) noted that *Atriplex corrugata* occupies some of the harshest, most inhospitable habitats for plants on the Colorado Plateau. Therefore, some sites probably would be dominated by mat saltbush even in the absence of grazing. This phase is found mainly on clay soils derived from the Mancos Formation at elevations of 1510-1820 m (5000-6000 ft) near the Post, but also on the Moenkopi Formation near Fruita at 1880 m (6200 ft).

A3b. Grassland Phase

The grasses, *Hilaria jamesii* and *Oryzopsis hymenoides*, are important in this phase, as well as the mat saltbushes, especially *A. cuneata*. This phase may represent less severe soil conditions and/or less intense grazing pressure. It is found on clay soils derived either from the Mancos or Chinle Formation at elevations of 1510-2000 m (5000-6600 ft).

A3c. Buckwheat Phase

This phase is dominated by the low shrub, *Eriogonum corymbosum*, although *Atriplex cuneata* and *A. confertifolia* also are present. It is found on heavy clay and silt soils derived from the Moenkopi Formation (Tm) at elevations near 1730 m (5700 ft) in the vicinity of Fruita.

A4. GYPSUM BADLANDS COMMUNITY

This community is found on the gypsiferous member of the Carmel Formation (Jc) in the northern portion of the park at elevations of 1510-1970 m (5000-6500 ft). It is most common from the vicinity of Notom to the South Desert area. It also occurs in gypsiferous soils of the Moenkopi Formation (JTm) at 1510-1665 m (5000-5500 ft) near Fruita.

Species composition is highly variable in this community type, which is defined more by its consistently low plant cover (5-25%) and

its occurence on highly gypsiferous soils than by a list of species of high fidelity. Common species in this community include the low shrubs, *Ephedra torreyana, Atriplex confertifolia, Artemisia biglovii , Chrysothamnus nauseosus, C. viscidiflorus,* and *Eriogonum corymbosum,* and the grasses, *Hilaria jamesii* and *Oryzopsis hymenoides.*

This community is common but localized in the park; its occurrence elsewhere is unknown. It does not correspond to any of Tuhy and MacMahon's (1988) types.

B. GRASSLAND COMMUNITIES

Grasslands are found primarily on sandy soils in Capitol Reef National Park and throughout the Colorado Plateau region. The best developed grassland communities are seen where sand and silt deposits from weathered sandstone occur to depths of a meter or more (Loope 1977; West 1983c, 1988). On shallower deposits, and on more coarse or fine textured substrates, trees and shrubs tend to predominate, although grasses may still be an important component of the vegetation. Some sites in Capitol Reef National Park that we classify as the mixed grassland community contain a scattering of trees (pinyon and juniper) and so could instead be regarded as savannah communities. Similarly, our shadscale grassland community could be classified as a shrub steppe rather than a grassland. However, we include these community types under the grassland group because of the strikingly greater abundance of grasses in these communities than in other community types.

The dominant grass species on the Colorado Plateau are a mix of cool season bunchgrasses (e.g., *Aristida* spp.) and warm season sod-forming grasses (e.g., *Hilaria jamesii*). A variety of forbs, cacti, and low shrubs also grows in association with the grasses (West 1983c). On sites with minimal disturbance by livestock and vehicles, microphytic crusts cover the soil surfaces between the vascular plants and serve to reduce erosion and enhance nitrogen cycling (West 1983c, 1988).

The composition of grasslands in the southwest has been greatly altered by past heavy grazing by cattle, sheep, and other livestock species (West 1983c, 1988). Some of these changes are described below under the mixed grassland community. Heil et al. (1993) also discuss the effects of livestock grazing on plant cover and species composition of CARE grasslands. Ungrazed relict areas are extremely rare on the Colorado Plateau, so it is difficult to reconstruct pre-Columbian vegetation patterns and processes in grassland communities.

B1. SHADSCALE-GRASSLAND COMMUNITY

Shadscale-Grasslands are found on sandy soils, often mixed with overlying clay, at elevations of 1210-2060 m (4000-6800 ft). They are especially prominent on basaltic alluvial deposits (Qat) along the Fremont River and elsewhere in the park. These deposits support small (usually <100 ha), often disjunct patches of shadscale-grassland surrounded by other communities, e.g., pinyon-juniper.

This grassland is dominated by the grasses, *Hilaria jamesii* and *Oryzopsis hymenoides,* and the low shrub, *Atriplex confertifolia.* Other associated species include *Sitanion hystrix, Opuntia polyacantha, Ephedra torreyana,* and *Gutierrezia sarothrae.*

The Shadscale-Grassland community is common but localized in the park and elsewhere on the Colorado Plateau. It corresponds to Tuhy and MacMahon's (1988) *Atriplex confertifolia* cover type in Glen Canyon National Recreation Area (NRA).

B2. EOLIAN GRASSLAND COMMUNITY

Eolian grasslands are found on Quaternary sand dune deposits throughout the park at elevations of 1510-2300 m (5000-7600 ft). These deposits are patchily distributed and range from very small (<1 ha) to moderately sized (10-100 ha). Sand dunes at lower elevations (<1510 m [5000 ft]) generally support the eolian shrub community (described below).

Dominant species on all sites are the grasses, *Muhlenbergia pungens, Bouteloua gracilis,* and *Oryzopsis hymenoides. M. pungens* is most abundant on the least stable sites, e.g., shifting dunes and "blowout" pockets. *B. gracilis* and *O. hymenoides* dominate deep, stabilized dunes. *Stipa comata* is a major component of this community on inaccessible sites that have not been subjected to heavy grazing, e.g., in Hall's Narrows (N. Henderson, personal communication); it may have

been more abundant and widespread throughout the park area prior to European settlement. The cacti, *Opuntia polyacantha* and *O. fragilis*, are present even in ungrazed stands, but become abundant and even dominant following sustained heavy grazing. Some stands also contain an important component of shrubs, usually *Chrysothamnus nauseosus*, *Artemisia tridentata* or *Artemisia frigida*, or trees, usually *Pinus edulis* or *Juniperus osteosperma*; but the typical grass species listed above are also present. It is not clear why the shrubs and trees are common on some eolian deposits but not on others; subtle differences in substrate and grazing history may be involved.

This community is common but localized throughout the park and elsewhere on the Colorado Plateau. It corresponds at least partially to Tuhy and MacMahon's (1988) *Stipa-Hilaria* Grassland community type in Glen Canyon NRA, and to grasslands described by Everitt (1970) near the Henry Mountains and by Loope (1977) in Canyonlands National Park (but see also the mixed grassland community described below).

B3. MIXED GRASSLAND COMMUNITY

This community is found on sandy soils derived either from Quaternary alluvium (Qal) or from fine-textured sandstones, such as the Entrada sandstone (Je), at elevations of 1455-1880 m (4800-6200 ft). It is most common in the northern portion of the park, especially in the South Desert and Middle Desert areas.

This is a complex community type that varies in composition with gradients in soil texture and grazing history. Deep sandy loams support communities dominated by the grasses, *Bouteloua gracilis*, *Oryzopsis hymenoides*, *Sporobolus airoides*, and *S. cryptandrus*, and the shrubs, *Chrysothamnus nauseosus* and *Gutierrezia sarothrae*. Shallow, rocky soils are dominated by the grass, *Hilaria jamesii*, and the shrubs, *Artemisia biglovii* and *Ephedra torreyana*. Grazing leads to reduced abundance of *O. hymenoides*, and to increased abundance of *H. jamesii*, *Sporobolus* spp., and the shrubs listed above. Prolonged, extremely heavy grazing may eventually eliminate even the *Hilaria* and *Sporobolus* that appear to increase initially under light to moderate grazing. The exotic annual grass, *Bromus tectorum*, is common to abundant on some heavily grazed or otherwise disturbed sites, and is often present even on lightly grazed sites. Apparently no ungrazed stands of this community type exist within the park. However, observations of similar habitats within relict ungrazed portions of Glen Canyon NRA (Tuhy and MacMahon 1988) suggest that *Stipa comata* was an important component of this community type in prehistoric times.

The Mixed Grassland Community is similar in composition and physiognomy to both the Shadscale-Grassland and the Eolian Grassland. It is distinguished from the former by the presence of *Bouteloua gracilis* and the absence of *Atriplex confertifolia* as dominants; and from the latter by the non-eolian substrates.

Mixed grasslands are common and extensive within the park, especially the northern portion, and elsewhere on the Colorado Plateau. They correspond at least in part to Tuhy and MacMahon's (1988) *Stipa-Hilaria* Grassland community type, and to grasslands described by Everitt (1970) near the Henry Mountains and by Loope (1977) in Canyonlands National Park (but see also the eolian grassland community described above).

C. UPLAND SHRUB COMMUNITIES

Shrub-dominated communities are common and widespread in southern Utah. Sites dominated by shrub species of low stature are usually dry and unfavorable for plant growth; examples include the badlands communities decribed above and the blackbrush communities below. Communities dominated by tall shrubs generally represent an intermediate position on a moisture gradient between the more xeric badlands communities and the more mesic forest and woodland communities. Tall shrub communities in CARE are found in relatively mesic habitats at lower elevations (e.g., along ephemeral stream courses and on sandstone-derived soils), and in relatively xeric habitats at higher elevations (e.g., on south-facing slopes).

Shrub communities dominated by big sagebrush (*Artemisia tridentata*) have been the subject of considerable research, especially in the northern Great Basin region (West 1988). The sagebrush semi-desert of the southern Great Basin and Colorado Plateau has been

less well studied (West 1983d), and some of the other community types described below have received very little attention (West 1983e).

C1. EOLIAN SHRUB COMMUNITY

This community is found in deep sandy soils, derived usually from Quaternary sand dunes (Qed) but occasionally also from fine-grained sandstones such as the Entrada Formation (Je). In Capitol Reef National Park, it is apparently restricted to lower elevations (<1510 m [5000 ft]) south of the Bitter Creek Divide. Eolian deposits at higher elevations and in the northern portion of the park support the eolian grassland community (described above).

Major species include the shrubs, *Coleogyne ramossisimum, Ephedra viridis, Vanclevia stylosa, Artemisia filifolia, Poliomentha incana,* and the grass, *Oryzopsis hymenoides.*

More research is needed to determine why some eolian deposits support grasslands, whereas others support shrub-dominated communities. Some investigators have suggested that the shrub communities are former grasslands that have been degraded by prolonged heavy grazing. Alternatively, shrubland communities may represent a late stage in the normal process of dune stabilization and plant succession. Shrub-dominated dunes in the park appear to be very stable, whereas the grass-dominated dunes often are unstable and shifting. The restricted distribution of this community type in CARE (low elevations in the extreme southern portion of the park) suggests that it may be more a consequence of unique environmental conditions than of disturbance history.

This community is common but localized in the southern portion of the park (it is absent in the north) and elsewhere on the Colorado Plateau.

Composition varies from site to site, and two phases can be identified. These are recognizably different, and they contribute to biological diversity in Capitol Reef National Park, but they are not sufficiently distinctive in composition or habitat to warrant their classification as separate community types.

C1a. Blackbrush - Mormon Tea Phase

In this, the most common phase of the eolian shrub community, the dominant shrubs are *Coleogyne ramossisimum* and *Ephedra torreyana.* Blackbrush on the Colorado Plateau is usually associated with thin soils developing over sandstone, pediments, or a shallow caliche layer (West 1983e, Harper and Jaynes 1986), but it occasionally is a co-dominant in deep, sandy soils, as is seen here. This phase corresponds at least partially to Tuhy and MacMahon's (1988) *Coleogyne ramossisimum* cover type and to blackbrush communities described by Everitt (1970) near the Henry Mountains (but see also the blackbrush-rabbitbrush community described below).

C1b. Sand Sagebrush Phase

This phase is dominated by *Artemisia filifolia* and *Poliomentha incana.* It may correspond to Tuhy and MacMahon's (1988) sand-shrub community type, or may represent a severely overgrazed eolian grassland that has been converted into a shrub-dominated community. Similar communities exist near the Henry Mountains (Everitt 1970). Rasmussen and Brotherson (1986) described similar communities dominated by *Artemisia filifolia* in southwestern Utah, and reported that soil nutrient levels in these communities were generally lower than in adjacent communities having soils with higher clay content and cation exchange capacity.

C2. BLACKBRUSH-RABBITBRUSH COMMUNITY

This community in CARE is restricted to shallow, rocky soils developing over sandstone substrates of the Carmel (Jc), Navajo (JTn) and Kayenta (Tk) Formations at low elevations (1210-1545 m [4000-5100 ft]). It is found only in the southern portion of the park, south of the Bitter Creek Divide.

The dominant species are the shrubs, *Coleogyne ramossisimum* and either *Chrysothamnus nauseosus* or *C. nauseosus* var. *biglovii.* Other species present in variable amounts include the tree, *Juniperus osteosperma,* the shrubs, *Fraxinus anomala* and *Gutierrezia sarothrae,* and the forb, *Brickelia microphyta.* Cryptogamic crusts are well developed in the shrub interspaces where trampling and vehicular use have not been excessive (West 1983e).

Grasses are generally unimportant components of this community, evidently because

the shallow soils become too dry between precipitation events to support grasses (West 1983e). Mean soil depth in 12 blackbrush dominated stands in the Kaiparowits region was 22.2 cm, with standard deviation of 14.9 cm (Harper and Jaynes 1986). Blackbrush communities are found in some of the driest habitats on the Colorado Plateau, with average annual precipitation of <160 mm and frequent drought periods when precipitation is far less than average (West 1983e).

It is not known why blackbrush does not grow north of the Bitter Creek Divide in CARE. Its restriction to those parts of the park that are southerly and at low elevation (<1510 m [5000 ft]) suggests either a latitudinal or elevational limit. However, Everitt (1970) reports that blackbrush grows as high as 1820 m (6000 ft) in the eastern foothills of the Henry Mountains, and it extends along the eastern slope of the San Rafael Swell for some distance north of CARE; the species is rare on the west slope of the Henry Mountains. Everitt (1970) suggests that it is restricted to extremely dry areas within the rain shadow created by the Henry Mountains. It also may be intolerant of the windy conditions that characterize westerly and northerly sites.

An alternative explanation for the restricted distribution of blackbrush may be related to the species' intolerance of low temperatures. The southern portion of CARE, where blackbrush is common, lies at generally lower elevations than the northern portion, where blackbrush is absent. Presumably the southern portion of CARE is warmer than the northern portion. Moreover, West (1983e) observes that blackbrush rarely grows in concave microtopography or in riparian areas, but grows instead on benches, slopes, and pediments. This pattern suggests that cold air drainage may inhibit blackbrush. Everitt (1970) also noted that blackbrush is more abundant on southeast-facing slopes than on northeast-facing slopes. However, soil moisture characteristics also vary with microtopography, and moisture relations or interactions among these and other factors may be more important than temperature alone in limiting the plants' distribution. More research is needed to understand the reasons for the striking distribution pattern of blackbrush-dominated communities in CARE.

This community is common but localized in the southern portion of the park (it is absent in the north), and elsewhere on the Colorado Plateau. Blackbrush-dominated communites are found primarily in the extremely arid, low-elevation lands along the Colorado, Green, and San Juan Rivers in southeastern Utah (West 1983e). The blackbrush-rabbitbrush community in CARE corresponds at least in part to Tuhy and MacMahon's (1988) *Coleogyne ramossisimum* cover type in Glen Canyon NRA and to the blackbrush community described by Everitt (1970) near the Henry Mountains (but see also the Blackbrush-Mormon Tea Phase of the Eolian Shrub Community, described above).

C3. INTERMITTENT RIPARIAN SHRUB COMMUNITY

This community is found on deep alluvial deposits (Qal) along ephemeral streams and washes and on old alluvial terraces along perennial streams, often in broad valleys, at elevations of 1455-2000 m (4800-6600 ft).

Major species include the shrubs, *Sarcobatus vermiculatus, Artemisia tridentata, Atriplex canescens,* and *Chrysothamnus nauseosus,* and the grasses, *Oryzopsis hymenoides, Sporobolus contractus, S. airoides, Hilaria jamesii,* and *Bouteloua gracilis.*

This community type merges with the mixed grassland community in many areas, with a broad ecotone in which the shrubs become gradually less abundant and the grasses more abundant. The shrub community contains a large component of graminoid species, and has been substantially altered by heavy grazing in many places (West 1983d); see the discussion of grazing effects under the mixed grassland community above.

The intermittent riparian shrub community is common and widespread throughout the park and elsewhere on the Colorado Plateau.

Three phases of this community type can be recognized. They evidently represent different positions along gradients of soil salinity and texture, as described below, but habitat differences usually are not obvious in the field. Phases overlap in species composition and often are closely intermingled on any particular site. Therefore, we have chosen not to classify them as separate community types,

though the phases do contribute to biological diversity in the park.

C3a. Greasewood-Rabbitbrush Phase

This phase is dominated by the shrubs, *Sarcobatus vermiculatus* and *Chrysothamnus nauseosus*. It probably is found on more saline and/or more frequently flooded soils having a relatively low sand component. Of all the shrub species in the intermittent riparian shrub community, *Sarcobatus vermiculatus* apparently is the most tolerant of soil salinity (West 1988), and it tends to grow on sites where soil water is usually available within 1 m of the soil surface (West 1988). This phase of the intermittent riparian shrub community corresponds to Tuhy and MacMahon's (1988) *Sarcobatus vermiculatus* cover type in Glen Canyon NRA.

C3b. Four-Wing-Saltbush - Rabbitbrush Phase

Dominant species are the shrubs, *Atriplex canescens* and *Chrysothamnus nauseosus*. The absence of greasewood suggests that this phase occurs on less saline soils than the greasewood-rabbitbrush phase (described above), although both *Atriplex* and *Chrysothamnus* have some tolerance of saline conditions (West 1988). This phase of the intermittent riparian shrub community corresponds to Tuhy and MacMahon's (1988) *Atriplex canescens* cover type in Glen Canyon NRA.

C3c. Big Sagebrush Phase

The shrub, *Artemisia tridentata* ssp. *tridentata*, and the grass, *Bouteloua gracilis*, predominate; the trees, *Pinus edulis* and *Juniperus osteosperma*, are often present also. This phase appears to develop on alluvial soils of low salinity and high sand content. Of all the shrub species in the intermittent riparian shrub community, *Artemisia tridentata* has the lowest tolerance of soil salinity and does not survive on sites where conductivity exceeds 18 mS/cm (West 1983d, 1988). *Artemisia tridentata* ssp. *tridentata* commonly grows on wetter sites than most other species of *Artemisia* on the Colorado Plateau (West 1983d). This phase of the intermittent riparian shrub community corresponds to Tuhy and MacMahon's (1988) *Artemisia tridentata* ssp. *tridentata* cover type in Glen Canyon NRA.

C4. LOW SHRUB COMMUNITY

This community is very similar to the Pinyon - Juniper - Low Shrub Community (described below) in terms of habitat and species composition. The major distinction between the two is the absence or paucity of trees in the Low Shrub Community. The habitats supporting the Low Shrub Community evidently are drier than those supporting the Pinyon - Juniper - Low Shrub Community, although the two kinds of habitats appear very similar visually, and they overlap almost completely in geological substrate and elevation. It would be appropriate to classify these two vegetational units as phases of a single community type. However, because they are so different structurally, we have designated them as two separate community types. In terms of species composition, though, they are characterized by the same suite of low shrubs, grasses, and forbs.

This community is found on a wide variety of moderately xeric sites over a broad range of elevations (1455-2240 m [4800-7400 ft]). The habitat generally is characterized by shallow, coarse-textured soils developing over unfractured sandstone bedrock or a hardpan. Common substrates include sandstone members of the Moenkopi (TRm), Chinle (Tc), Carmel (Jc), Summerville (Js), Morrison (Jms), and Mancos (Kmf, Kme) Formations.

The shrubs most consistently found in this community are *Atriplex confertifolia, Ephedra torreyana, Eriogonum corymbosum, Chrysothamnus viscidiflorus*; other species sometimes present include the shrubs, *Artemisia biglovii, Ephedra viridis, Shepherdia rotundifolia*, and *Gutierrezia sarothrae*, and the grasses, *Oryzopsis hymenoides* and *Hilaria jamesii*. At high elevations, small-sized *Artemisia nova* and *Purshia tridentata* are the major low shrubs.

The actual species composition in this community type is extremely variable from site to site, although the dominant life-forms are constant throughout. Some of the variation in species composition reflects gradients in soil texture, moisture, nutrients, and salinity, but more research is needed to clarify these gradients. There also appears to be a strong random element in the distribution of the low shrubs that characterize this community type. Many of the species listed above appear to be roughly equivalent in their habitat requirements. The

actual composition of a given stand appears to be a sort of sample taken from those suitable species, and may be influenced by past events of disturbance and subsequent plant re-establishment. Alternatively, the distribution of shrub species in this community type may reflect subtle environmental controls not yet recognized. This community type is one of the most variable in terms of species composition of any community in the park, and it warrants additional research to clarify the species-environment relationships.

C5. DRY CANYONBOTTOM SHRUB COMMUNITY

This community is found on rocky sites along intermittent streambeds and the adjacent lower slopes of narrow canyons at elevations of 1210-2000 m (4000-6600 ft). It is most common in the southern portion of the park, where water has cut deep canyons and ravines into the sandstone bedrock of the Waterpocket Fold.

The major species are highly variable from site to site, but one or more of the following species are the dominants in any particular stand: the shrubs, *Fraxinus anomala* and *Rhus trilobata*; the forb, *Artemisia ludoviciana*; and the grass, *Oryzopsis hymenoides*. Species from the adjacent upland community on the canyon slopes usually also are present in the dry canyonbottom shrub community.

This community type is similar in habitat and composition to the Mesic Canyonbottom Shrub Community, described below, which occupies somewhat wetter and possibly cooler canyonbottom sites. The two canyonbottom shrub communities represent the xeric and mesic ends of a moisture gradient, with the xeric community most common at lower elevations and in the southern portion of the park, and the mesic community prevalent at higher elevations and in the northern portion.

This community is common but localized in the park, especially the southern portion, and elsewhere on the Colorado Plateau. It corresponds in part to Tuhy and MacMahon's (1988) ephemeral washes and higher terraces community type in Glen Canyon NRA (but see also the mesic canyonbottom shrub community, described below).

C6. MESIC CANYONBOTTOM SHRUB COMMUNITY

This community type is found on rocky sites along intermittent streambeds and on adjacent lower slopes of narrow canyons and ravines. It also is found on some moderately wide alluvial bottoms. It is most common in the northern portion of the park, especially in the vicinity of Fruita and Deep Creek, at elevations of 1605-2090 m (5300-6900 ft). In the southern part of the park it is usually found on relatively mesic sites adjacent to waterpockets at elevations below 1510 m (5000 ft).

The major species are highly variable from site to site. Any particular stand may be dominated by one or more of the following species: the shrubs, *Cercocarpus intricatus, Chrysothamnus nauseosus, Fraxinus anomala, Ephedra viridis, Amelanchier utahensis, Shepherdia rotundifolia, Berberis fremontii, Artemisia biglovii, Symphoricarpos oreophilus, Rhus trilobata, Quercus gambelii*, and *Gutierrezia sarothrae*; the cactus, *Opuntia polyacantha*; the forbs, *Heterotheca villosa* and *Artemisia ludoviciana*; and the grass, *Oryzopsis hymenoides*.

This community overlaps the Dry Canyonbottom Shrub Community somewhat in habitat and species composition at the lower end of its distribution. It represents the mesic end of a moisture gradient in canyonbottom habitats, as explained in the description of the Dry Canyonbottom Shrub Community. It also overlaps somewhat with the mesic montane woodland community, described below, at the upper elevational limits of its distribution.

The Mesic Canyonbottom Shrub Community is common but localized in the park, especially the northern portion, and elsewhere on the Colorado Plateau. It corresponds in part to Tuhy and MacMahon's (1988) ephemeral washes and higher terraces community (but see also the Dry Canyonbottom Shrub Community described above).

C7. SAGEBRUSH - BITTERBRUSH COMMUNITY

This community is found on dry, upland slopes at high elevations (>2425 m [8000 ft]) in the upper Deep Creek area. Within the park this community occurs on unconsolidated colluvial material (Qnb). However, the distribution of this community appears to be determined primarily by elevation and aspect,

as it evidently occurs on other substrates outside of the park. Generally, the Sagebrush - Bitterbrush Community is found on dry, high elevation slopes that may be too xeric to support forest and woodland communities.

Dominant species include the shrubs, *Artemisia nova, A. tridentata, Purshia tridentata,* and *Chrysothamnus viscidiflorus;* the grass, *Bouteloua gracilis;* and the forb, *Petradoria pumila.* Among the species of *Artemisia* on the Colorado Plateau, *A. nova* is one of the most xerophytic (West 1983d).

This community is rare and localized within the park, occurring only at the highest elevations in the upper Deep Creek area. However, it appears to be common and widespread just outside the park on Thousand Lakes Mountain and probably elsewhere on the Colorado Plateau. It does not correspond to any of Tuhy and MacMahon's (1988) community types.

D. PINYON - JUNIPER WOODLAND COMMUNITIES

Woodlands dominated by various combinations of the pygmy conifers, *Pinus edulis* and *Juniperus osteosperma,* cover extensive upland areas at middle elevations in CARE and throughout the Colorado Plateau. These woodlands exhibit great diversity in structure and composition, and provide important wildlife habitat. Both tree species are present in most stands in the park, but relative abundance varies along gradients of elevation and soil texture. Researchers in pinyon-juniper woodlands elsewhere in the southwest have found that juniper usually is more abundant at lower elevations (below about 2120 m [7000 ft] in New Mexico [Woodin and Lindsey 1954] or below about 1820 m [6000 ft] in Nevada [Tueller et al. 1979], cited in Pieper and Lymbery [1987]). Pinyon is the more abundant tree at higher elevations.

Abundance patterns are similar in CARE (Heil et al. 1993). At the lowest elevations (<1510 m [5000 ft]), *Juniperus osteosperma* commonly is the only tree present. These sites represent the most xeric sites within the pinyon-juniper zone, and reflect the juniper's greater drought tolerance. From 1510-1665 m (5000-5500 ft) pinyon is often present but juniper is nearly always more abundant. Stands from 1665-1970 m (5500-6500 ft) may contain roughly equal amounts of pinyon and juniper or be dominated by either species. Above 1970 m (6500 ft) there is an increasing tendency for pinyon to be more abundant than juniper, although in many stands the two are roughly equal. In a few stands above 1970 m (6500 ft), *Pinus edulis* is the only tree present. These stands probably represent the most mesic sites within the pinyon-juniper zone, although other factors may be more important in explaining the absence of juniper. At the highest elevations *J. osteosperma* also may be replaced by *J. scopulorum.*

Soil texture, which is largely a function of geologic substrate in this region, also influences the relative abundance of pinyon and juniper. Stands on fine-textured substrates, which in this region are relatively xeric, tend to be dominated by juniper, whereas stands on the more mesic coarse-textured substrates contain a higher proportion of pinyon. Again, this pattern apparently reflects the juniper's greater drought tolerance.

Tree density generally increases with elevation in the pinyon-juniper zone. Most stands in CARE are open woodlands with shrubs, herbs, and grasses well represented. At the highest elevations, however, above about 2210 m (7300 ft), tree cover may exceed 50%, and in places the trees form a nearly closed canopy.

Pinyon-juniper woodlands are subject to a variety of natural disturbances (West and Van Pelt 1987). In many parts of the southwest and intermountain region, fire has been a major disturbance (Erdman 1970, Everett 1987). Most of the pinyon-juniper woodlands in CARE show little evidence of fire. This probably is because of the rocky terrain and discontinuous fuels that exist in areas. Lightning ignites fires periodically, but the fires apparently rarely spread beyond the original tree. Loope (1977) described a similar situation in pinyon-juniper woodlands of Canyonlands National Park.

A more pervasive disturbance in the pinyon-juniper woodlands of CARE is livestock grazing, especially in those segments containing a substantial grass component. Grazing effects are described below. Past human disturbances by aboriginal peoples and by Anglo settlers in the late 1800s also have affected woodland structure and composition in some areas (Betancourt 1987), but these effects appear minimal in most of CARE.

D1. PINYON - JUNIPER - GRASS COMMUNITY

This community is found over a broad range of elevations (1545-2365 m [5100-7800 ft]) on sites with sandy soils. Common substrates are eolian deposits (Qed), alluvium (Qal), or weathered sandstone of the Entrada (Je) or Moenkopi (TRm) Formations.

Dominant species are the trees, *Pinus edulis* and *Juniperus osteosperma*, and one or more of the grasses, *Bouteloua gracilis, Oryzopsis hymenoides, Hilaria jamesii*, and *Stipa* spp. Other graminoids also are important in some stands: on unstable aeolian deposits *Muhlenbergia pungens* is a major species; at higher elevations (>1820 m [6000 ft]) the sedge *Carex geophila* is commonly present; and *Elymus salinus* is the dominant grass where this community occurs on sandy clay soils of the Moenkopi Formation (TRm) at elevations of 1790-1910 m (5900-6300 ft).

This community is similar in composition and habitat to the mixed grassland community, described above. It differs primarily in that the trees are more abundant in this community. In many places the ground layer vegetation remains roughly constant as one proceeds through a broad ecotone from the mixed grassland, through a sort of savannah with scattered pinyons and junipers, and finally into a well developed woodland. The pinyon - juniper - grass community has been drastically altered in many areas by heavy grazing, which promotes increased cover of the shrub *Gutierrezia sarothrae* and the cactus, *Opuntia polyacantha*, and reduced cover of the palatable graminoids, especially *Stipa* spp. As in the mixed grassland community, past grazing has so altered the composition of the pinyon - juniper - grass community that it is difficult to reconstruct the pre-settlement distribution of the major graminoid species in any detail. Almost no stands of this community exist within the park that have not been subjected to heavy grazing in the past.

This community also is similar in composition and habitat to the Pinyon - Juniper - Low Shrub Community, described below. The latter community lacks *Bouteloua gracilis* and *Muhlenbergia pungens*, however, which are diagnostic of grassland communities in this area.

The Pinyon - Juniper - Grass Community is common and widespread throughout the park and elsewhere on the Colorado Plateau. It corresponds at least in part to Tuhy and MacMahon's (1988) *Juniperus osteosperma*/ Grass Community type in Glen Canyon NRA.

D2. JUNIPER - MORMON TEA COMMUNITY

This community is found on coarse textured soils developing on steep clay slopes overlain by sandstone colluvium, at elevations of 1575-1940 m (5200-6400 ft). It may occur throughout the park, but is most common near the Post and the Oyster Shell Reef on the Mancos Formation (Kmt) and near Fruita on the Moenkopi Formation.

The tree, *Juniperus osteosperma*, and the low shrub, *Ephedra torreyana*, are always present. In addition, the low shrubs, *Artemisia biglovii, Gutierrezia sarothrae*, and *Atriplex confertifolia*, and the grasses, *Hilaria jamesii, Oryzopsis hymenoides*, and *Agropyron intermedium*, may be present in variable amounts. Pinyon trees usually are absent in this community.

This community is common but localized throughout the park and elsewhere on the Colorado Plateau. It does not correspond to any of Tuhy and MacMahon's (1988) types.

D3. JUNIPER - SALTBUSH COMMUNITY

This community is found on heavy clay soils of the Chinle (Tc) and Mancos (Kmf) Formations at elevations of 1575-1940 m (5200-6400 ft).

Dominant species are the tree, *Juniperus osteosperma*, and the low, often matlike shrubs, *Atriplex confertifolia* and *A. cuneata*. Pinyon usually is not present.

The habitat and species composition of this community overlap the Mat Saltbush Community, described earlier. The major difference is the conspicuous presence of juniper in this community. It also appears to occur on generally steeper sites than the Mat Saltbush Community, often where sandstone colluvial material is mixed with the clay and provides a somewhat more coarse soil texture.

The Juniper - Saltbush Community is common but localized in the park and elsewhere on the Colorado Plateau. It does not correspond to any of Tuhy and MacMahon's (1988) types.

D4. PINYON-JUNIPER-LOW SHRUB COMMUNITY

This community is found on a wide variety of moderately xeric sites over a broad range of elevations (1455-2240 m [4800-7400 ft]). The habitat generally is characterized by shallow, coarse-textured soils developing over unfractured sandstone bedrock or a hardpan. Common substrates include sandstone members of the Moenkopi (TRm), Chinle (Tc), Carmel (Jc), Summerville (Js), Morrison (Jms), and Mancos (Kmf, Kme) Formations.

The trees, *Juniperus osteosperma* and *Pinus edulis*, are nearly always present in various amounts, depending on elevation and soil moisture (see discussion above). Associated with the trees are a number of low-stature, xerophytic shrubs. The shrubs most consistently found in this community are *Atriplex confertifolia, Ephedra torreyana, Eriogonum corymbosum, Chrysothamnus viscidiflorus*; other species sometimes present include the shrubs, *Artemisia biglovii, Ephedra viridis, Shepherdia rotundifolia*, and *Gutierrezia sarothrae*, and the grasses, *Oryzopsis hymenoides* and *Hilaria jamesii*. At high elevations, small-sized *Artemisia nova* and *Purshia tridentata* are the major low shrubs.

The actual species composition in this community type is extremely variable from site to site, although the dominant life-forms are constant throughout. Some of the variation in species composition reflects gradients in soil texture, moisture, nutrients, and salinity. The phases described below reflect some of this environmentally controlled variation, but more research is needed to more clearly elucidate these relationships. There also appears to be a strong random element in the distribution of the low shrubs that characterize this community type. Many of the species listed above appear to be roughly equivalent in their habitat requirements. The actual composition of a given stand appears to be a sort of sample taken from those suitable species, and may be influenced by past events of disturbance and subsequent plant re-establishment. Alternatively, the distribution of shrub species in this community type may reflect subtle environmental controls not yet recognized. This community type is one of the most variable in terms of species composition of any community in the park; and it warrants additional research to clarify the species-environment relationships.

This is one of the most common and widespread communities in the Park and elsewhere on the Colorado Plateau. It may correspond partly with Tuhy and MacMahon's (1988) *Pinus edulis - Juniperus osteosperma / Shepherdia rotundifolia / Elymus salinus* community types.

D4a. Pinyon-Juniper-Cushion Plant Phase

This phase is found especially on the tops of narrow ridges projecting out above cliffs, where soils are commonly thin and the plants are subjected to wind and sun. In addition to the usual low shrubs, the ground layer vegetation contains a large component of low, mat-like forbs or "cushion plants," such as *Phlox muscoides, Erigeron compositus, Hymenoxys depressa, Parthenium ligulatum, Penstemon caespitosus, Petrophytum caespitosum, Paronychia sessiliflora*, and *Arenaria eastwoodiae*.

Several of these cushion plant species are listed or candidates for listing as threatenened or endangered. Therefore, the Cushion Plant Phase of the Pinyon - Juniper - Low Shrub Community is an important reservoir of biological diversity in the park and warrants special protection from development and unnecessary disturbance.

D4b. Pinyon-Juniper-Galleta Phase

This phase occurs on rocky sites where pockets of deeper soil support an important component of grass species, in addition to the usual shrubs of this community. *Hilaria jamesii* is the most common grass in this phase, but in some stands *Bouteloua eriopoda* or *Elymus salinus* is also important.

D4c. Pinyon-Juniper-Pygmy Sagebrush Phase

This phase is known only from a small, localized area of about 100 ha atop the Waterpocket Fold near the Burr Trail. The substrate is sandstone of the Salt Wash member of the Morrison Formation (Jms), and the elevation is 2060 m (6800 ft). *Artemisia pygmaea* is the dominant shrub species in this area, though it is rare in the park as a whole. The reasons for its unusual abundance in this particular area are unknown; it may be related to subtle and

undocumented soil conditions, to historical accidents of disturbance and establishment, or to a combination of these factors.

This may be a rare element of biological diversity in the park that warrants special attention and protection. Its occurrence outside the park is unknown.

D5. PINYON - JUNIPER - TALL SHRUB COMMUNITY

This community is found on more mesic upland sites over a broad range of elevations (1545-2335 m [5100 - 7700 ft]). Examples of substrates that provide the supplemental soil moisture needed to support this community include deeply fractured sandstone bedrock of the Navajo (JTn), Kayenta (Tk), and Wingate (Tw) Formations overlain by shallow soils. Ephemeral washes and deep bouldery colluvium also support this community, and it occurs on clayish soils at high elevations where precipitation is greater and temperatures are lower.

The major species are the trees, *Pinus edulis* and *Juniperus osteosperma*, plus a variable component of shrubs. The diagnostic tall shrub species that distinguish this community from the Pinyon - Juniper - Low Shrub Community (discussed above) are *Cercocarpus intricatus*, *Purshia mexicana* (especially common on slickrock sites), *Fallugia paradoxa* (common in washes), *Cercocarpus montanus* (common at higher elevations), *Amelanchier utahensis*, and *Berberis fremontii*. Many of the usually smaller shrubs common in the Pinyon-Juniper -Low Shrub Community are also found in the Pinyon - Juniper - Tall Shrub Community, such as *Shepherdia rotundifolia*, *Artemisia biglovii*, *Ephedra viridis*, and *Rhus trilobata*.

There appears to be a large random element in the shrub species composition of any particular stand (Heil et al. 1993). Perhaps several species are adapted to the few favorable micro-sites available, and whichever happens to become established in a given suitable site remains there for a long time. Alternatively, the plants may be responding to subtle gradients in soil or microclimate that we have not yet detected.

This is one of the most common and widespread communities within the park and elsewhere on the Colorado Plateau. It corresponds at least partly with Tuhy and MacMahon's (1988) *Pinus edulis-Juniperus osteosperma/ Fraxinus-Cercocarpus-Amelanchier* community type (but see also the Dwarf Mountain-Mahogany Slickrock Community, described below).

D6. DWARF MOUNTAIN-MAHOGANY SLICKROCK COMMUNITY

This community is found on steep, light-colored sandstone at elevations of 1730-2060 m (5700-6800 ft). Navajo sandstone (JTn) is the most common substrate, though it occurs in places on the Shinarump member of the Chinle Formation (TRc) and other sandstones.

The shrub, *Cercocarpus intricatus*, is the dominant species. The trees, *Pinus edulis* and *Juniperus osteosperma*, and the shrubs, *Artemisia biglovii*, *Amelanchier utahensis*, and *Fraxinus anomala*, are often present as well.

This community is common and widespread in the park and elsewhere on the Colorado Plateau. It corresponds partly to Tuhy and MacMahon's (1988) *Pinus edulis-Juniperus osteosperma/Fraxinus-Cercocarpus-Amelanchier* community type (but see also the Pinyon - Juniper - Tall Shrub Community, described above).

Kimball Harper (personal communication) described similar communities in Zion National Park, which he referred to as Crevice Plant Assemblages. The flora of these assemblages contains a higher proportion of evergreen forms than is seen in the regional flora as a whole, and the plants generally have a slower metabolic rate as measured by Q_{10}. Based on these distinctive features, Harper recommends separating the slickrock communities from the pinyon-juniper woodlands and classifying them as a distinct formation of their own.

E. UPLAND FOREST AND WOODLAND COMMUNITIES

Upland forests and woodlands are found only at the highest elevations on the Colorado Plateau, where precipitation is highest and temperatures are relatively cool. In the park, forests and woodlands are largely restricted to the upper Deep Creek area at elevations above about 2425 m (8000 ft). Most of the communities described below appear to be more extensive on Thousand Lakes Mountain to the

west; the park just barely extends into this high-elevation landscape.

E1. BRISTLECONE PINE - CUSHION PLANT COMMUNITY

This community occurs only on exposed ridgetops composed of the whitish, laminated, gypsiferous siltstone member of the Carmel Formation (Jc) at elevations above 2600 m (8600 ft).

Pinus longaeva is the major tree species. The trees are widely spaced and many appear extremely old, with only a narrow strip of intact bark supporting a fragment of living crown. The ground layer stratum is composed largely of cushion plants, including *Hymenoxys acaulis, Oxytropis oreophila, Phlox muscoides, Thelosperma subnuda,* and *Eriogonum corymbosum* var. *revealianum*. The grass, *Elymus salinus,* is often present also.

This community is very rare and localized in the park. It is restricted to a few small stands comprising about 0.5 ha (1.5 ac) in the upper Deep Creek area. It probably also occurs outside of the park, but its distribution is presently unknown. It does not correspond to any of Tuhy and MacMahon's (1988) types.

The Bristlecone Pine - Cushion Plant Community is a very special element in the park's vegetation because of its rarity and the apparent extreme age of the trees. The living trees and the dead wood on the ground may contain dendrochronological information of great significance, since the trees obviously are many centuries old and some of the dead boles and branches may be thousands of years old. The extreme northwest corner of the park where this community occurs should be protected from all forms of disturbance and development. Even recreational activities pose a potential threat to the old trees and their dendrochronological information, e.g., campers may unknowingly burn ancient wood in their campfires.

E2. PONDEROSA PINE - BITTERBRUSH WOODLAND COMMUNITY

This community is found on moderately dry slopes at high elevations (2455-2665 m [8100-8800 ft]) in the upper Deep Creek area. It occurs on a variety of substrates including sandstones (JTn) and unconsolidated material (Qnb).

The major tree species are *Pinus ponderosa, Juniperus scopulorum,* and *Pseudotsuga menziesii. P. menziesii* is most abundant on more mesic sites, e.g., north-facing slopes, and may be absent on the driest sites. The trees usually form an open woodland, with the understory dominated by the shrub, *Purshia tridentata.* The grass, *Poa fendleriana,* is often present also.

This community has been disturbed periodically by fires, as evidenced by multiple fire scars on most of the old ponderosa pine trees. Recent fire suppression and the warmer, wetter climate of the twentieth century have produced an increase in the density and cover of trees. In a few localized places the bitterbrush appear to be dying in the shade of the expanding canopy trees (cf. Harper and Buchanan 1983). Where the tree canopy is more open, the shrubs generally are very dense, and this dense shrub cover may also be an effect of fire suppression. The heavy shrub cover may have reduced the abundance of forbs in some places. This community also has been disturbed by at least one major windthrow event that occurred perhaps 40 years ago; all of the large trees in an area of about 1 ha are snapped off at a height of about 1-2 m, and the fallen boles are oriented in the same direction (toward the northeast).

This community is rare and localized in the park, where it is restricted to a small area of a few hundred hectares in the extreme northwest corner. However, it may be fairly common at high elevations on Thousand Lakes Mountain just outside the park, and similar communities are found in Bryce Canyon National Park (Harper and Buchanan 1983) and probably elsewhere on the Colorado Plateau. It may correspond in part to Tuhy and MacMahon's (1988) *Pseudotsuga menziesii* cover type in Glen Canyon NRA, although species composition and habitats described for this community in Glen Canyon and Capitol Reef appear to differ substantially.

One phase can be recognized in this community. It contributes to the park's biological diversity, but does not differ enough in species composition or habitat to warrant classification as a separate community type.

E2a. Mountain-Mahogany Phase

In some portions of the ponderosa pine - bitterbrush woodland community, especially where soils are derived from Navajo sandstone (JTn) and have a sandy texture, *Cercocarpus ledifolius* is an important shrub or small tree. The most impressive development of this species actually occurs just outside the park boundary, on an east-facing slope at 2700 m (8900 ft), where it forms a nearly pure stand of small trees covering an area of about a hectare.

E3. PONDEROSA PINE - MANZANITA WOODLAND COMMUNITY

This community occurs on deep, light-colored, sandy soils derived from Navajo sandstone (JTn) and eolian deposits on gentle slopes. It is best developed in the upper Deep Creek area at elevations of 2485-2515 m (8200-8300 ft), but small stands also occur atop the Waterpocket Fold at 2030-2060 m (6700-6800 ft) near Notom.

The dominant species are the tree, *Pinus ponderosa*, which forms an open woodland, and the shrub, *Arctostaphylos patula*. Other species often present include *Purshia tridentata* and *Pseudotsuga menziesii* at the higher elevations, and *Cercocarpus intricatus* at the lower elevations.

This community is uncommon and localized in the park, occurring only in the upper Deep Creek area and on top of the Waterpocket Fold near Notom. It probably occurs outside of the park, but its distribution elsewhere is not yet known. It apparently does not correstpond to any of Tuhy and MacMahon's (1988) types.

E4. MESIC MONTANE WOODLAND COMMUNITY

This community is found in canyon bottoms along perennial and intermittent streams at high elevations (>2425 m [8000 ft]). Along intermittent streams, the habitat includes both the riparian corridor and the adjacent mesic upland slopes. Along perennial streams it includes only the adjacent slopes, since the riparian corridor is occupied by either the cottonwood - willow or the dogwood - spruce riparian woodland community (both described below). The mesic montane woodland community most commonly occurs in deep, narrow canyons cut into Navajo sandstone (JTn) in the upper Deep Creek area.

The dominant species are variable from site to site, but include one or more of the following: the trees, *Acer glabrum*, *Pseudotsuga menziesii*, *Pinus ponderosa*, and *Juniperus scopulorum*; and the shrubs, *Cornus stolonifera*, *Purshia tridentata*, *Rosa woodsii*, and *Symphoricarpos oreophilus*. In terms of habitat and species composition, this community overlaps the mesic canyonbottom shrub community at lower elevations. The mesic montane woodland occupies the most mesic end of a moisture gradient in canyon bottom communities, with the dry canyonbottom shrub community at the most xeric end and the mesic canyonbottom shrub community in the middle.

This community is uncommon and localized in the park. It is restricted to the upper Deep Creek area in the northwest corner. It probably occurs outside the park, but its distribution elsewhere is not yet known. It does not correspond to any of Tuhy and MacMahon's (1988) types.

E5. ASPEN WOODLAND COMMUNITY

This community is found on mesic slopes and in shallow ravines at elevations around 2515 m (8300 ft). In the park it occurs on unconsolidated substrates (Qnb), with a well-developed organic soil layer.

The dominant tree species is *Populus tremuloides*. *Symphoricarpos oreophilus* forms a prominent shrub stratum, and a variety of forbs grow on the forest floor, including *Lupinus argenteus* and *Thalictrum fendleri*.

Many aspen stands in the southwestern U.S. appear to be successional stages after fire or other disturbances, and apparently are being replaced by coniferous tree species. The aspen stands in CARE appear stable, however, with no evidence of successional replacement. These stands probably have burned in the past, but aspen appears to be able to perpetuate itself in this area even without disturbance. Stable aspen stands of this kind have been described elsewhere in the Rocky Mountain region (Mueggler and Campbell 1986).

This community is rare in the park, where it is restricted to several small stands of a few hectares in size located in the Upper Deep Creek area. Aspen woodlands are common

and widespread on Thousand Lakes Mountain just outside of the park and at high elevations elsewhere on the Colorado Plateau, although the abundance and distribution of stands with similar species composition to those in CARE is not known. This community does not correspond to any of Tuhy and MacMahon's (1988) types.

F. RIPARIAN AND WETLAND COMMUNITIES

Riparian and wetland communities are uncommon in the arid environment of the Colorado Plateau, but they add immensely to the aesthetic and biological diversity of the landscape. They also are crucial components in the functioning of ecosystems. A well-vegetated riparian zone can reduce flooding and sedimentation, stabilize nutrient input to streams, and provide habitat for a great variety of animal species that occur nowhere else.

Most riparian communities in CARE, and on the Colorado Plateau in general, have been greatly altered by human activity (Barth and MacCullough 1988; Heil et al. 1993). The most significant alterations are related to heavy livestock grazing, introduction of exotic plant species, and disruption of normal stream flows through water diversions and reservoir construction.

Livestock prefer areas near water, so some of the heaviest grazing impacts occur in riparian communities. Preferred plant species, such as grasses, cottonwood, and willow, have been reduced in abundance and vigor on many sites, and unpalatable species such as rabbitbrush have increased. Trampling by livestock also can break down streambanks and lead to increased erosion and sedimentation. Grazing is being phased out in Capitol Reef National Park (Henderson 1985), but evidences of past excessive grazing will remain for many decades.

One of the most significant introduced plant species on the Colorado Plateau is *Tamarix ramosissima*, the tamarisk or salt-cedar. This phreatophytic small tree from the Middle East has become established in riparian areas throughout the region (Horton 1977). It is very resistant to disturbance and tends to displace the native woody plants of the riparian community. For example, photographic evidence suggests that the native cottonwood groves along the Colorado River in Glen Canyon were largely replaced by *Tamarix* between 1938 and 1958 (Everitt 1970). Unfortunately, *Tamarix* does not perform the ecological functions of maintaining water quality and providing wildlife habitat as well as the natives that it displaces.

Tamarix is well established in many places along the Fremont River both within CARE and downstream at least as far as the Dirty Devil River near Hanksville (Everitt 1970). However, some riparian communities exist in CARE where *Tamarix* is not yet established. These areas should receive high priority in protection and research to better understand the kinds of ecological conditions that promote or retard the spread of this aggressive addition to the park's flora.

Water developments, such as reservoir construction and stream diversions, can drastically alter the riparian ecosystems downstream by reducing total streamflow and changing the timing of peak flows (e.g., Johnson et al. 1976, Ohmart et al. 1977, Irvine and West 1979, Fenner et al. 1985, Akashi 1988, Rood and Heinze-Milne 1989). Many of the important native riparian species have life histories that are closely synchronized with seasonal variations in stream flow. An example is *Populus fremontii*, which requires high spring flows to create sand bars where seedlings can become established, and then low flows during the summer to prevent flooding and death of the seedlings. Unfortunately, prudent reservoir operation usually dictates low flows in the spring followed by sustained moderate to high flows throughout the summer irrigation season. The result can be a nearly complete failure of cottonwood regeneration, with progressive deterioration of the cottonwood community as the older trees gradually die. Riparian cottonwood communities throughout the west are currently disintegrating because of the effects of reservoirs upstream. On the Colorado Plateau, regulation of streamflow by reservoir construction also appears to enhance the spread and abundance of *Tamarix*, thus accentuating the problems described above.

F1. COTTONWOOD - RABBITBRUSH WOODLAND COMMUNITY

This community is found on stream

terraces and former floodplains adjacent to, but several meters higher than, perennial and intermittent streams throughout the park at elevations of 1180-1880 m (3900-6200 ft).

The dominant species are the tree, *Populus fremontii*, and the shrub, *Chrysothamnus nauseosus*. Often present are the tree, *Juniperus osteosperma*, the shrub, *Atriplex canescens*, the cacti, *Opuntia* spp., the forb, *Hymenopappus filifolius*, and the grasses, *Sporobolus contractus* and *Oryzopsis hymenoides*.

Nearly all stands in this community have been altered by heavy livestock grazing, such that it is difficult to reconstruct the presettlement abundance and distribution of the graminoid species. In general, heavy grazing leads to reduced cover of grasses and increased cover of unpalatable forbs, cacti, and shrubs.

This community is common but localized throughout the park and elsewhere on the Colorado Plateau. It does not correspond to any of Tuhy and MacMahon's (1988) types.

F2. WATERPOCKET COMMUNITY

This community develops in sandy depressions in slickrock that catch water during rainstorms and remain moist between rains. It is most common in the southern portion of the park on Navajo sandstone (JTn) at elevations of 1210-1665 m (4000-5500 ft).

Individual waterpockets and their surrounding wetland vegetation are all very small; each site comprises an area of about 0.1 ha or less. Waterpockets occur as isolated individual sites or as clusters of sites along a single drainage. Most waterpockets contain a pool of perennial water surrounded by a band of emergent, semi-aquatic vegetation and adjacent bands of mesophytic plants. The slickrock that surrounds the waterpockets has extremely low rates of water infiltration and high rates of runoff, so even very small precipitation events can recharge the perennial pools. We observed a brief summer rain shower at the Willow Tanks that lasted only a few minutes and barely required putting on rain gear; nevertheless, every little depression in the Navajo sandstone was flowing with water, and the waterpockets received many gallons of fresh water from that one small rain event.

Major species in the waterpocket community include the trees, *Acer negundo*, *Populus fremontii*, and *Salix exigua*; the forbs, *Equisetum hyemale* and *Brickellia longifolia*; and the grass, *Muhlenbergia asperifolia*.

The species composition is highly variable from stand to stand. This probably is because many species are adapted to the warm, mesic conditions present, but few suitable sites are available at any given time for plant establishment and growth. Disturbance by flooding is frequent, however, so new sites for colonization are created periodically. The first species to become established in these sites then tend to remain until the next disturbance. Consequently, species composition varies from stand to stand and probably also within the same stand over time. The temporal changes in stands probably are stochastic rather than directional and reflect random events of disturbance and plant establishment rather than succession towards any stable "climax" (Heil et al. 1993).

Waterpocket communities that are accessible to livestock have been greatly altered by excessive grazing (Heil et al. 1993). Grazing effects are conspicuous at the Willow and Cottonwood Tanks near the Post. When the lowermost waterpockets that are grazed are compared with the upper waterpockets that are only a few hundred meters away but are ungrazed because of intervening slickrock, it is apparent that the grazed sites have higher cover of bare ground and unpalatable plant species and lower cover of the palatable plant species. Trampling and pollution of the perennial pools of water also are evident at the grazed sites.

This community is rare and localized in the park and elsewhere on the Colorado Plateau. It does not correspond to any of Tuhy and MacMahon's (1988) types.

The Waterpocket Community is a particularly significant element in the vegetation of CARE. It provides a distinctive mesic contrast to the generally xeric environment, it supports a variety of water-requiring animal species including amphibians and invertebrates, and it is the namesake of the Waterpocket Fold. Waterpockets are vulnerable to damage from excessive grazing, and those that are accessible to livestock have been seriously degraded in the past, both by reduction in palatable forage species and pollution of the water by feces. Recreation also poses a poten-

tial threat to the ecological integrity of the Waterpocket Community since these are highly preferred sites for camping.

F3. COTTONWOOD - WILLOW RIPARIAN WOODLAND COMMUNITY

This community is found in the riparian zone along perennial streams throughout the park, over a wide range of elevations (1180-2425 m [3900-8000 ft]). The most important characteristic of this habitat is that moisture is available to plants during the entire growing season.

Species composition varies greatly from site to site throughout this community-type, depending upon subtle differences in environmental conditions and the local history of disturbance by flooding, grazing, and other factors. However, the following species are usually conspicuous: the trees, *Populus fremontii* (at lower and middle elevations), *P. angustifolia* (at higher elevations), and *Salix exigua*; and the herbs, *Scirpus* spp., *Juncus* spp., *Carex* spp., and *Oxytenia acerosa*. Two phases can be identified on the basis of their distincitive species composition, although they do not occupy any distinctive habitats within the general habitat of this community-type. These are the Reed Phase and Baltic Rush Phase.

This community is common but localized throughout the park and elsewhere on the Colorado Plateau. It does not correspond to any of Tuhy and MacMahon's (1988) types.

F3a. Reed Phase

This phase is dominated by the tall grass, *Phragmites australis*. It is found in several locations along the Fremont River and elsewhere.

F3b. Baltic Rush Phase

This phase is dominated by the rush, *Juncus balticus*. It is commonly found along major streams in the park.

F4. ALDER-BIRCH RIPARIAN COMMUNITY

This community is found in portions of the Fremont River Gorge west of Fruita, where the riparian zone is extremely narrow. We did not collect a relevé sample in this community type, but the species composition has been described by Welsh (1988). Dominant species are *Alnus tenuifolia, Betula occidentalis, Salix* spp., *Acer negundo*, and *Fraxinus anomala*.

F5. DOGWOOD - SPRUCE RIPARIAN WOODLAND COMMUNITY

This community is found in small, wet, almost marsh-like riparian sites along upper Deep Creek at elevations of 2425-2605 m (8000-8600 ft).

The dominant species are the tree, *Picea pungens*, and the shrub, *Cornus stolonifera*. Other species present include *Ribes aureum* and *Alnus tenuifolia*.

This community is extremely rare and localized in the park; it is known only from two small sites, each of about a hectare in extent. Its distribution elsewhere on the Colorado Plateau is unknown. It does not correspond to any of Tuhy and MacMahon's (1988) types.

F6. HANGING GARDEN COMMUNITY

This community is found on perennial seeps and springs in sandstone cliffs, most commonly in Navajo sandstone (JTn) at 1240-1335 m (4100-4400 ft).

Species composition varies from site to site, but the following species are usually present: the fern, *Adiantum capillus-veneris*, the forb, *Mimulus eastwoodii*, and the shrub, *Rhus radicans*. Additional species often present include *Epipactus gigantea* and *Smilacina stellata*. Malanson (1980, 1982) and Malanson and Kay (1980) found that hanging garden communities in Zion National Park showed low floristic similarity despite high habitat similarity, which agrees with our observations in CARE. Malanson and Kay concluded that any particular site could support a wide range of mesophytic species assemblages, and that species-specific dispersal capabilities and the frequency of disturbance by flooding interacted to control community composition at any particular time and place within the potential habitat of this community type (also see Heil et al. 1993).

This community is extremely rare and localized in the park; stands are small (< 1 ha), isolated, and often on the faces of inaccessible cliffs. Most stands are located in Hall's Narrows in the extreme southern portion of the park. Similar communities exist in Canyonlands National Park (Loope 1977), Zion

National Park (Malanson 1980, 1982; Malanson and Kay 1980), Arches National Park (personal observations), and elsewhere on the Colorado Plateau (Welsh and Toft 1976, Welsh and Wood 1976, Wood and Welsh 1976), but are everywhere rare. This community does not correspond to any of Tuhy and MacMahon's (1988) types.

F7. HOPHORNBEAM - BOX-ELDER - OAK WOODLAND COMMUNITY

This community is found on sandy stream terraces or eolian deposits in the bottom of deep, narrow canyons at an elevation of about 1210 m (4000 ft). Stands are located adjacent to springs or seeps at the bases of high, north-facing cliffs.

The major species include the trees, *Acer negundo, Quercus gambelii, Ostrya knowltoni, Celtis reticulata,* and *Rhamnus betulifolia;* the forb, *Equisetum hyemale,* and the grass, *Poa fendleriana.* The physiognomy of the community is reminiscent of deciduous woodlands at the eastern margin of the Great Plains, and as such it provides the visitor an unusual experience in the arid landscape of the Colorado Plateau.

This community is extremely rare and localized in the park; it is restricted to a few small sites of about a hectare or less in extent in Hall's Narrows in the extreme southern portion of the park. Similar communities exist in Canyonlands National Park (Loope 1977) and elsewhere along the Colorado River system, but this assemblage of species apparently is everywhere rare.

F8. CULTIVATED ORCHARDS AND SETTLEMENTS

This community is found on irrigated lands in the vicinity of Fruita. It is a human-created assemblage of plants, and could not persist without cultivation. The major species are agricultural varieties of fruit trees and pasture grasses and forbs.

This community is uncommon and localized in the park; similar communities are common in irrigated valleys elsewhere on the Colorado Plateau. It does not correspond to any of Tuhy and MacMahon's (1988) types.

F9. PERENNIAL WETLAND COMMUNITY

This community is found in an oxbow lake along the Fremont River near the east park boundary at an elevation of 1545 m (5100 ft). It was created by highway construction.

Dominant species are hydrophytic and mesophytic plants including *Eleocharis macrostachya, Juncus balticus, J. ensifolius, Muhlenbergia asperifolia, Equisetum laevigatum,* and *Phragmites australis.*

This community is extremely rare in the park; only one site is known. However, it is in a human-created habitat. Similar sites and plant assemblages exist elsewhere on the Colorado Plateau, but are nowhere common.

Part II: Fitting CARE's Plant Communities into the Brown-Lowe-Pase System

Plant community classifications have been developed for several other areas near CARE, including The Henry Mountains (Everitt 1970), Canyonlands National Park (Loope 1977), and Glen Canyon NRA (Tuhy and MacMahon 1988). Coniferous forest habitat types (Youngblood and Mauk 1985) and aspen community types (Mueggler and Campbell 1986) have been identified for national forests throughout Utah, including areas close to CARE. The USDA Soil Conservation Service also has classified the rangeland communities in south-central Utah. Several types of plant associations occur in all of these areas, though similar associations may have been given different names by the different investigators.

This entire portion of the northern Colorado Plateau can be regarded as a single ecological unit for purposes of interpretation and management. Therefore, to facilitate communication and to demonstrate some of the similarities and differences among the various individual units of the northern Colorado Plateau, we have attempted to summarize the plant communities described elsewhere that correspond to the plant communities that we recognized in CARE (Table 2).

Of the 34 community types in CARE, 23 comparable types have been described in surrounding areas, and the remaining 11 either are unique to CARE or simply have not yet been described elsewhere. Those communities which to date have been described only from CARE include the hopsage badlands community, sagebrush - bitterbrush community, bristlecone pine - cushion plant community, mesic montane woodland, cottonwood - rabbitbrush woodland, water-

Table 2. Summary of plant community types and phases in Capitol Reef National Park (CARE), and comparable vegetation units that have been described in systematic classifications elsewhere on the Colorado Plateau. Several of the community types may exist outside of CARE but have never been formally described; for these the table indicates no comparable types.

A1. Bentonite Badlands Community (CARE)
- Vegetation on Morrison shale in the Henry Mountains

A2. Hopsage Badlands Community (CARE)
- No comparable types

A3. Mat Saltbush Community
- *Atriplex gardneri* var. *cuneata* and *Atriplex corrugata* cover types in Glen Canyon NRA
- *Atriplex* in Canyonlands National Park
- Matsaltbush in the Henry Mountains
- ATNUC/HIJA-ATCO and ATCO4/HIJA in Utah rangelands

A4. Gypsum Badlands Community
- EPTO/HIJA and EPTO/COHI in Utah rangelands

B1. Shadscale - Grassland Community
- *Atriplex confertifolia* cover type in Glen Canyon NRA
- Shadscale in the Henry Mountains (at least in part)
- ATCO/HIJA, ATCO-CORA/ORHY, ATCO/HIJA-ARSP5, ATCO/HIJA-EPTO, and ELSA/ATCO in Utah rangelands

B2. Eolian Grassland Community
- *Stipa-Hilaria* grassland community type in Glen Canyon NRA (in part; also see Mixed Grassland Community)
- Grasslands in Canyonlands National Park (in part; also see Mixed Grassland Community)
- Vegetation of drift sand in the Henry Mountains (at least in part)
- ATCA2/ORHY, ORHY/STCO4-ATCA2, and SPORO-STCO4/EPHED in Utah rangelands

B3. Mixed Grassland Community
- *Stipa-Hilaria* grassland community type in Glen Canyon NRA (in part; also see Eolian Grassland Community)
- Grasslands in Canyonland National Park (in part; also see Eolian Grasslands)
- Desert grassland in the Henry Mountains (at least in part)

Table 2, continued

C1. Eolian Shrub Community
- C1a. Blackbrush - Mormon Tea Phase (CARE)
  - *Coleogyne ramossisumum* cover type in Glen Canyon NRA (in part; also see Blackbrush - Rabbitbrush Community)
  - Blackbrush and sand desert shrub in the Henry Mountains (in part)
  - CORA/HIJA-MUPO2, CORA/HIJA, CORA/HIJA-ATCO, CORA/ORHY-ATCA2, and CORA/HIJA-ORHY in Utah rangelands
- C1b. Sand Sagebrush Phase (CARE)
  - Sand shrub community type in Glen Canyon NRA (perhaps)
  - Sand desert shrub in the Henry Mountains (in part)
  - ORHY/SPCR/ARFI2 and SPORO/EPCU in Utah rangelands

C2. Blackbrush - Rabbitbrush Community (CARE)
- *Coleogyne ramossisumum* cover type in Glen Canyon NRA (in part; also see Blackbrush Mormon Tea Phase of Eolian Shrub Community)
- Coleogyne in Canyonlands National Park
- Blackbrush in the Henry Mountains (in part)
- CORA/HIJA-EPHED, EPTO/HIJA, and CORA/EPTO-ARBI3 in Utah rangelands

C3. Intermittent Riparian Shrub Community (CARE)
- *Artemisia-Atriplex* in Canyonlands National Park
- Annual and riparian vegetation in the Henry Mountains (in part)
- C3a. Greasewood - Rabbitbrush Phase (CARE)
  - *Sarcobatus vermiculatus* cover type in Glen Canyon NRA
  - SAVE4/SPAI and SAVE4/SIHY in Utah rangelands
- C3b. Four Wing Saltbush - Rabbitbrush Phase (CARE)
  - *Atriplex canescens* cover type in Glen Canyon NRA
  - ORHY/ATCA2 and ATCA2/ORHY in Utah rangelands
- C3c. Big Sagebrush Phase (CARE)
  - *Artemisia tridentata* spp. *tridentata* cover type in Glen Canyon NRA
  - ARTRT, ARTRW/ORHY, ARTRT/STCO4, and ARARN/PONE3-BOGR2 in Utah range lands

C4. Low Shrub Community (CARE)
- Variable Shrubland in Canyonlands National Park (at least in part)
- Sand desert shrub in the Henry Mountains (in part)

C5. Dry Canyonbottom Shrub Community (CARE)
- Ephemeral Washes and Higher Terraces Community Type in Glen Canyon NRA (in part; also see Mesic Canyonbottom Shrub Community)

C6. Mesic Canyonbottom Shrub Community (CARE)
- Ephemeral Washes and Higher Terraces Community Type in Glen Canyon NRA (in part; also see Mesic Canyonbottom Shrub Community)

C7. Sagebrush - Bitterbrush Community (CARE)
- No comparable types

D1. Pinyon - Juniper Grass Community Type (CARE)
- *Juniperus osteosperma*/Grass Community Type in Glen Canyon NRA (at least in part)
- Pinyon - juniper woodland in the Henry Mountains (in part: also see the other pinyon - juniper types)
- PIED-JUOS/CORA and PIED-JUOS/ELSA in Utah rangelands

D2. Juniper - Mormon Tea Community (CARE)
- Pinyon - juniper woodland in the Henry Mountains (in part: also see the other pinyon - juniper types)

D3. Juniper - Saltbush Community (CARE)
- Pinyon - juniper woodland in the Henry Mountains (in part: also see the other pinyon - juniper types)

D4. Pinyon - Juniper - Low Shrub Community (CARE)
- *Pinus edulis - Juniperus osteosperma/Shepherdia rotundifolia/Elymus salinus* community types in Glen Canyon NRA (at least in part)
- Pinyon-Juniper/Shrub in Canyonlands National Park (in part; also see Pinyon - Juniper - Tall Shrub Community)
- Pinyon - juniper woodland in the Henry Mountains (in part: also see the other pinyon - juniper types)
- JUOS/ORHY, PIED-JUOS/ARBI3, JUOS-PIED/CORA, PIED-JUOS/ELSA, and JUOS-PIED/ARBI3 in Utah rangelands

Table 2, continued

D5. Pinyon - Juniper - Tall Shrub Community (CARE)
- *Pinus edulis - Juniperus osteosperma/Fraxinus-Cercocarpus-Amelanchier* community type in Glen Canyon NRA (at least in part; also see Dwarf Mountain Mahogany Slickrock Community)
- Pinyon-Juniper/Shrub in Canyonlands National Park (in part; also see Pinyon - Juniper - Low Shrub Community)
- Pinyon - juniper woodland in the Henry Mountains (in part: also see the other pinyon - juniper types)
- PIED-JUOS/ELSA and PIED-JUOS/SHRO in Utah rangelands

D6. Dwarf Mountain Mahogany Slickrock Community (CARE)
- *Pinus edulis - Juniperus osteosperma/Fraxinus-Cercocarpus-Amelanchier* community type in Glen Canyon NRA (at least in part; also see Pinyon - Juniper - Tall Shrub Community)

E1. Bristlecone Pine - Cushion Plant Community (CARE)
- No comparable types

E2. Ponderosa Pine - Bitterbrush Woodland Community (CARE)
- *Pseudotsuga menziesii* cover type in Glen Canyon NRA (in part, perhaps)
- *Pinus ponderosa/Purshia tridentata* habitat type in central and southern Utah

E3. Ponderosa Pine - Manzanita Woodland Community (CARE)
- *Pinus ponderosa/Arctostaphylos patula* habitat type in central and southern Utah

E4. Mesic Montane Woodland Community (CARE)
- No comparable types

E5. Aspen Woodland Community (CARE)
- Possibly *Populus tremuloides/Symphoricarposoreophilus/Carex geyeri* community type in Utah
- Possibly Douglas-fir - quaking aspen forest in the Henry Mountains (in part)

F1. Cottonwood - Rabbitbrush Woodland Community (CARE)
- No comparable types

F2. Waterpocket Community (CARE)
- No comparable types

F3. Cottonwood - Willow Riparian Woodland Community (CARE)
- Annual and riparian vegetation in the Henry Mountains (in part)
- POFR2/SAEX/SPAI in Utah rangelands

F4. Alder- Birch Riparian Community (CARE)
- No comparable types

F5. Dogwood - Spruce Riparian Woodland Community (CARE)
- No comparable types

F6. Hanging Garden Community (CARE)
- Hanging Gardens in Canyonlands National Park

F7. Hornbeam - Boxelder - Oak Woodland Community (CARE)
- No comparable types

F8. Cultivated Orchards and Settlements (CARE)
- No comparable types

F9. Perennial Wetland Community (CARE)
- No comparable types

References:

Canyonlands National Park (Loope 1977)
Glen Canyon NRA (Tuhy and MacMahon 1988)
Henry Mountains (Everitt 1970)
Utah rangelands (Jarman, T., and H. Swenson. 1984. Ecological Site Descriptions, SCS-BLM Utah, unpublished draft report.)
Central and southern Utah (Youngblood and Mauk 1985)
Utah (Mueggler and Campbell 1986)

pocket community, alder - birch riparian woodland, dogwood - spruce riparian woodland, hornbeam - boxelder - oak woodland, cultivated orchards and settlements, and perennial wetland community (Table 2).

Recently, the Colorado Plateau Vegetation Advisory Committee of the National Park Service has recommended that vegetation classification systems used in National Park units throughout the Colorado Plateau should conform to the most part to the system developed by Brown, Lowe, and Pase (1980), referred to hereafter as BLP. Perhaps unfortunately, we constructed our plant community classification prior to this recommendation. We have attempted to reconcile the two systems (below), but it should be pointed out that there are two inherent difficulties in doing so.

First, our classification is based as much on habitat and physiognomy as on species composition, whereas BLP appears to stress species composition and biogeographic affinity as well as physiognomy. Thus, communities in CARE such as the hanging gardens and waterpockets, which have distinctive habitats and physiognomy but highly variable species composition, do not fit any of BLP's categories well. Secondly, because CARE's flora is composed of diverse elements from the Rocky Mountains, Sierra Madre, Great Basin, Great Plains, and southwestern deserts, the biogeographic affinities of some communities are not clear. For example, the montane coniferous woodlands in CARE could be classified as either Rocky Mountain, Madrean, or Great Basin types — a distinction that takes place rather high in the hierarchical structure of BLP. Spence (1993) has addressed these issues, and has proposed several revisions of the original BLP system that would facilitate incorporation of the distinctive plant communities of the Colorado Plateau.

Table 3 represents a first attempt to classify CARE's plant communities according to the original BLP system (Brown, Lowe, and Pase 1980). Several of our community types are ambiguous in this system and could be classified in more than one way. For most of CARE's community types we propose new subassociations, associations, series, or even formations in the system to adequately account for the uniqueness of the vegetation in this area. The reason that the present BLP system does not incorporate these elements adequately is the paucity of previous vegetation work in this portion of the Colorado Plateau; many of the plant assemblages in CARE have never been reported before in the literature (Spence 1993).

Table 3. Preliminary classification of plant communities and phases in CARE according to the Brown, Lowe, and Pase (1980) system.

A1.	Bentonite badlands community	
	1,152._:	Cold temperate desertlands, new regional formation (Colorado Plateau desertscrub?) and series ... could force it into Great Basin desertscrub, but it doesn't seem to fit well
A2.	Hopsage badlands community	
	1,152._:	Cold temperate desertlands, new regional formation (Colorado Plateau desertscrub?) and series ... could force it into Great Basin desertscrub, but it doesn't seem quite appropriate
A3.	Mat saltbush community	
	1,152._:	Cold temperate desertlands, new regional formation (Colorado Plateau desertscrub?) and series ... could force it into Great Basin desertscrub, but it may be unique to Colorado Plateau
A4.	Gypsum badlands community	
	1,152._:	Cold temperate desertlands, new regional formation (Colorado Plateau desertscrub?) and series ... could force it into Great Basin desertscrub, but may not be appropriate
B1.	Shadscale-grassland community	
	1,152.12_:	Cold temperate desertlands, Great Basin desertscrub, shadscale series, new association ... could alternatively be included under new Colorado Plateau desertscrub or grassland formation

Table 3, continued

B2. Eolian grassland community
1,142._: Cold temperate grasslands, new regional formation (Colorado Plateau grasslands ?) ... could force it into Plains grassland, gramma series, *Bouteloua gracilis* association, but it is quite different from grasslands on the western Great Plains

B3. Mixed grassland community
1,142._: Cold temperate grasslands, new regional formation (Colorado Plateau grass lands ?) and series ... could force it into Plains grassland, but it is quite different from grasslands on the western Great Plains

C1a. Eolian shrub community, blackbrush-Mormon tea phase
1,152.13_: Cold temperate desertlands, Great Basin desertscrub, Blackbrush series, new association

C1b. Eolian shrub community, sand sagebrush phase
1,152.1_: Cold temperate desertlands, Great Basin desertscrub, new series ... could force it into 1,153.273, but it does not seem like a Chihuahuan desert type of vegetation

C2. Blackbrush-rabbitbrush community
1,152.13_: Cold temperate desertlands, Great Basin desertscrub, Blackbrush series, new association

C3a. Int. riparian shrub community, greasewood-rabbitbrush ph.
1,152.171: Cold temperate desertlands, Great Basin desertscrub, saltbush series, *Sarcobatus vermiculatus* association

C3b. Int. rip. shrub community, 4wing saltbush-rabbitbrush ph.
1,152,172: *Atriplex canescens* association

C4. Low shrub community
1,152.1_: Cold temperate desertlands, Great Basin desertscrub, new series

C5. Dry canyonbottom shrub community
1,132.1_: Cold temperate scrublands, Great Basin montane scrub, new series
- or -
1,152.1_: Cold temperate desertlands, Great Basin desertscrub, new series

C6. Mesic canyonbottom shrub community
1,132.1_: Cold temperate scrublands, Great Basin montane scrub, new series
- or -
1,152.1_: Cold temperate desertlands,Great basin desertscrub, new series

C7. Sagebrush-bitterbrush community
1,132.15_: Cold temperate scrublands, Great Basin montane scrub, bitterbrush series, new association

D1-D5. Pinyon-juniper woodland communities
Each of the five community-types and three phases described here constitutes a new subassociation under
1,122.414_: Cold temperate forests and woodlands, Great Basin conifer woodland, *Pinus edulis-Juniperus osteosperma* association

E1. Bristlecone pine - cushion plant community
1,121.32_: Boreal forests and woodlands, Rocky Mountain subalpine conifer forest and woodland, Bristlecone pine - limber pine series, new *Pinus longaeva* association

E2. Ponderosa pine - bitterbrush woodland community
1,122.322_: Cold temperate forests and woodlands, Rocky Mountain montane conifer forest, pine series, *Pinus ponderosa* - mixed conifer association, new subassociation
- or -
1,122.622_: Cold temperate forests and woodlands, Madrean montane conifer forest, pine series, *Pinus ponderosa* association, new subassociation

Table 3, continued

E3. Ponderosa pine - manzanita woodland community
1,122.322_: Cold temperate forests and woodlands, Rocky Mountain montane conifer forest, pine series, *Pinus ponderosa* - mixed conifer association, new subassociation
- or -
1,122.622_: Cold temperate forests and woodlands, Madrean montane conifer forest, pine series, *Pinus ponderosa* association, new subassociation

E4. Mesic montane woodland community
1,122.322_: Cold temperate forests and woodlands, Rocky Mountain montane conifer forest, pine series, *Pinus ponderosa* - mixed conifer association, new subassociation
- or -
1,122.622_: Cold temperate forests and woodlands, Madrean montane conifer forest, pine series, *Pinus ponderosa* association, new subassociation
- or -
1,122.61_: Cold temperate forests and woodlands, Madrean montane conifer forest, Douglas-fir - mixed conifer series, new association

E5. Aspen woodland community
1,122.71_: Cold temperate forests and woodlands, Rocky Mountain deciduous forest, aspen series, new association

F1. Cottonwood-rabbitbrush woodland community
1,223.212_: Warm temperate swamp and riparian forests, Interior southwestern riparian deciduous forest and woodland, cottonwood-willow series, *Populus fremontii* association, new subassociation

F2. Waterpocket community
1,223.21_: Warm temperate swamp and riparian forests, Interior southwestern riparian deciduous forest and woodland, cottonwood-willow series, new association

F3. Cottonwood-willow riparian community
1,223.212: Warm temperate swamp and riparian forests, Interior southwestern riparian deciduous forest and woodland, cottonwood-willow series, *Populus fremontii* association

F4. Alder-birch riparian community
1,223.2_: Warm temperate swamp and riparian forests, Interior southwestern riparian deciduous forest and woodland, new series

F5. Dogwood-spruce riparian woodland community
1,232.3_: Cold temperate swamp and riparian scrub, Rocky Mountain riparian scrub, new series

F6. Hanging garden community
This really does not fit anywhere at all well. Perhaps it should be a new formation under 1,200 (Nearctic wetland vegetation), although that seems too high a level at which to classify it

F7. Hornbeam-boxelder-oak woodland community
1,223.22_: Warm temperate swamp and riparian forests, Interior southwestern riparian deciduous forest and woodland, mixed broadleaf series, new association

F8. Cultivated orchards and settlements not a natural vegetation type

F9. Perennial wetland community
1,242.5_: Cold temperate marshlands, Great Basin interior marshland, perhaps a new association within the rush series or a new series

PART III: Producing a Vegetation Map For CARE Using GIS

The distribution of each plant community or complex of communities in the park can be defined by a unique combination of geologic substrate, elevation, slope, and vegetation class (derived from a coarse-scale, physiognomic vegetation map in the park's GIS), as outlined in Table 4. Some of the community-types could not be mapped uniquely using only the data themes available in the park's GIS, so they were combined into "complexes". The "complexes" on the vegetation map are groups of community-types whose distributions completely or partially overlap; they are defined in Table 5. Several community-types are mapped both separately, where they occupy a unique combination of values of the defining parameters, and as part of one or more complexes. For example, the widely distributed pinyon-juniper-low shrub community appears on the vegetation map by itself (unit #15), as part of the pinyon-juniper-shrub complex (#17), and as part of the pinyon-juniper-woodland complex (#18).

The use of complexes in the vegetation map is unfortunate but unavoidable, since the park's GIS does not contain data for all of the environmental parameters that segregate community-types in the field. Nevertheless, the combination of parameters listed in Table 4 encompasses all of the park's geographic area and includes all of the plant community-types that we recognized.

An alternative approach to constructing a vegetation map is to perform spectral analysis of remotely sensed data, e.g., satellite imagery, thereby classifying the community types and mapping their distribution directly in a GIS. This approach is currently being used, for example, in Mesa Verde National Park (L. Floyd-Hanna and A. Loy, personal communication). As more of this kind of work is completed, it will be instructive to compare the relative utility and efficiency of these two contrasting approaches to classifying and mapping vegetation in the southwestern National Parks.

Table 4. Boolean combinations of existing data layers in the GIS to produce the vegetation map as a new map layer. Geologic formations (e.g., Jmb) are defined in Billingsley et al. (1987). Elevation classes (e.g., El01), physiognomic vegetation classes (e.g., V5), and riparian classes (e.g., II) are defined in unpublished files at the GIS laboratory, Capitol Reef National Park.

#	ACRONYM	COMMUNITY/COMPLEX	DEFINING PARAMETERS
1	BEBA	Bentonite badlands community	Jmb + V5
2	CHBA	Chinle badlands complex	TRc + not V4
3	MOBA	Moenkopi badlands complex	TRm + (El01-El05) + not V4
4	MASA	Mat saltbush community	Kmt or Kmm or Kmb
5	GYBA	Gypsum badlands community	Jc + (El03-El09) + not V4
6	SHGR	Shadscale grassland community	[Qat + (El01-El10) + not V4] or [Qap + not V4]
7	EOGR	Eolian grassland community	Qed + (El03-El10) + not V4
8	MIGR	Mixed grassland community	[Je + (V1 or V6)] or [Qal + not (II or IO or IC or IB or PI or PO or PC or PB)]
9	EOSH	Eolian shrub community	Qed + (El01-El02)
10	BLSH	Blackbrush-rabbitbrush community	Jc + (El01-El02) + not V4
11	INRI	Intermittent riparian shrub community	IO or IB
12	CBSH	Canyonbottom shrub complex	(II or IC) + (El01-El08)
13	LOSH	Low shrub community	(Js or Kmv or Kme or Kmf or Kd or Jms or Pc or Pk or Qms) + not V4

Table 4, continued

14	PJGR	Pinyon-juniper-grass	Ti or [Jmb + not V5] or[Qnb + (El01-El08)] or [(Qat or Qap or Qed) + V4]
15	PJLO	Pinyon-juniper-low shrub community	Js + V4
16	PJTA	Pinyon-juniper-tall shrub community	JTn + (El01-El08) + V4
17	PJSH	Pinyon-juniper-shrub complex	[(Kmv or Kme or Kmf or Kd or Jms or Pc or Pk or TRk or TRw or Qms) + V4] or [Jc+(El03-El09) + V4] or [TRm + (El06-El10) + V4]
18	PJWO	Pinyon-juniper woodlands complex	[TRm + (El01-El05) + V4] or [Je + not V1]
19	DWSL	Dwarf mountain-mahogany slickrock community	[(JTn or TRk or TRw) + not V4 + (El01-El08)] or [JTn + (El09-El10) + Slope3]
20	BRCU	Bristlecone pine - cushion plant community	Jc + El10 + Slope1
21	POMA	Ponderosa pine - manzanita community	JTn + Slope1 + (El09-El10)
22	DEMO	Deep Creek montane woodland complex	[Qnb + (El09-El10)] or [Jc + E110 + (Slope2-Slope3) or [JTn + Slope2 + (El09-El10)]
23	MEMO	Mesic montane woodland community	(El09-El10) + (II or IC)
24	CORA	Cottonwood-rabbitbrush community	PB + (El01-El07)
25	CORI	Cottonwood-willow riparian woodland community	(PO or PC(?)) + (El01-El08)
26	ABRI	Alder-birch riparian community	(PI or PC(?)) + (El03-El10)
27	CULT	Cultivated orchards and settlements	V9
28	DORI	Dogwood-spruce riparian community	UTM hand digitized
29	WATR	Waterpocket community	UTM hand digitized
30	HOBO	Hophornbeam - boxelder - oak woodland community	UTM hand digitized
31	HAGA	Hanging gardens community	UTM hand digitized
32	PEWE	Perennial wetlands community	UTM hand digitized

Table 5. Definitions of complexes on the vegetation map.

NAME OF COMPLEX	COMMUNITY-TYPES INCLUDED
Canyonbottom shrub complex	Dry canyonbottom shrub community Mesic canyonbottom shrub community
Chinle badlands complex	Hopsage badlands community Mat saltbush community
Deep Creek montane woodlands complex	Sagebrush-bitterbrush shrub community Ponderosa pine -bitterbrush woodland community Aspen woodland community
Moenkopi badlands complex	Hopsage badlands community Gypsum badlands community Shadscale grassland community
Pinyon-juniper-shrub complex	Pinyon-juniper-low shrub community Pinyon-juniper-tall shrub community
Pinyon-juniper woodlands complex	Pinyon-juniper-grass community Pinyon-juniper-low shrub community Pinyon-juniper-tall shrub community Juniper - Mormon tea community

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Appendix 1. Key to Plant Communities in Capitol Reef National Park

Note: Dominant species in the statements below are defined as having >10% total cover. Several communities may be reached via more than one pathway in the key, since some of the choices (e.g., riparian or wetland habitat) may be ambiguous in some stands.

1. Riparian or wetland habitat 2
1. Upland habitat 10
    2. Pond or pool of water present most of year 3
    2. Stream, spring, seep, or irrigated land 4
3. Large pond in oxbow of river ..... PERENNIAL WETLAND
3. Small pool in slickrock ..... WATERPOCKET
    4. Lands irrigated by humans ..... CULTIVATED ORCHARDS
    4. Not irrigated by humans 5
5. Habitat in seeps from cracks of sandstone slickrock; dominant species are herbs ..... HANGING GARDENS
5. Habitat not as above; dominant species include trees and shrubs 6
    6. High elevations (>2400 m); dominant species include *Cornus stolonifera* and *Picea pungens* ..... DOGWOOD-SPRUCE RIPARIAN WOODLAND
    6. Variable elevations; dominant species not as above 7
7. Low elevations (<1500 m); dominant species include *Rhamnus betulaefolia* ..... HOPHORNBEAM-BOX ELDER OAK WOODLAND
7. Variable elevations; dominant species other than above 8
    8. Narrow canyon habitat; dominants include *Alnus tenuifolia* and *Betula occidentalis* ..... ALDER-BIRCH RIPARIAN COMMUNITY
    8. Variable habitat; dominants include *Populus fremontii* 9
9. Moist riparian habitat; dominants include *Salix* spp. ..... COTTONWOOD-WILLOW RIPARIAN COMMUNITY
9. Dry stream terrace habitat; dominants include *Chrysothamnus nauseosus* ..... COTTONWOOD-RABBITBRUSH WOODLAND
    10. Soils with high gypsum content usually on Carmel Formation; dominants include various shrubs and small trees but not *Pinus longaeva* ..... GYPSUM BADLANDS COMMUNITY
    10. Soils with low gypsum content, or *Pinus longaeva* a dominant species 11
11. Soils with high bentonite content, usually on Brushy Basin member of Morrison Formation; total plant cover extremely low (<10%) ..... BENTONITE BADLANDS COMMUNITY
11. Not as above 12
    12. Woodland or forest; trees dominate community 13
    12. Shrubland or grassland; trees absent or only a minor component of community 28
13. Deciduous trees dominant; conifers present as minor component or absent 14
13. Coniferous trees dominant; deciduous species present as a minor component or absent 16
    14. Stand at high elevations (>2200 m); *Populus tremuloides* a dominant species ..... ASPEN WOODLAND
    14. Stand at low to middle elevations (<2000 m); *Populus tremuloides* not a dominant species 15
15. Stand in a canyon bottom at low elevation (<1500 m); *Rhamnus betulaefolia* a dominant species ..... HOPHORNBEAM-BOX ELDER-OAK WOODLAND
15. Stand along stream terraces at various elevations; *Populus fremontii* and *Chrysothamnus nauseosus* both dominant species ..... COTTONWOOD-RABBITBRUSH WOODLAND
    16. Stand at lower to middle elevations (<2400 m); dominant species include *Juniperus osteosperma* or *Pinus edulis* 17
    16. Stand at high elevations (>2400 m); dominant species include *Pinus ponderosa, Pinus longaeva,* or *Pseudotsuga menziesii* 24
17. Slickrock habitat; *Cercocarpus intricatus* a dominant species ..... DWARF MOUNTAIN MAHOGANY SLICKROCK COMMUNITY
17. Not slickrock habitat; *Cercocarpus intricatus* may be present but not dominant 18
    18. Pinus edulis rare or absent; dominant species include *Atriplex cuneata* or *A. confertifolia* ..... JUNIPER-SALTBUSH COMMUNITY
    18. Not as above 19

19. Dominant ground layer species include one or more of the following grasses: *Bouteloua gracilis, Muhlenbergia pungens, Oryzopsis hymenoides,* and *Stipa* spp. ..... PINYON-JUNIPER-GRASS COMMUNITY
19. Ground layer dominated by shrubs, or if grasses are important then the dominant species are other than those listed in the previous statement 20
    20. Dominant species include one or more of the following: *Cercocarpus intricatus, C. montanus, Cowania mexicana, Fallugia paradoxa, Amelanchier utahensis,* and *Berberis fremontii.* ..... PINYON-JUNIPER-TALL SHRUB COMMUNITY
    20. Dominant species include one or more of the following: *Ephedra* spp., *Chrysothamnus* spp., *Artemisia biglovii, Shepherdia rotundifolia,* but none of the species listed in the previous statement 21
21. *Artemisia pygmaea* a dominant shrub ..... PYGMY SAGEBRUSH PHASE OF PINYON-JUNIPER LOW SHRUB COMMUNITY
21. Not as above 22
    22. Ground layer dominated by cushion plants, including one or more of the following: *Phlox muscoides, Erigeron compositus, Hymenoxys depressa, Parthenium ligulatum, Penstemon caespitosus, Petrophytum caespitosum, Paronychia sessiliflora,* and *Arenaria eastwoodiae* ..... CUSHION PLANT PHASE OF PINYON-JUNIPER LOW SHRUB COMMUNITY
    22. Not as above 23
23. Ground layer dominated by one or more of the following grasses: *Hilaria jamesii, Bouteloua eriopoda,* and *Elymus salinis* ..... GALLETA PHASE OF PINYON-JUNIPER LOW SHRUB COMMUNITY
23. Not as above ..... PINYON-JUNIPER LOW SHRUB COMMUNITY
    24. Site with shallow soils, usually on Carmel Formation; dominant trees include *Pinus longaeva* ..... BRISTLECONE PINE - CUSHION PLANT COMMUNITY
    24. Not as above 25
25. Site in a ravine or canyon bottom; dominant species include one or more of the following: *Acer glabrum, Symphoricarpos oreophilus, Rosa woodsii,* and *Cornus stolonifera* ..... MESIC MONTANE WOODLAND
25. Site on upland slope or ridge; dominant species include *Pinus ponderosa* or *Pseudotsuga menziesii* 26
    26. Site with sandy soil; dominant species include *Arctostaphyolos patua* ..... PONDEROSA PINE - MANZANITA COMMUNITY
    26. Site with variable soil texture; dominant species include *Purshia tridentata* or *Cercocarpus ledifolius* 27
27. *Cercocarpus ledifolius* a dominant species ..... MOUNTAIN MAHOGANY PHASE OF PONDEROSA PINE - BITTERBRUSH COMMUNITY
27. *Cercocarpus ledifolius* not a dominant species ..... PONDEROSA PINE - BITTERBRUSH COMMUNITY
    28. Stand dominated by shrubs 29
    28. Stand dominated by grasses or forbs; shrubs may be present as minor constituents of the community 47
29. Site at high elevations (>2400 m); dominant species include *Artemisia nova* and *Purshia tridentata* ..... SAGEBRUSH - BITTERBRUSH COMMUNITY
29. Not as above 30
    30. *Coleogyne ramosissimum* a dominant species 31
    30. Not as above 32
31. Site with shallow, coarse soils; dominant species include *Chrysothamnus nauseosus* or *C. nauseosus* var. *biglovii* ..... BLACKBRUSH - RABBITBRUSH COMMUNITY
31. Site with sandy soils; dominant species include *Ephedra torreyana* ..... BLACKBRUSH - MORMON TEA PHASE OF EOLIAN SHRUB COMMUNITY
    32. Site with sandy soils; dominant species include *Artemisia filifolia* ..... SAND SAGE PHASE OF EOLIAN SHRUB COMMUNITY
    32. Site with variable soils; *Artemisia filifolia* not a dominant species 33
33. Dominant species include *Grayia brandegii;* usually very low plant cover (<25%) ..... HOPSAGE BADLANDS COMMUNITY
33. *Grayia brandegii* not a dominant species; variable plant cover 34
    34. Site on alluvial soils; dominant species include one or more of the following: *Sarcobatus vermiculatus, Artemisia tridentata,* and *Atriplex canescens* 35
    34. Site on variable soil types; dominant species do not include those listed in previous statement 37

35. Dominant species include *Sarcobatus vermiculatus* ..... GREASEWOOD - RABBITBRUSH PHASE OF INTERMITTENT RIPARIAN SHRUB COMMUNITY
35. *Sarcobatus vermiculatus* not a dominant species 36
    36. *Artemisia tridentata* is most abundant shrub species ..... BIG SAGEBRUSH PHASE OF INTERMITTENT RIPARIAN SHRUB COMMUNITY
    36. *Atriplex canescens* is most abundant shrub species ..... FOUR WING SALTBUSH PHASE OF INTERMITTENT RIPARIAN SHRUB COMMUNITY
37. Site in narrow canyon bottom; community dominated by erect shrubs 38
37. Site located other than in a narrow canyon bottom; community dominated by shrubs of various stature 39
    38. Dominant species include one or more of the following: *Cercocarpus intricatus, Amelanchier utahensis, Berberis fremontii, Symphoricarpos oreophilus,* and *Quercus gambelii* ..... MESIC CANYON BOTTOM SHRUB COMMUNITY
    38. Dominant species do not include any of the species listed in the previous statement; dominants do include *Fraxinus anomala* or *Rhus trilobata* ..... DRY CANYON BOTTOM SHRUB COMMUNITY
39. Dominant species include one or more of the following: *Ephedra viridis, Artemisia biglovii, Chrysothamnus viscidiflorus,* and *Shepherdia rotundifolia* 40
39. Dominant species do not include any of the species listed in the above statement 41
    40. *Pinus edulis* and/or *Juniperus osteosperma* present as more than just an occasional individual ..... PINYON - JUNIPER LOW SHRUB COMMUNITY
    40. *Pinus edulis* and *Juniperus osteosperma* absent or present only as an occasional individual ..... LOW SHRUB COMMUNITY
41. Dominant species include one or more of the following: *Atriplex cuneata, A. corrugata,* and *Eriogonum corymbosum;* total plant cover usually very low (<25%) 42
41. Dominant species do not include those listed in preceding statement; plant cover variable 44
    42. *Eriogonum corymbosum* a dominant species ..... BUCKWHEAT PHASE OF MAT SALTBUSH COMMUNITY
    42. Not as above 43
43. Grasses (e.g., *Hilaria jamesii, Oryzopsis hymenoides*) with >10% total cover ..... GRASS PHASE OF MAT SALTBUSH COMMUNITY
43. Grasses with <10% total cover ..... SHRUB PHASE OF MAT SALTBUSH COMMUNITY
    44. *Atriplex confertifolia* a dominant species 45
    44. Not as above 46
45. Grasses, including *Hilaria jamesii* and/or *Oryzopsis hymenoides,* together having >10% cover ..... SHADSCALE GRASSLAND COMMUNITY
45. Grasses having <10% total cover; *Atriplex cuneata* usually present ..... SHRUB PHASE OF MAT SALTBUSH COMMUNITY
    46. Site with sandy soils; dominant species include *Bouteloua gracilis* and/or *Muhlenbergia pungens* ..... EOLIAN GRASSLAND COMMUNITY
    46. Site with variable soils and other dominant species 47
47. *Atriplex confertifolia* a dominant species ..... SHADSCALE GRASSLAND COMMUNITY
47. Not as above ..... MIXED GRASSLAND COMMUNITY