

# Dune Communities of SE Colorado: Patterns of Rarity, Disjunction and Succession

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**ABSTRACT.** Dune communities occur across the western Great Plains and in isolated spots in eastern Colorado. They are biologically important due to their endemic nature, their rapid succession, and their ephemeral abundance in response to climate, grazing practices, and rangeland management. The abundance of these terrestrial islands has changed considerably over scales from tens to thousands of years. The Colorado dune communities have high conservation value due to their unusual biota and diminished presence. They also are of value as sentinel communities for more wide-scale biotic change in surrounding grasslands. These communities have not received detailed documentation of their interactive biotic and geological profiles in recent years. This study provides such a profile for an isolated dune complex in El Paso County, Colorado where we examine their plant species, vegetation patterns, and geochemical characteristics. Dune communities are threatened in part because of rangeland practices that seek to diminish their presence. We identify here areas of mutual interest and potential collaboration between ranchers and biologists that might serve to mitigate conflicts between conservation goals for a unique biota and the practical exigencies of rangeland management in semi-arid grasslands.

## INTRODUCTION

Dune “blowouts” occur as craters of unstable sand in dune fields around the globe. Across arid grasslands of southeastern Colorado, New Mexico and the western Great Plains, dune extent has varied over scales that range from thousands of years to less than a decade, responding to patterns of temperature, precipitation and aeolian activity as well as land use practices. Reports from nineteenth century explorers suggest that dunefields were then considerably more extensive than today (Muhs and Holliday, 1995), although expansion occurred during the 1930’s and 1950’s (McGinnies and others, 1991) due to

drought and inappropriate agricultural practices.

Signature vegetation patterns with unique elements of the grasslands flora (Rydberg, 1895; Pool, 1914; Rameley, 1939) occur across blowouts on their slopes, crests, and crater bottoms. Although not species-rich, blowout communities are of conservation concern in Colorado (Colorado Natural Heritage Program, 1999; 2001) due to their infrequency and the habitat endemism of the biota, in which some members are rare. Others exemplify disjunctions in distribution where substantial populations appear only in habitat islands across an intervening matrix of more vegetated grasslands on stabilized

soils. From a ranching point of view, however, blowout communities are problematic. They are prone to spreading and thus diminish range already limited in quality and quantity. For decades, ranchers have expended considerable effort to eradicate blowouts with attempts at revegetation and sand control. The prospect of a continuing drought and its related economic stresses have understandably exacerbated these concerns.

As land management practices have aimed at dune minimization conservation interest in these restricted communities has risen (Colorado Natural Heritage Program 2001) for several reasons. In addition to their unique biota, dune communities may be highly sensitive indicators of short and longterm climate change (Muhs and Maat, 1993; Muhs and Holliday, 1995; Muhs and others, 1996; Muhs and others, 1999, Swinehart, 1998). Early studies on plant succession in dune communities of Nebraska (Weaver, 1965, 1968; Weaver and Albertson, 1954) and northern Colorado (Ramaley, 1939) described species-specific phases that reflected interactive aspects of vegetation, climate and soil stabilization. In light of increasing concern about global warming and ecological impacts of climate change on grassland communities, the rapid succession on dune complexes in response to seasonal moisture and wind (McGinnies and others, 1991) suggests the potential to use dunes as sentinel communities for other more subtle changes in surrounding grasslands. Monitoring small-scale community changes could provide an early opportunity to detect wider scale changes and implement management strategies for grassland

systems under climatic and grazing stress.

Our study focused on a dune complex ca 50 km southeast of Colorado Springs Colorado in the Chico Basin region of El Paso County (Fig. 1). We held the following objectives:

- ❑ To document plant community stratification across the Chico Basin dunes and the dominant plant species that represent different stages of succession here.
- ❑ To document the regional dune flora with particular attention to the abundance and ecology of rare species.
- ❑ To provide a detailed topographic profile of the dune complex.
- ❑ To assess differences of soil texture on different dune faces that correlate with vegetation zonation.
- ❑ To provide a botanical and geological baseline for comparison with other dune complexes in southeastern Colorado and long term monitoring.
- ❑ To provide a vegetation-based system of assessment for dune succession to assist local ranchers in understanding the dynamics of local dune communities.
- ❑ To suggest strategies that might balance conservation of dune biota with the management needs of ranchers.

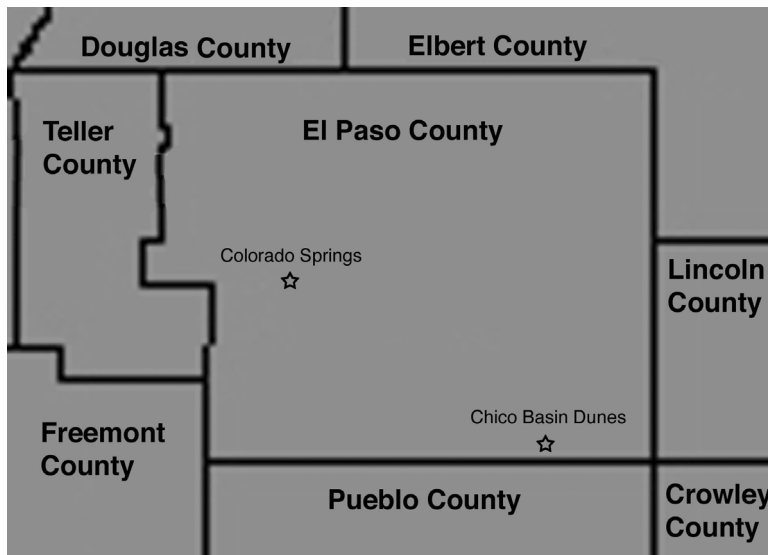


FIGURE 1. Location of Chico Basin dune system in El Paso County.

## METHODS

**Study Site.** The dominant vegetation of the Chico Basin region contains a complex of sand-sage and shortgrass prairies underlain by deep aeolian sands (Natural Resources Conservation Service, 2004). The area has been recognized by the Nature Conservancy as a significant conservation region for southeastern grasslands (The Nature Conservancy, 1998); it contains a number of potential conservation sites with high biotic values for the county (Colorado Natural Heritage Program, 2001). One of those sites is the dune complex. Given a history of intensive grazing, most of the grasslands have been impacted from their historical composition and the dunes are surrounded by dense stands of sand-sage with a few interspersed native grasses. Current grazing practices implemented over the past four years restrict cattle access to the dunes. The open sand complexes here occur in a three-dune cluster over a regional sand sheet of ca 1000 ha overall; the dunes are isolated from other large complexes in

northeastern Colorado by ca 270 km, although a few minor blowouts occur within 20 km.

This dune system consists of three blowout complexes; our primary study site was the largest and most northerly of them, covering about four km<sup>2</sup> with several connected parabolic dunes. Open craters occur primarily on the north and northwest faces, the direction of prevailing winds in the winter. Like other parabolic dune systems, these show long trailing edges in the

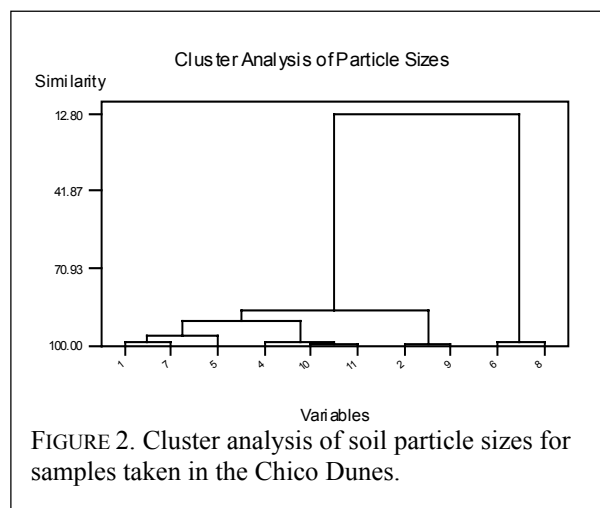
windward direction (Pye and Tsoar, 1990) with dune movement to the south. Aerial photographic records shows progressive dune stabilization and steadily increasing vegetative cover across the regional sand sheet from 1955 to the present; where significant blowouts were numerous across the landscape in the 1950's, the Chico complex is the only one remaining now.

**Vegetation Sampling.** We visited the site regularly from May to October 2003 for botanical surveys; preliminary surveys had been conducted on other dunes and blowouts in the area in 1999, 2000, and 2001. Vegetation stratification and dominant species across different dune faces were assessed throughout the growing season with voucher specimens deposited in the Colorado College Herbarium (COCO). Overall conditions with respect to rainfall and temperature in 2003 were consistent with 30-year averages after the exceptional drought year of 2002 (Table 1).

TABLE 1. Summer temperature and precipitation for Pueblo, CO. Data from [www.crh.noaa.gov/pub/climate](http://www.crh.noaa.gov/pub/climate) indicate short and longterm means for the months of June-August

| Year           | Daily Mean °F | Total Precipitation (inches) |
|----------------|---------------|------------------------------|
| 1999           | 75.3          | 5.03                         |
| 2000           | 74.2          | 4.88                         |
| 2001           | 74.2          | 5.80                         |
| 2002           | 76.5          | 1.57                         |
| 2003           | 75.0          | 5.21                         |
| mean 1971-2000 |               | 5.64                         |

**Soil Sampling and Topographic Mapping.** A baseline profile of the dune using a Trimble GPS unit was conducted in October, 2003 and soil samples corresponding to different dune aspects were collected and plotted at that time. Soil analyses were performed in the laboratory at Colorado College in the winter of 2003-2004. Physical fractionation was achieved with a series of sieves (Tyler #10, 25, 40, 50, 60, 70, 120, 140, and 230). The smallest particle size fraction ( $<63\mu$ ) was subsequently chemically fractionated and analyzed; the results of that analysis will be reported elsewhere. The particle size distributions were analyzed using cluster analysis (Minitab 13, 2000) to produce dendrograms (Fig. 2) and Excel to produce a histogram (Fig. 3) of particle sizes.



## RESULTS

**Soils.** The results of the soil particle size fractionation are presented in Fig. 3. The samples collected from the most exposed locations (6, 8) were generally on the windward side of the dunes, or in saddles between ridges. These locations are the most barren of vegetation and have the largest mean particle sizes. Samples from the leeward side of the dunes have on average a finer grain size and a more bimodal distribution of grain sizes. These sites (2, 9) exhibit more plant cover than that found on the windward sites. The third group (1, 5, 7) exhibits the greatest plant cover with samples taken from enclosed bowls and leeward sites. The final group of samples (4, 10, 11) is from locations on the south and northeast edge of the complex (4 and 10, respectively) where the underlying plain is not covered by loose sand, and from an extradunal site (11) a few kilometers west. These last sites exhibit the regionally abundant sand-sage and shortgrass cover.

**Flora and Vegetation.** The Chico Basin dune flora is relatively small. Our survey documented ca 50 species, representing 19 families (Appendix A). Almost half of the flora is composed of habitat specialists of deep open sandy soils; two species (*Chenopodium cycloides* and *Oxybaphus carletonii*) carry conservation tracking status with the Colorado Natural Heritage Program. We identified five vegetation zones representing different slope positions and aspects (Table 2). Dune zonation correlates with wind exposure and the concomitant different degrees of soil stability and textural profiles; they represent different successional stages of dune vegetation, with Zones I, II, and

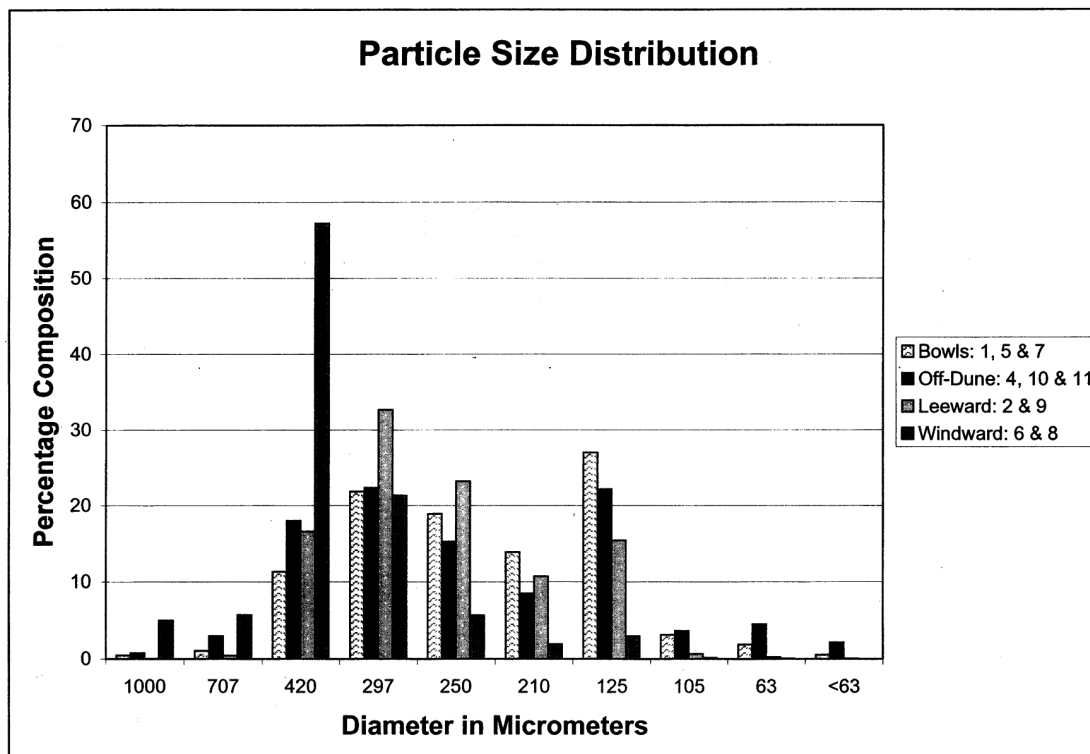


FIGURE 3. Histogram of particle sizes fractions for samples taken from the Chico Basin.

TABLE 2. Vegetation patterns occurring on the Chico Basin Dunes.

| Location                                               | Topography/<br>Cover           | Dominant Species                                                                                                              | Other Species                                                                                                                                                                                                                                                                                                 |
|--------------------------------------------------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I. Dune Crests                                         | Slope: 0 -<5%<br>Cover 40-50%  | <i>Redfieldia flexuosa</i> ,<br><i>Psoralidium lanceolatum</i><br><i>Muhlenbergia pungens</i>                                 | Sporadic annuals                                                                                                                                                                                                                                                                                              |
| II. Windward Craters                                   | Slope: 18-33%<br>Cover <10%    | <i>Psoralidium lanceolatum</i> ,<br><i>Muhlenbergia pungens</i>                                                               | <i>Euploca convolvulacea</i> , <i>Palafoxia sphacelata</i> , <i>Helianthus petiolaris</i>                                                                                                                                                                                                                     |
| III. Upper Leeward Slopes                              | Slope: 0 -10%<br>Cover 50-75%  | <i>Andropogon hallii</i> ,<br><i>Oryzopsis hymenoides</i> ,<br><i>Sporobolus giganteus</i> ,<br><i>Sporobolus cryptandrus</i> | <i>Polanisia jamesii</i> , <i>Oenothera latifolia</i> , <i>Cenchrus longispinus</i> ,<br><i>Asclepias arenaria</i> , <i>Ipomopsis longiflora</i> , <i>Helianthus petiolaris</i>                                                                                                                               |
| IV. Interdunal Leeward Swales and Lower Leeward Slopes | Slope: 0- <10%<br>Cover 50-75% | Mixed forbs, graminoids,<br>and suffrutescents                                                                                | <i>Corispermum</i> spp., <i>Chenopodium</i> spp., <i>Nuttalia nuda</i> , <i>Ambrosia</i> spp.,<br><i>Helianthus petiolaris</i> , <i>Physalis pumila</i> , <i>Machaeranthera</i> spp.,<br><i>Ipomopsis longiflora</i> , <i>Chamaesyce missurica</i> , <i>Oligosporous filifolius</i> ,<br><i>Aristida</i> spp. |
| V. Interdunal Windward Swales                          | Slope: 0- <10%<br>Cover 20-40% | <i>Psoralidium lanceolatum</i> ,<br><i>Helianthus petiolaris</i> ,<br><i>Corispermum</i> spp.,<br><i>Muhlenbergia pungens</i> | Sporadic annuals; outer crater edges on windward side transitioning into <i>Oligosporous filifolius</i> - <i>Aristida</i> spp. community                                                                                                                                                                      |

inner Zone V being in early succession (soil samples 6 & 8), Zones II and IV in intermediate succession (soil samples 1, 2, 5, 7 & 9), and outer Zone V (soil samples 4, 10) in late succession.

#### DISCUSSION

Dune Flora. Regional differences in climate and the surrounding source floras provide minor floristic differences between these dunes and those documented in the early studies of Ramaley (1939) and Poole (1914). These differences may also reflect the shifts in plant community composition that plains grasslands underwent following the droughts of the 1930's and 1950's (Weaver and Albertson 1954). Since the studies were done, additional decades of intensive grazing impact coupled with periods of drought decreased components of native grasses such as little bluestem (*Schizachyrium scoparium*) and increased the density of sand-sage (*Oligosporous/Artemisia filifolius*) shrubland across the plains (Weaver and Albertson 1954). However, with the exception of small differences in composition, the dune vegetation here generally correlates to that seen on other Great Plains dune systems as profiled by Weaver (1965), McGinnies et al. (1991), Ramaley (1939) and Poole (1914).

Vegetation Patterns and Soils. As in other plains dune systems, pioneer stages are dominated by a few rhizomatous species, notably blowout grass (*Redfieldia flexuosa*), lemon scurfpea (*Psoralidium lanceolatum*) and sand muhly (*Muhlenbergia pungens*), followed by intermediate stages where these species drop out and the vegetation is dominated by tall bunchgrasses, tap-rooted perennials and annuals. Later

succession brings the incursion of bunchgrasses such as three-awn (*Aristida* spp.) and sand-sage. On the Chico Basin dunes, early succession occurs in Zones 1, 2 and inner portions of 5 (Table 2). These zones on dune crests and craters have highly unstable soils dominated by the rhizomatous species with a few seasonally abundant annuals. Soils of early successional zones are dominated by larger particle sizes as would be expected where active ablation occurs (Fig. 4, samples 6 & 8, mode at 420  $\mu$ ). Intermediate successional phases seen in Zones 3 and 4 (leeward slopes and swales) hold the greatest diversity of plant species; these soils have with the greatest percentage of intermediate particle sizes (Fig. 3, samples 1-5, 7, mode at 300  $\mu$ m). Outer Zone 5 (leeward interdunal swales transitioning into shrub-grassland) is in late successional stage. Soils here are dominated by finer particle sizes (Fig. 3, samples 4, 9-11, mode at 125  $\mu$ ). Approximately one third of the study site lies in each of the early, middle, and late successional stages.

Much of the dune complex has some plant cover during the growing season. The greatest cover occurs in June when annuals appear and in August-September with late summer moisture initiating a resurgence in flowering, seed head development of grasses, and appearance of late season species typical of dunes. This progression makes estimates of vegetative cover quite variable according to the month of the year. In winter and early spring, the dunes appear to hold much less vegetative cover overall than they do in the growing season; even within this season, apparent cover varies

according to the degree to which certain temporally sensitive species are present.

#### Plant Diversity and Succession.

Leeward swales and slopes representing intermediate stages of succession have the highest plant diversity. This diversity correlates with a larger percentage of mid-range soil particle sizes, in comparison to late succession where finer particle sizes dominate the soils and to early succession where larger particle sizes dominate. Wind protection, mid-range of particle sizes and downslope position may contribute to species diversity here by positively influencing soil water availability and substrate stability. This leeward flora includes large populations of *Chenopodium cycloides* (sand goosefoot), a rare dune endemic for Colorado and New Mexico (conservation rating S1 and S2, respectively) and habitat specialists such as sand bluestem (*Andropogon hallii*), sand milkweed (*Asclepias arenaria*) and sand gilia (*Ipomopsis longiflora*). Other examples include woolly indigo bush (*Dalea villosa*), James' clammyweed (*Polanisia jamesii*) and broad-leaved evening primrose (*Oenothera latifolia*). While these do not generally carry ratings for immediate conservation concern, substantial populations are restricted to the occurrence of deep, open dune soils. As dune control has made such habitats increasingly sporadic and diminished in extent, populations of such endemics become restricted in numbers. Here they are abundant throughout the complex but notably lacking in the surrounding communities and regionally uncommon. Although zoological surveys were not part of this study, we consistently observed a diversity of vertebrates and invertebrates. Tiger beetle (*Cicindela*)

species are often associated with dune complexes and at least two species of tiger beetles are already known from the Chico dunes; other may occur here as well (Bleed and Flowerday 1998; Colorado Natural Heritage Program 2001). Some of the dune fauna may be of conservation interest as they are in other dune complexes (Bleed and Flowerday 1998).

Dune Succession and Management. The overall stability of any dune complex can be assessed by the relative amount of each successional zone that occurs; the clarity of these species-specific zones also makes it easy to track annual changes in dune systems. For management purposes, dunes with large areas in early succession are more likely to be expansive than those with more area in intermediate and late stages that indicate stabilizing soils. Expansive dune complexes benefit from grazing control at least in the growing season and/or revegetation with stage-appropriate species such as the rhizomatous species in *Redfieldia*, *Muhlenbergia*, and *Psoralidium*.

Allowing some open dune complexes to persist could be an effective way of providing nearby source material for introduction or reintroduction of stabilizing species in the event of dune reactivation. This could be particularly important after successive drought years that diminish or eliminate soil seed banks and as long distances between open dune fields make seed dispersal more difficult. Nearby blowout complexes, even small ones, may provide a source for seeds or rhizomatous genets. As vegetation of any sort slows sand movements, even annual species may enhance the rate of succession on dune fields and provide ecological benefits. Thus, an argument

can be made for allowing small dune complexes to persist at different stages and for grazing restrictions to allow stabilizing species to become established.

Small regional source complexes not only have the potential to enhance cover on problematic complexes, they also provide signals of regional change that may be occurring at a more subtle level. Reversion to earlier successional stages in a small, easily monitored complex, for example, would suggest imminent regional dune reactivation and grazing practices adjusted accordingly. Dune endemic species may be particularly well adapted to living in relatively small colonies and thus maintenance of even small blowout communities promotes persistence of their biota.

#### CONCLUSIONS

Dune blowout complexes are unique systems that have not received as much biological attention as they might merit, in part because of their arguably problematic nature, and in part because of a flora that can lack visual appeal and is often taxonomically challenging. However, dunes command interest due to their signature flora and fauna, some components of which are rare and many endemic. Plant-animal interactions as well as dune invertebrate diversity and ecology remain poorly known. Dune systems have diminished in recent years due to active eradication programs and these communities are increasingly disparate. They carry the potential to serve as indicators for other regional ecological changes. However, the merits of dune conservation must be balanced with the management concerns that recognize a region under economic and climatic stress. Given that major dune reactivation would pose a significant

threat, concerns about dune stability are fully justified. However, dune conservation is not incompatible with dune control; collaboration between ranchers and biologists can accommodate different objectives. Detailed surveys and monitoring, using dune assessment for strategic management, and viewing at least modest dune complexes for their potential as early warning signals for system dynamics and as revegetation sources may promote collaboration towards the compatible goals of promoting grassland health and stabilizing an intriguing biota as well.

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Appendix A. Plant Species of Chico Basin  
Ranch: northern sandhills open dune  
communities.

Nomenclature follows Weber & Wittmann (2001),  
unless otherwise noted; commonly recognized  
alternative genera are given in parentheses. Species  
with an asterisk \* are ecological specialists to sandy  
soils.

**Amaranthaceae**

*Amaranthus arenicola* I.M. Johnston\*

**Asclepiadaceae**

*Asclepias arenaria* Torrey\*

**Asteraceae**

*Ambrosia acanthicarpa* Hooker

*Ambrosia artemisiifolia* L.

*Ambrosia psilostachya* DC

*Cirsium undulatum* (Nuttall) Sprengel

*Erigeron bellidiastrum* Nuttall\*

*Helianthus petiolaris* Nuttall

*Heterotheca canescens* (DC) Shinnars

*Machaeranthera bigelovii* (Gray) Greene

*Machaeranthera linearis* Greene\*

This taxon is delineated by the Great Plains Flora  
(1986) as a morphologically distinctive member  
of *Machaeranthera* that is known only from deep  
sandy soils. Our material fits the description of this  
taxon with narrow upright rayflowers and single  
stems; it is easily distinguished from more  
characteristic *M. bigelovii* that occurs around the  
dunes.

*Oligosporus* [*Artemisia*] *filifolius* (Torrey) Poljakov\*

*Palafoxia sphacelata* (Nuttall) Cory\*

**Boraginaceae**

*Euploca convolvulacea* Nuttall\*

*Oreocarya* [*Cryptantha*] *suffruticosa* (Torrey) Greene

**Cactaceae**

*Opuntia macrorhiza* Engelm

**Capparaceae**

*Polanisia jamesii* (Torrey & Gray) Iltis\*

**Chenopodiaceae**

*Chenopodium cycloides* Nelson\*

*Chenopodium leptophyllum* (Nuttall) Watson

*Corispermum americanum* (Nuttall) Nuttall\*

*Corispermum villosum* Rydberg\*

*Cycloloma atriplicifolium* (Sprengel) Coulter\*

**Cyperaceae**

*Mariscus schweinitzii* (Torrey) Koyama\*

**Euphorbiaceae**

*Chamaesyce missurica* (Rafinesque) Shinnars

*Croton texensis* (Klotsch) Muller-Argoviensis\*

**Fabaceae**

*Astragalus ceramicus* Sheldon\*

*Dalea villosa* (Nuttall) Sprengel\*

[*Lupinus pusillus* Pursh]

This species was not found in the primary dune  
complex but occurred in small blowout craters in the  
surrounding 3 km so is included here as part of the  
dune community flora.

*Psoralidium* [*Psoralea*] *lanceolatum* (Pursh) Rydberg

**Fumariaceae**

*Corydalis curvisiliqua* Englemann

**Loasaceae**

*Nuttallia nuda* (Pursh) Greene

**Nyctaginaceae**

*Abronia fragrans* Nuttall\*

*Oxybaphus glaber* Watson

[*Oxybaphus carletoni* (Standley) Weatherby]

This species was not found in the primary dune  
complex but occurred in small blowout craters in the  
surrounding 3 km so is included here as part of the  
dune community flora. Taxonomic disagreement  
occurs as to whether or not this is a recognizable taxon  
at the species level, but the dune forms in our region  
are sufficiently distinctive from *O. glaber* that we  
recognize it as such here.

**Onagraceae**

*Oenothera albicaulis* Pursh

*Oenothera latifolia* (Rydberg) Munz.\*

**Poaceae**

*Andropogon hallii* Hackel\*

*Aristida divaricata*\* Humboldt & Bonpland

*Aristida purpurea* Nuttall

*Chondrosium* [*Bouteloua*] *hirsuta* (Lagasca) Sweet

*Calamovilfa longifolia* (Hooker) Scribner\*

*Cenchrus longispinus* (Hackel) Fernald\*

*Muhlenbergia pungens* Thurber\*

*Redfieldia flexuosa* (Thurber) Vasey\*

*Sporobolus giganteus* Nash\*

*Triplasis purpurea* (Walter) Chapman\*

**Polemoniaceae**

*Ipomopsis longiflora* (Torrey) V. Grant\*

**Polygonaceae**

*Eriogonum annuum* Nuttall\*

*Eriogonum effusum* Nuttall

**Santalaceae**

*Comandra umbellata* (L.) Nuttall

**Solanaceae**

*Physalis pumila* Nuttall ssp. *hispida* (Waterfall)  
Hinton\*