Astragalus missouriensis Nutt. var. *humistratus* Isely (Missouri milkvetch): A Technical Conservation Assessment

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COVER PHOTO CREDIT

Astragalus missouriensis var. *humistratus* (Missouri milkvetch). Photograph by Peggy Lyon, used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ASTRAGALUS MISSOURIENSIS* VAR. *HUMISTRATUS*

Status

Astragalus missouriensis var. *humistratus* (Missouri milkvetch) is a local endemic plant whose global distribution is limited to the upper basin of the San Juan River in southwestern Colorado and northwestern New Mexico. Documented locations include four sites on the Pagosa and Columbine Ranger Districts of the San Juan National Forest in USDA Forest Service (USFS) Region 2, and one on the Jicarilla Ranger District of the Carson National Forest in USFS Region 3. The species is also known from Southern Ute tribal lands and private property. Although data are lacking, population numbers generally appear to be small. *Astragalus missouriensis* var. *humistratus* is considered a sensitive species in USFS Region 2. NatureServe has assigned it a rank of G5T1 (a critically imperiled variety of an otherwise widespread and common species), and the Colorado Natural Heritage Program has assigned it a rank of S1 (critically imperiled in the state) due to its small global distribution. It is not listed as threatened or endangered on the Federal Endangered Species List (ESA of 1973, U.S.C. 1531-1536, 1538-1540).

Primary Threats

Based on the available information, threats to *Astragalus missouriensis* var. *humistratus* in approximate order of decreasing priority include effects of small population size, land development, surface disturbance, invasive species, air pollution, and global climate change. The entire global range of *A. missouriensis* var. *humistratus* is small (about 800 square miles), and effects of threats to the population may be compounded by this restricted range.

Primary Conservation Elements, Management Implications and Considerations

Because most known populations of *Astragalus missouriensis* var. *humistratus* have not been repeatedly or recently observed, it is impossible to give an accurate tally of the total numbers of individuals of the species in existence, much less any sort of analysis of population trends. This lack of quantitative information also makes it difficult to assign a conservation status with any degree of confidence.

Land and resource development activities that result in surface disturbance are the primary source of habitat change in the area. Anthropogenic activities that fragment the habitat of *Astragalus missouriensis* var. *humistratus* are increasing throughout its range, especially in the Pagosa Springs area, and could have a negative effect on the persistence of the species in the Region. The dispersed nature of the *A. missouriensis* var. *humistratus* populations may render them especially susceptible to environmental changes or management policies that introduce fragmentation into once continuous habitat. The co-occurrence of *A. missouriensis* var. *humistratus* with several other rare species should enable management and conservation efforts for this species to be linked with efforts to preserve other sensitive species in the area.

TABLE OF CONTENTS

EDITOR: Richard Vacirca, USDA Forest Service, Rocky Mountain Region

List of Tables and Figures

Tables:

Figures:

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2), USDA Forest Service (USFS). The Missouri milkvetch (*Astragalus missouriensis* var. *humistratus*) is the focus of an assessment because it is designated a sensitive species in Region 2 (USDA Forest Service 2005). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (USDA Forest Service Manual 2670.5(19)). A sensitive species requires special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *A. missouriensis* var. *humistratus* throughout its range in Region 2 and in adjacent areas of Region 3. This introduction defines the goal of the assessment, outlines it scope, and describes the process used in its production.

Goal of Assessment

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, and conservation status of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Instead, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and, examines the success of those recommendations that have been implemented.

Scope of Assessment

This assessment examines the biology, ecology, and management of *Astragalus missouriensis* var. *humistratus* with specific reference to the geographic and ecological characteristics of USFS Region 2. Although some of the information on this species and its congeners is derived from field investigations outside the region, this document places that information in the ecological context of the central and southern Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *A. missouriensis* var. *humistratus* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but it is placed in a current context.

In producing this assessment, refereed literature, non-refereed publications, research reports, herbarium specimens, and data accumulated by resource management agencies were reviewed. There are no refereed publications devoted entirely to *Astragalus missouriensis* var. *humistratus*, but it is mentioned in a variety of sources. As far as is known, all publications that include information on *A. missouriensis* var. *humistratus* are referenced in the assessment. Because basic research has not been conducted on many facets of the biology of *A. missouriensis* var. *humistratus*, literature on its congeners was used to make inferences. The refereed and non-refereed literature on the genus *Astragalus* and its included species is more extensive and includes many endemic or rare species. Material treating non-native species of *Astragalus* was generally omitted. For reference, Barneby's (1964) classification of each conspecific mentioned is given in **Table 1**.

This assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were used in the assessment when refereed material directly pertaining to *Astragalus missouriensis* var. *humistratus* was lacking. However, these reports should be regarded with greater skepticism.

In this document, the term population or populations is used to refer to discrete groups of *Astragalus missouriensis* var. *humistratus* individuals that are separated by at least 1 km. Within a population, individual plants may be distributed in a more-or-less patchy fashion, but all are within the minimum separation distance. This usage is synonymous with "occurrence" as used by NatureServe and state Natural Heritage Programs. In this usage, population/occurrence implies that members of such a group are much more likely to interbreed with one another than with members of another group. To lessen confusion, I have often used the term "location" or "station" to refer to such a discrete group. In this document, the term population is not used to refer to the entire complement of *A. missouriensis* var. *humistratus* individuals present in Region 2 or worldwide (the meta-population).

Table 1. Classification of *Astragalus* species mentioned in this document (Barneby 1964).

Astragalus species	"Phalanx"	"Series"	Section	Subsection
miser	B. Homaloboid	*Genuine Homalobi	XI. *Genistoidei*	—
lonchocarpus	B. Homaloboid	*Genuine Homalobi	XII. *Lonchocarpi*	*Lonchocarpi*
applegatei	B. Homaloboid	*Genuine Homalobi	XIV. *Solitarii*	—
kentrophyta	B. Homaloboid	*Genuine Homalobi	XX. *Ervoidei*	*Submonospermi*
montii (*limnocharis* var. *montii*)	B. Homaloboid	**Piptoloboid Homalobi	XXIII. *Jejuni*	—
linifolius	B. Homaloboid	***Seleniferous Homalobi	XXIX. *Pectinati*	*Pectinati*
osterhouti	B. Homaloboid	***Seleniferous Homalobi	XXIX. *Pectinati*	*Osterhoutiani*
oocalycis	B. Homaloboid	***Seleniferous Homalobi	XXVIII. *Oocalyces*	—
neglectus	B. Homaloboid	*****Arrect Homalobi	LII. *Neglecti*	—
scaphoides	B. Homaloboid	*****Arrect Homalobi	XLII. *Reventi-arrecti*	*Eremitichi*
***missouriensis* (all var.)**	**E. Piptoloboid**	***Large-flowered Piptolobi**	**LVI. *Argophylli***	***Missourienses***
bibullatus	E. Piptoloboid	*Large-flowered Piptolobi	LXI. *Sarcocarpi*	*Sarcocarpi*
tennesseensis	E. Piptoloboid	*Large-flowered Piptolobi	LXII. *Tennesseenses*	—
lentiginosus var. *salinas*	E. Piptoloboid	***Small-flowered Piptolobi	LXX. *Diphysi*	—
lentiginosus var. *wahweepensis*	E. Piptoloboid	***Small-flowered Piptolobi	LXX. *Diphysi*	—
amblytropis	E. Piptoloboid	***Small-flowered Piptolobi	LXXIV. *Platytropides*	—
cremnophylax var. *cremnophylax*	E. Piptoloboid	***Small-flowered Piptolobi	LXXVII. *Humillimi*	*Humillimi*

Outline designations (letters, asterisks, roman numerals) given as in the original source.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. Because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). It is difficult, however, to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, critical thinking, and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty, then, is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Treatment of This Document as a Web Publication

To facilitate the use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site (http://www.fs.fed.us/r2/projects/scp/index.shtml). Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, Web publication facilitates the revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review of This Document

Assessments developed for the Species Conservation Project have been peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Astragalus missouriensis var. *humistratus* is considered a sensitive species in Region 2 of the USFS (USDA Forest Service 2005). The 15 documented locations of this species include at least three sites on the Pagosa Ranger District and one on the Columbine Ranger District of the San Juan National Forest in Region 2. One site is located on the Jicarilla Ranger District of the Carson National Forest in USFS Region 3 (**Figure 1**). Although *A. missouriensis* var. *humistratus*

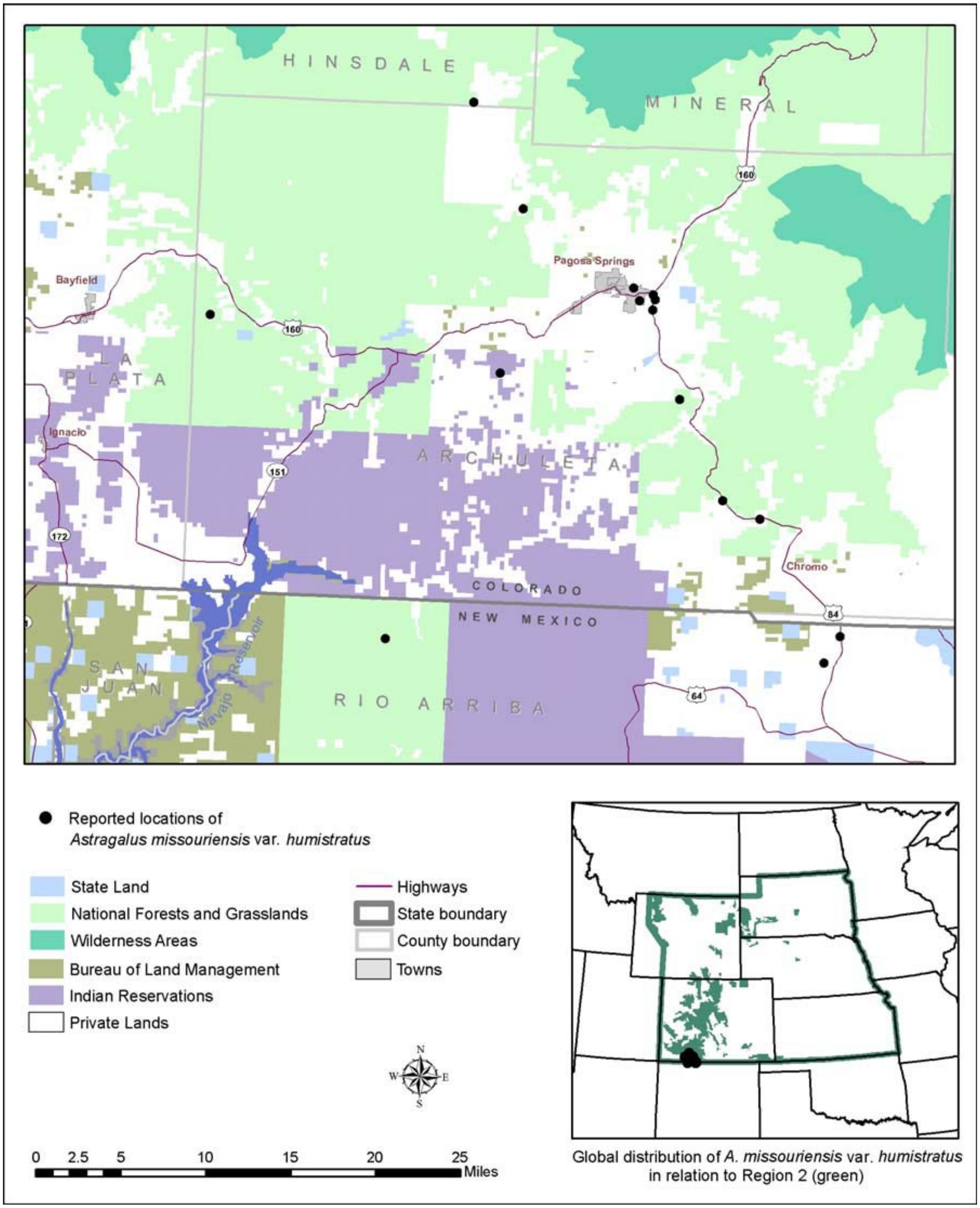


Figure 1. Land ownership in the distribution of *Astragalus missouriensis* var. *humistratus*.

occurs in Region 3 within New Mexico, it is not designated a sensitive species in that region (USDA Forest Service 2000). The species is also not included on Bureau of Land Management Sensitive Species Lists for Colorado or New Mexico. Of the five locations on USFS land in Regions 2 and 3, none are in designated wilderness areas or Research Natural Areas. Although none of the USFS lands supporting *A. missouriensis* var. *humistratus* is specifically managed for the conservation of that species, Forest Service Manual directions regarding sensitive species require that management actions be reviewed for potential effects on these species, and that any impacts be minimized or avoided. Any impact allowed must not result in loss of species viability or create significant trends toward Federal listing (USDA Forest Service Manual 2670.32).

The current global NatureServe rank for *Astragalus missouriensis* var. *humistratus* is G5T1 (NatureServe 2005). In this ranking system, the status of an infraspecific taxon (subspecies or variety) is indicated by a "T-rank" following the global rank. The global (G) rank is based on the status of a taxon throughout its range. A G5 ranking is defined as "Secure-Common; widespread and abundant" (NatureServe 2005). The T1 ranking indicates that the infraspecific taxon (variety) is considered "Critically Imperiled, at very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors" (NatureServe 2005). In the case of *A. missouriensis* var. *humistratus*, the G5T1 ranking indicates that it is a critically imperiled variety of an otherwise widespread and common species. The State Natural Heritage Program ranking is S1 for Colorado, the only state in which this species is tracked. The state (S) rank is based on the status of a taxon in an individual state. As with the T1 global rank, the S1 ranking indicates that the species is considered "Critically Imperiled in the nation or state/province because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state/province" (NatureServe 2005). Although more than five occurrences were documented during the compilation of this assessment, the S1 ranking for Colorado will be retained until better information about the size and viability of the additional locations is available. The New Mexico Natural Heritage Program does not track this variety of *A. missouriensis*.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Astragalus missouriensis var. *humistratus* is not listed as threatened or endangered in accordance with the Endangered Species Act; therefore there are no laws concerned specifically with its conservation. Because it is on the sensitive species list in Region 2, USFS personnel are required to "develop and implement management practices to ensure that species do not become threatened or endangered because of Forest Service activities" (USDA Forest Service Manual, Region 2 supplement, 2670.22). As of this writing, a conservation strategy has not been written for this species at a national or regional level by the USFS or any other federal agency. All occurrences of *A. missouriensis* var. *humistratus* on the San Juan National Forest are on lands managed for multiple uses.

Adequacy of current laws and regulations

Although USFS policy requires the maintenance of viable populations within the planning area, population trend data that would allow an evaluation of the conservation status of *Astragalus missouriensis* var. *humistratus* are generally not available. There is no way to know whether current management practices on lands supporting *A. missouriensis* var. *humistratus* populations are effective in protecting the species in the long term. It is unlikely that the species could be suddenly decimated by anthropogenic activities, but without range-wide monitoring of the species, individual populations could decline and disappear without much notice.

Adequacy of current enforcement of laws and regulations

There are no confirmed instances in which populations of *Astragalus missouriensis* var. *humistratus* have been extirpated by human activities, but it is probable that a few such occurrences have gone unrecorded. Populations in the immediate vicinity of Pagosa Springs are most likely to have been eliminated or impacted as a result of development in the area. Because location information is so imprecise for some older specimens, there is no way to relocate the occurrences with any certainty, and hence no way to determine if the population is extant.

Biology and Ecology

Classification and description

Astragalus missouriensis var. *humistratus* is a member of the Pea Family (Fabaceae, sometimes known as Leguminosae). This family is a member of the Class Angiospermae (flowering plants), Subclass Dicotyledoneae (dicots), Superorder Rosidae, Order Fabales (formerly Order Leguminales) (Heywood 1993). The Fabaceae is among the largest of the plant families, containing something on the order of 600 to 700 genera and 13,000 to 18,000 species (Smith 1977, Heywood 1993, Zomlefer 1994). Within this large family, the genus *Astragalus* falls under the subfamily Papilionoideae (also known as Lotoideae or Faboideae). Members of this subfamily are characterized by having papilionaceous or butterfly-like flowers. More than two thirds of the Fabaceae are in this group, including most of the commonest species (Zomlefer 1994).

Within the subfamily Papilionoideae, Heywood (1993) recognizes 10 to 11 tribes. The genus *Astragalus* is part of the tribe Galegeae (characterized by pinnate leaves, with 5 or more leaflets), of which it is the largest member, comprising some 1,600 to 2,000 species worldwide (Smith 1977, Zomlefer 1994). The worldwide distribution of *Astragalus* is cosmopolitan outside the tropics and Australia (Allen and Allen 1981), and the greatest concentration of *Astragalus* species is in southwestern Asia (Isely 1983a). Species commonly occur in prairies, steppes, and semi-desert areas (Allen and Allen 1981). Western North America is a center of *Astragalus* diversity for the western hemisphere, and many of those species are broadly to narrowly endemic (Barneby 1964).

Beginning with Torrey and Gray's (1838) Flora of North America, North American *Astragalus* have largely been considered separately from the Old World species. North American treatments have tended to focus on characters of the fruit while European and Asian species have historically been differentiated by characters involving the stipules, leaves, vesture, calyx, and petals (Barneby 1964). Barneby (1964) notes that "Perhaps the most remarkable single characteristic of the genus *Astragalus* as a whole, and it is especially marked in North America, is that there are hardly two species, even very closely related, which do not differ one from another in form or structure of the fruit". This characteristic allows for easy description of individual species, but at the same time, it is less valuable as an indicator of phylogeny (Barneby 1964). While recent phylogenetic research in *Astragalus* (e.g., Liston 1990, Sanderson 1991, Sanderson and Doyle 1993, Liston and Wheeler 1994, Sanderson and Wojciechowski 1996, Wojciechowski et al. 1999, Wojciechowski 2005) has led to some rearrangement of species within subsections, overall the work has tended to confirm the basic structure of Barneby's classification.

The monumental revision of Barneby (1964) presents 368 species and 184 varieties for a total of 552 taxa. Barneby's treatment is still widely accepted and used, due to its broad scope, thorough assessment of variation, and attention to detail. Isely's (1983a, 1984, 1985, 1986) treatments largely follow Barneby, adding new information as appropriate, and presenting entirely new keys. His 1998 synopsis includes 375 species, and with varieties, about 570 taxa.

History of knowledge

Astragalus missouriensis is a common species of the western Great Plains from Canada to Texas, first collected by Lewis and Clark, and subsequently described by Nuttall (1818). Since its original description, a number of distinct varieties have been recognized. Barneby, in his 1947 revision of section *Argophylli*, distinguished a single variety (var. *amphibolus*) from the parent taxon, then designated var. *typicus*. In his 1964 revision of the genus, Barneby added var. *mimetes*, and redesignated the original taxon as var. *missouriensis*. At the same time, he continued the treatment of the closely related *A. accumbens* as a distinct species. *Astragalus accumbens* was later recombined with *A. missouriensis* as var. *accumbens* by Isely (1983b), but this treatment has not been adopted by all authorities. The variety eventually recognized as *A. missouriensis* var. *humistratus* was first mentioned by Barneby (1964) as "a remarkable form of *A. missouriensis*, locally common on barren clay hills about Pagosa Springs in Archuleta County, Colorado." Barneby (1964) included a brief description, but he did not give the variety further nomenclatural treatment, noting merely that it resembled a possible hybrid between *A. missouriensis* and *A. humistratus* var. *humistratus*, which reaches its northern extent near the Colorado-New Mexico border. The variety was eventually described as *A. missouriensis* var. *humistratus* by Isely (1983b), completing the current catalog of *A. missouriensis* varieties. The potential hybrid origin of *A. missouriensis* var. *humistratus* has never been investigated. **Figure 2** shows the generalized distributions of all varieties of *A. missouriensis*.

The type specimen of *Astragalus missouriensis* var. *humistratus* is Weber and Livingston 6348, housed at the University of Colorado (COLO) as accession number 8005. Additional specimens are housed at the University of Colorado (COLO), University of Northern Colorado (GREE), Rocky Mountain Herbarium (RM), San Juan College (SJNM), New Mexico State University (NMC), Iowa State University (ISC), New York Botanical Garden (NY), and possibly at other locations.

Barneby (1964) places the varieties of *Astragalus missouriensis* in the Piptoloboid Phalanx, large-flowered Piptolobi, under section *Argophylli*, subsection *Missourienses*, together with *A. castaneiformis*, *A. chamaeleuce*, *A. amphioxys*, *A. musimonum*, *A. cymboides*, and *A. accumbens*. *Astragalus missouriensis* var. *humistratus* is more-or-less sympatric with varieties *missouriensis* and *amphibolus*, and specimens currently identified as var. *missouriensis* or var. *amphibolus* have been collected at several locations where var. *humistratus* was also collected, including the type locality.

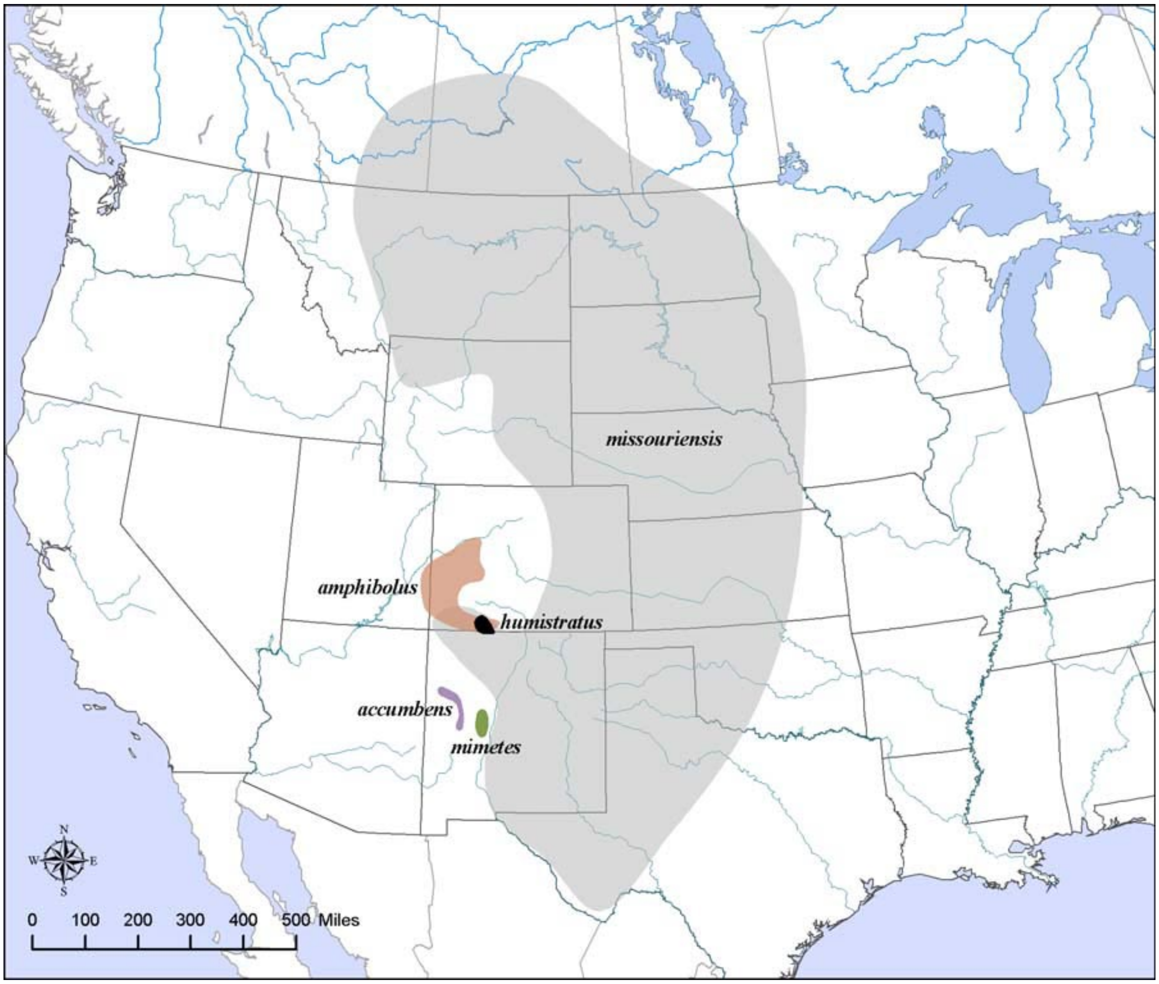


Figure 2. Generalized distribution of all varieties of *Astragalus missouriensis*.

Recent knowledge of *Astragalus missouriensis* var. *humistratus* has been augmented by biological inventory surveys in Archuleta County (Lyon personal communication 2005) and by occasional collections in Colorado and New Mexico by area botanists.

Description

As described by Barneby (1964) and Isely (1983b, 1986, 1998), *Astragalus missouriensis* var. *humistratus* is a low-growing perennial with greenish-gray foliage. In contrast to other *A. missouriensis* varieties, var. *humistratus* has noticeable aboveground prostrate stems 7 to 20 cm in length (**Figure 3**). Stipules (scale-like appendages) are present at the base of the leaf stalk, and in var. *humistratus* these are 2 to 11.5 mm long, fused together (connate), and clasping the leaf stalk (amplexicaul). The pinnately compound leaves are 4 to 14 cm in length, and typically have 11 to 17 narrowly elliptic leaflets. The racemes typically hold 8 to 12 ascending or spreading flowers with pinkish-purple, white-tipped petals. Flowers of the varieties *missouriensis*, *humistratus*, and *amphibolus* are large, with total length of calyx and banner typically in the range of 23 to 35 mm. The legumes (pods) are oblong-ellipsoid, straight, about 1.7 to 2 cm in length, without hairs (or very sparsely pubescent along the ventral suture and on the beak), and they remain on the plant after seeds have dispersed. Pods contain 33 to 40 ovules, and seeds are small (about 2 to mm long). **Table 2** summarizes the distinguishing characters of the varieties of *A. missouriensis*.

Published descriptions and other sources

Technical descriptions are available in Barneby (1964) and Isely (1983b, 1986, 1998). The variety *humistratus* is not yet included in regional floras or rare plant publications. A photograph of the plant in flower and fruit is shown in **Figure 4**.

Figure 3. Herbarium specimen (H.M. Schmoll 1085) of *Astragalus missouriensis* var. *humistratus*, showing aboveground prostrate stems. Photograph by the author.

Table 2. Distinguishing characters of the varieties of *Astragalus missouriensis* (Barneby 1964, Isely 1985).

	missouriensis	***humistratus***	***amphibolus***	***accumbens***	***mimetes***
Flower size (calyx + banner) and number	large (25-38 mm), 5-15	large (16-30 mm), mostly 8-12	large, usually 4-8	small (~15 mm)	small (~15 mm)
Pod	straight	straight	usually abruptly upturned, at least at the tipusually abruptly upturned, at least at the tip	straight	straight, smaller than *missouriensis*
Stipules	Free	connate or amplexicaul	free	semi- or fully amplexicaul but none connate	free?
Stems	subcaulescent to shortly caulescent	strongly caulescent	shortly caulescent	acaulescent to shortly caulescent	subcaulescent to shortly caulescent
Range	Widespread east of the continental divide from Canada to Texas, extending around the south foothills of the rockies to the upper San Juan River in nw NM and sw CO	CO: Archuleta and Hinsdale counties, (potentially La Plata) NM: Rio Arriba county	CO: Garfield to La Plata and Montezuma counties UT: Grand and San Juan counties	NM: McKinley and Catron counties	NM: Valencia and Socorro counties

Figure 4. *Astragalus missouriensis* var. *humistratus* in flower and fruit. Photograph by Peggy Lyon, used with permission.

Distribution and abundance

Documented locations of *Astragalus missouriensis* var. *humistratus* are shown in **Figure 1**, and they are listed in detail in **Table 3**. Because a nationwide herbarium search was not conducted for this assessment, there may be other specimens of *A. missouriensis* var. *humistratus* that could be added to the list of known locations. Due to the lack of precise location information on many herbarium specimens, land ownership/management could not be determined for some sites. The species is known from just 15 locations, 12 in Colorado representing at least eight distinct populations, and three in New Mexico. At least four of the Colorado locations are on the San Juan National Forest, and one New Mexico location is on the Carson National Forest. Two Colorado locations are not known with enough precision to determine ownership/management status and may be on either San Juan National Forest or privately owned land. One occurrence is known from Southern Ute tribal land in Colorado, and the remaining seven are on privately owned land. No occurrences have been documented from lands under other ownership/management in the area (i.e., Bureau of Land Management, Bureau of Reclamation-Navajo Reservoir, Jicarilla Apache tribe, and the states of Colorado and New Mexico).

The global distribution of *Astragalus missouriensis* var. *humistratus* is shown in the inset of **Figure 1**, and lies in the upper basin of the San Juan River, west of the continental divide as it meanders through the San Juan Mountains of Colorado and New Mexico. As far as is known, this also represents the historic distribution of the species. Within Region 2, *A. missouriensis* var. *humistratus* is restricted to Archuleta and Hinsdale counties in southern Colorado, but it is possible that it extends into adjacent portions of La Plata County. In Region 3, this species occurs only in northwestern New Mexico in Rio Arriba County. The greater part of this species' known range lies within Colorado. *Astragalus missouriensis* var. *humistratus* species is usually regarded as a local endemic. In the schema of rarity outlined by Rabinowitz (1981), *A. missouriensis* var. *humistratus* appears to fit the categories of narrow geographic range/various or narrow habitats/small populations.

Table 3. Documented occurrences of *Astragalus missouriensis* var. *humistratus*. Occurrences are arranged by location (state and county) and arbitrarily numbered.

	County	Ownership/Management	Date last observed	Location	Elevation (ft.)	Habitat[1]	Population size[2]	Source ID[3]
COLORADO								
1	Archuleta	Private	2-Jun-1997	East of Pagosa Springs, near junction of Hwy 160 and Hwy 84 (type locality)	7,160	Dry hills, Grassy hills, On brow of shale hillside. Waste land. Clay knolls in thin ponderosa woodland	—	CNHP EO-01; Weber & Whittmann 19235; Weber & Livingston 6337; Bethel, Willey & Clokey 4148; Penland & Hartwell 3713; R.C. Barneby 18257
2	Archuleta	Private	2005	Pagosa Springs, Reservoir Hill trail	7,240	Along trail in forested area	~50	Lyon, 2005
3	Archuleta	Private	2005	Archuleta County Fairgrounds	~7,160	—	~50	Lyon, 2005
4	Archuleta	Private	2005	Tierra del Oro Road, off Hwy 84	7,160	Weedy roadside on Mancos shale	~500	Lyon, 2005
5	Archuleta	Private	10-Jun-1924	North side of Pagosa Springs	—	Open spaces between shrubs	—	H.M. Schmoll 1085
6	Archuleta	Unknown	26-May-1987	7 miles northwest of Chromo	~7,480	Clay banks in parkland with scattered ponderosa pines	—	R.C. Barneby 18258
7	Archuleta	Unknown	8-May-1940	18 miles south of Pagosa Springs on road to Chromo	~7,480	—	—	L.N. Goodding Sel 51-40
8	Archuleta	USDA Forest Service (USFS), San Juan National Forest, Pagosa Ranger District	22-Jun-2001	Turkey Mountain / Eightmile Mesa	7,470 to 7,650	Dry meadow, Disturbed roadside and along horse trail in ponderosa pine/Gambel oak community. Flat shale meadows and shallow slopes	750+	CNHP EO-02; P. Lyon 9254; Johnston & Lucus 1726; S.L. O'Kane 4479
9	Archuleta	USFS, San Juan National Forest, Columbine Ranger District	23-Jun-2001	Pine-Piedra Stock Driveway	8,400 to 8,600	North facing slope with Gambel oak	several hundred	CNHP EO-04
10	Archuleta	Southern Ute	4-Jun-1992	Hall Canyon	7,500	Ponderosa pine community	—	Heil & Melton 7142
11	Archuleta	USFS, San Juan National Forest, Pagosa Ranger District	May-1998	North of Hatcher Reservoir	~8,000	Ponderosa pine and Gambel oak	—	K. Heil 11878 B 26
12	Hinsdale	USFS, San Juan National Forest, Pagosa Ranger District	26-May-1998	Piedra River valley near campground	8,000	Clay hills	—	K. Heil 11898
NEW MEXICO								
13	Rio Arriba	Private	4-Jun-1997	Highway 84 near state line	8,000	Mancos shale hillside	—	S.L. O'Kane 3939

Table 3 (concluded).

	County	Ownership/Management	Date last observed	Location	Elevation (ft.)	Habitat[1]	Population size[2]	Source ID[3]
14	Rio Arriba	Private	6-Jun-2000	Eagle Point	7,585	Rolling low hills of sage and grassland; clay of Mancos shale	—	S.L. O'Kane & K. Heil 4823
15	Rio Arriba	USFS, Carson National Forest, Jicarilla Ranger District	1987	Near head of Devils Canyon; northeast end of Carracas Mesa	~7,270	—	—	NMSC specimen

[1]Habitat type names are given as in the original source, using either scientific or common names.

[2]Population sizes are numbers of individual plants.

[3]Sources include Colorado Natural Heritage Program (CNHP) data and herbarium labels. ID information is from the source. CNHP ID's are Element Occurrence Records (of the format EO-00). Herbarium label ID's are collector name and collection number.

Population trend

Population trends for *Astragalus missouriensis* var. *humistratus* are largely unquantified. Numbers of individuals have been reported as 750+ for the Turkey Mountain population south of Pagosa Springs, several hundred for the Pine-Piedra stock driveway population in western Archuleta County, and approximately 50 individuals each for three locations in the Pagosa Springs vicinity (Colorado Natural Heritage Program 2005a, Lyon personal communication 2005). Only a total of about 1,500 individuals of this species can be confirmed. Because there are ten occurrences with no size information, the real number of individuals (the metapopulation) is higher. Three occurrences were discovered in 2005, and additional work in the area could add to the total number documented. Due to the lack of multi-year data sets of population counts of *A. missouriensis* var. *humistratus*, there is insufficient information to allow an assessment of current range-wide population trends.

Habitat

The global range of *Astragalus missouriensis* var. *humistratus* overlays the northern end of the geologic structure known as the Archuleta anticlinorium (Kelley and Clinton 1960), at the northeastern edge of the San Juan Basin (**Figure 5**). This is an area where shales and sandstones of late Cretaceous age are exposed in bands trending northwest-southeast between the Tertiary volcanics to the northeast and early Tertiary sandstones of the San Juan Basin to the southwest. Within this area, the known range of *A. missouriensis* var. *humistratus* encompasses about 800 square miles (2,000 km^2). *Astragalus missouriensis* var. *humistratus* appears to favor shaley substrates of late Cretaceous to early Tertiary origin; the majority of known populations are on sites underlain by substrates of either Mancos Shale or the almost identical Lewis Shale, with a few on shales of the Mesa Verde Formation. Two occurrences in the western and southwestern portions of the range are underlain by Tertiary age sedimentary siltstone, shale, and sandstone of the San Jose Formation (**Figure 5**). This variety of substrates indicates that edaphic requirements of *A. missouriensis* var. *humistratus* are not as narrow as for some of the other rare species of the area.

Elevations of reported occurrences range from about 7,100 to 8,600 ft. (1,645 to 2,285 m). Annual precipitation within the distribution of *Astragalus missouriensis* var. *humistratus* ranges from about 14 to 20 inches (18 to 48 cm). Precipitation is greatest in the northeastern part of the range near Pagosa Springs, and it is lowest in the western part of the range near Ignacio. Precipitation patterns are similar throughout the range, where it is relatively dry during the spring and early summer and the majority of precipitation is received during the late summer through winter months (Western Regional Climate Center 2005).

Within its range, *Astragalus missouriensis* var. *humistratus* is broadly associated with the Rocky Mountain Ponderosa Pine Woodland or Rocky Mountain Gambel Oak-Mixed Montane Shrubland ecological system types (Colorado Natural Heritage Program 2005b). These ecological systems are described as “matrix forming”, and they may cover extensive areas of hundreds to millions of acres in their various successional stages. Matrix communities occur across a fairly broad range of environmental conditions in an area and are shaped by regional-scale processes (Anderson et al. 1999). *Pinus ponderosa* (ponderosa pine) woodlands are found at the lower treeline/ecotone between grassland or shrubland and more mesic coniferous forests, typically in warm, dry, exposed sites. The communities are dominated by *P. ponderosa*, and while they normally have a shrubby understory, they may also have grassy or sparsely vegetated lower strata. Ponderosa woodlands are found on all slopes and aspects, with moderately steep to very steep slopes or ridgetops being the most common. Gambel oak-mixed montane shrublands are most commonly found along dry foothills and lower mountain slopes, and they are often situated above pinyon-juniper woodlands. In many occurrences, the canopy is dominated by *Quercus gambelii* (Gambel oak), *Amelanchier* spp., *Cercocarpus montanus* (alderleaf mountain mahogany), *Symphoricarpos* spp., and other shrubs may also be co-dominant. Within these ecological systems, *A. missouriensis* var. *humistratus* is typically found in open dry meadows or on sparsely vegetated soils (**Figure 6**). Data from specimen labels and element occurrence records show this species being associated with species shown in **Table 4**. Most specimens do not include associated species, so this list is not comprehensive.

Little information is available with which to characterize microhabitat preferences of *Astragalus missouriensis* var. *humistratus*. Soils are most often reported as clay or shale, but there is no information about slope, aspect, light, soil moisture, or nutrient availability for any *A. missouriensis* var. *humistratus* location. *Astragalus missouriensis* var. *humistratus* appears to favor open, less vegetated areas, but it does not appear to be an extreme habitat specialist. It

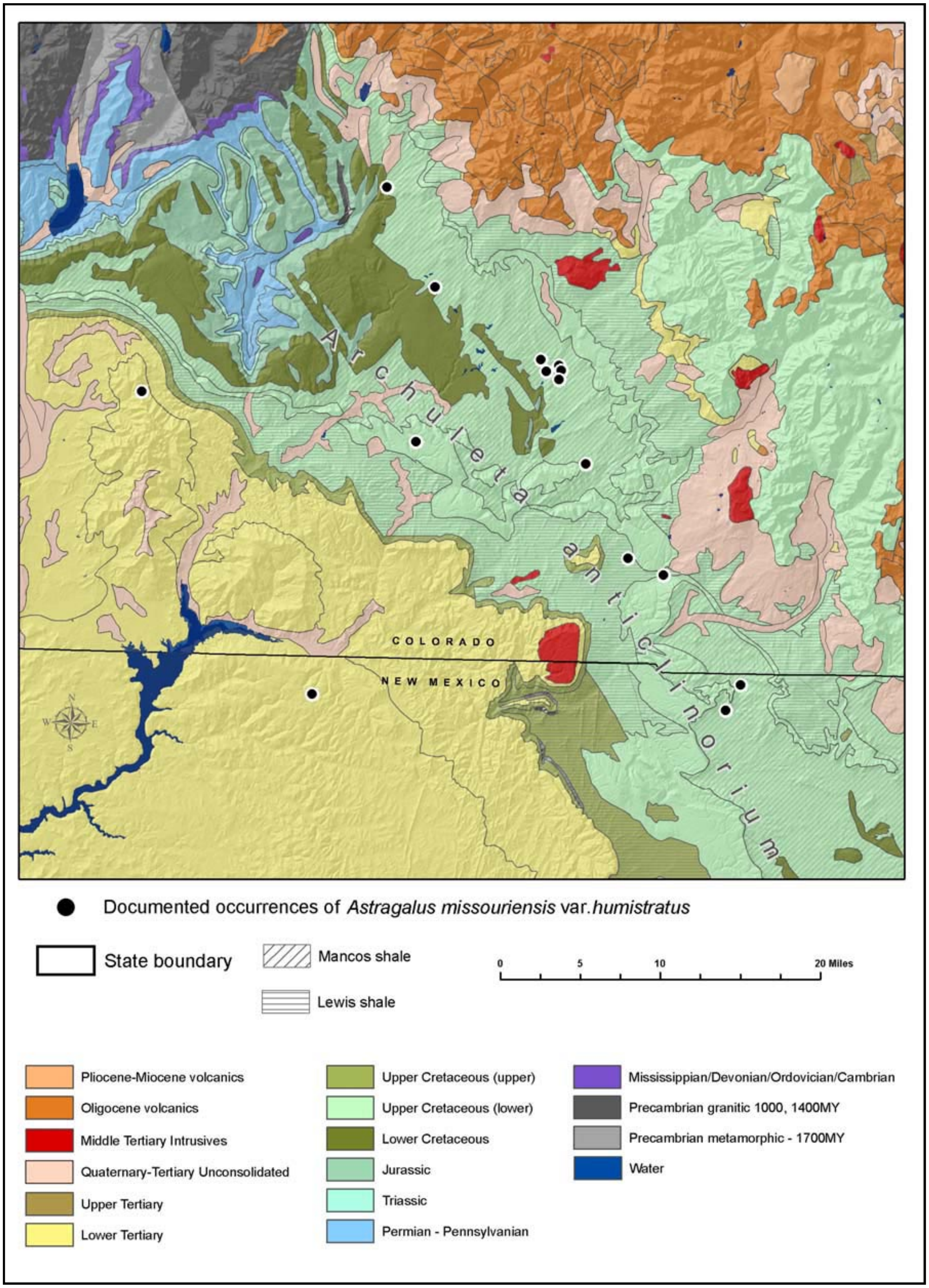


Figure 5. Surface geology in the range of *Astragalus missouriensis* var. *humistratus*.

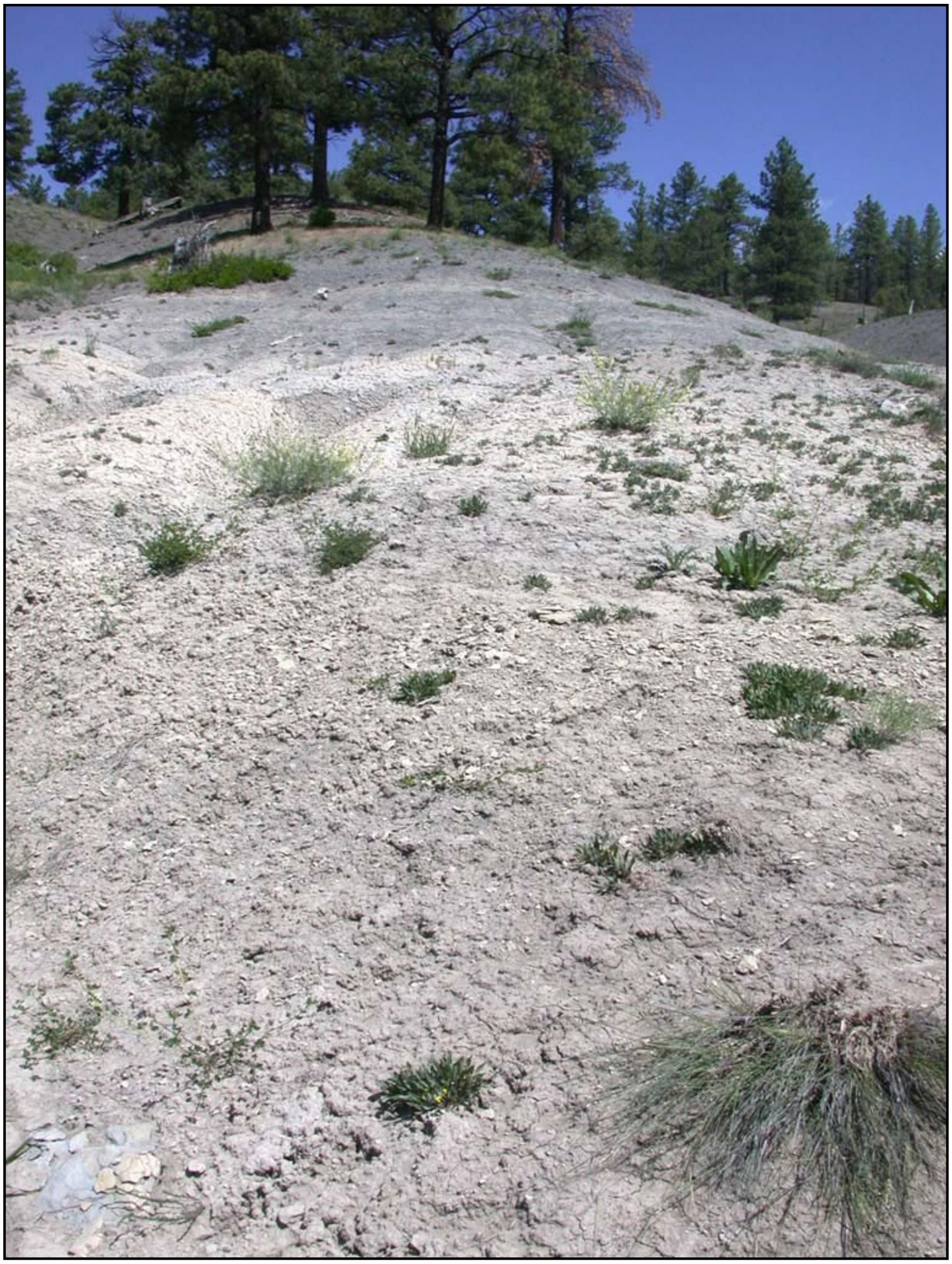


Figure 6. Habitat of *Astragalus missouriensis* var. *humistratus*. Photograph by Peggy Lyon, used with permission.

is possible that microhabitat characters controlling its distribution have not yet been identified.

Reproductive biology and autecology

Life history and strategy

Using the Competitive/Stress-Tolerant/Ruderal (C-S-R) model of Grime (2001), *Astragalus missouriensis* var. *humistratus* appears to fit best in the stress-tolerator category, along with many species of sparsely vegetated habitats. Stress in this habitat stems from nutrient limitation rather than competition. Grime (2001) notes that for perennials in low-rainfall habitats, restricted nutrient uptake is unavoidable. The reduced stature, apparent unpalatability, and potentially long lifespan of *A. missouriensis* var. *humistratus* tend to indicate that it is a stress-tolerator. This trait is probably shared by many other *Astragalus* species of the Intermountain West.

Table 4. Species reported to be associated with *Astragalus missouriensis* var. *humistratus*.

Trees:	Forbs:
Pinus ponderosa	*Achillea millefolium*
Quercus gambelii	*Allium acuminatum*
	Artemisia ludoviciana
Shrubs / Subshrubs:	*Astragalus bisulcatus* var. *haydenianus*
Mahonia repens	*Astragalus flavus*
	Astragalus lonchocarpus
Graminoids:	*Astragalus oocalycis*
Pascopyrum smithii	*Carex heliophila*
	Dugaldia hoopsii
	Erigeron flagellaris
	Eriogonum racemosum
	Eriogonum racemosum
	Lesquerella pruinosa
	Penstemon teucroides
	Phlox caryophylla
	Taraxacum officinale
	Wyethia arizonica

The common variety of *Astragalus missouriensis* is included in *Weeds of Nebraska and the Great Plains* (Stubbendieck et al. 1994) as a native species that can be undesirable (weedy) under certain management scenarios, but there is no documentation of weediness for variety *humistratus*. Although *A. missouriensis* var. *humistratus* is not considered a ruderal species, there is evidence that it is tolerant of some disturbance under certain conditions. Many collections have been made close to highways or on other disturbed ground, especially in the Pagosa Springs area; however, this may in part be an artifact of the relative ease of collecting in such locations. There is no information on how various factors such as degree and timing of disturbance, soil type, and precipitation may contribute to variation in disturbance tolerance or viability of individual occurrences.

As a perennial species that probably devotes one or more years to vegetative growth before reproducing, *Astragalus missouriensis* var. *humistratus* can be regarded more or less as a *K*-selected species (using the classification scheme of MacArthur and Wilson 1967). Although individuals can flower profusely under some environmental conditions, the percent of total biomass devoted to reproduction under normal conditions is probably not large.

Reproduction

Astragalus missouriensis var. *humistratus* is not rhizomatous and reproduces only by seed, not vegetatively or by clonal growth. As with all *Astragalus* species, flowers of *A. missouriensis* var. *humistratus* contain both male and female reproductive organs. The mating system and degree of self-compatibility have not been investigated for *A. missouriensis* var. *humistratus*. Geographically restricted species are predicted to be more self-compatible than widely distributed species (Stebbins 1957). This prediction was partly supported by the work of Karron (1989), who reported that two restricted (*A. linifolius* and *A. osterhouti*) and one widespread (*A. lonchocarpus*) *Astragalus* species were self-compatible, and capable of setting as many fruits by selfing as by outcrossing. Flower manipulation was important in percent fruit set; unmanipulated flowers set fruit at much lower levels. One widespread species was not self-compatible. The restricted species experienced lower overall levels of embryo abortion in self-pollinated ovules compared to the widespread species. In both restricted and widespread species (one each), selfed seeds were more likely to germinate, but the selfed seedlings of the restricted species showed evidence of inbreeding depression. Allphin et al. (2005) found that the predicted positive correlation between narrow distribution and self-compatibility held true in some, but not all varieties of *A. cremnophylax*.

Although none of the above mentioned species is closely related to *Astragalus missouriensis* var. *humistratus*, it may show the same pattern of self-compatibility and its effects as the two other restricted species. Future research could investigate the possibility of selfing in *A. missouriensis* var. *humistratus*, and whether this produces high levels of inbreeding depression.

Pollinators and pollination ecology

As do all members of the subfamily Papilionoideae, *Astragalus missouriensis* var. *humistratus* possesses papilionaceous flowers. The papilionaceous flower is the characteristic "pea" flower with a zygomorphic corolla consisting of large posterior and upright standard (banner), a lateral pair of long-clawed wings, and an innermost boat shaped keel (see figure in **Definitions** section). Flowers of this type typically share the pollination syndrome of *melittophily* or bee pollination (Faegri and van der Pijl 1979).

The presence of a "trip mechanism" in papilionaceous flowers means that large bees of the family Apidae and Anthophoridae (Green and Bohart 1975) and Megachilidae (Rittenhouse and Rosentreter 1994) are likely to be the primary pollinators. The bees typically alight on the landing platform provided by the wings, and then push their head between the banner and keel petals. The weight of the bee depresses the wings and keel, exposing the stamens and depositing pollen on the underside of the bee's head, thorax, and abdomen (Green and Bohart 1975).

Pollinators of *Astragalus missouriensis* var. *humistratus* have not been identified. Potential pollinators reported (Green and Bohart 1975, Sugden 1985, Karron 1987, Geer et al. 1995) for some *Astragalus* species of the western United States include native bumblebees (*Bombus* spp.), native digger bees (*Anthophora* spp.), native mason bees (*Osmia* spp.), and the introduced honeybee (*Apis mellifera*). Geer et al. (1995) reported over 27 species of bees visiting flowers of *Astragalus montii*, *A. kentrophyta*, and *A. miser*. *Osmia* spp. were the most frequent visitors to all three species. Green and Bohart (1975) concluded that pollen quantity and distribution on floral visitors belonging to Diptera and Coleoptera indicated that they were not likely to be successful pollinators of *Astragalus* species.

Phenology

Phenology is not known in detail for *Astragalus missouriensis* var. *humistratus*. Dates from herbarium specimens indicate that plants may have both flowers and fruits from late May to late June. Flowering probably begins somewhat earlier than these dates indicate. While fruits are probably mature by the end of July, it is not clear when seeds are fully mature. Germination site requirements for *A. missouriensis* var. *humistratus* are unknown.

Fertility and propagule viability

There are no data available that would allow an accurate assessment of the fertility and propagule viability of *Astragalus missouriensis* var. *humistratus*. Flowering individuals may have anywhere from one to 15 flowering stems, and each stem may have eight to 12 flowers. Fully fertilized flowers may produce 33 to 40 seeds (Barneby 1964). Under excellent conditions, without pollinator or resource limitations, an individual could potentially produce several hundred to several thousand seeds in a single season. Plants under natural conditions are undoubtedly producing far fewer viable seeds, perhaps a few hundred for a larger individual in an average year.

Dispersal mechanisms

The probability of dispersal of seeds and other propagules decreases rapidly with increasing distance from the source (Barbour et al. 1987). The majority of seeds will remain close to the parent plant; very few long-distance dispersals occur. Pods typically remain on the plant after dehiscence, and the small size of the seeds probably insures that most are not further dispersed. Individual seeds are fairly small (2 to 3 mm long), and they are likely to quickly lodge in soil microsites once they leave the pod.

Seed predation has been reported for a variety of *Astragalus* species (Green and Palmbald 1975, Friedlander 1980, Clement and Miller 1982, Nelson and Johnson 1983, Rittenhouse and Rosentreter 1994, Lesica 1995, Decker and Anderson 2004). No instances of insect damage on fruits of *A. missouriensis* var. *humistratus* have been reported by field observers, and no herbarium specimens examined for this assessment showed any obvious damage to fruits. Seed predation does not appear to be a significant source of mortality for *A. missouriensis* var. *humistratus*.

Cryptic phases

Seed bank dynamics and seed longevity have not been investigated for *Astragalus missouriensis* var. *humistratus*. Bowles et al. (1993) successfully germinated seeds from herbarium specimens of two rare *Astragalus* species (*neglectus* and *tennesseensis*) that were at least four years old. Successful germination of *A. neglectus* seeds included some specimens that were 97 years old. Although these seeds had been stored under herbarium conditions, the results indicate the possibility that *A. missouriensis* var. *humistratus* seeds under natural conditions may remain viable for many years.

Numbers of *Astragalus missouriensis* var. *humistratus* seeds in the seed bank have not been investigated. Some other *Astragalus* species appear to maintain variable but potentially large seedbanks. Ralphs and Cronin (1987) reported a mean density of 394 seeds per m^2 of soil for *A. lentiginosus* var. *salinas* in Utah. They found that seed density was not necessarily correlated with foliar cover of the species. Ralphs and Bagley (1988) reported widely variable seed density for *A. lentiginosus* var. *wahweepensis* in Utah, ranging from 20 to 4,346 seeds per m^2, and they hypothesize that the seed bank is sufficient to allow "population outbreaks" (un-quantified) in years with favorable environmental conditions. Morris et al. (2002) reported densities from 24 to 753 seeds per m^2 for *A. bibullatus* in the Central Basin of Tennessee.

Another possible cryptic phase is a dormant stage in which an individual plant does not produce aboveground vegetation for one or more years and then "reappears" at a later time. Lesica (1995) reported this type of dormant phase in *Astragalus* scaphoides. This type of sudden appearance could also indicate the presence of a seed bank that responds to the appropriate conditions with a large recruitment episode. The dynamics of either type of cryptic phase (seed bank or dormancy) are unknown for *A. missouriensis* var. *humistratus*.

Phenotypic plasticity

There are no reports of phenotypic plasticity in *Astragalus missouriensis* var. *humistratus*, but the species is so little known that the existence of such variation is impossible to discount. Barneby (1964) reported that *A. missouriensis* var. *missouriensis* exhibits continuous variation in flower size from small in northern latitudes to large on calcareous or gypseous soils in the southern part of the range. The possibility of a genetic component of this variation has not been investigated.

Mycorrhizal relationships

Endomycorrhizal fungi belonging to the taxonomic order Glomales are a key component of one of the most common underground symbioses. These endomycorrhizae are characterized by inter- and intracellular fungal growth in the root cortex where they form fungal structures known as vesicles and arbuscles (Quilambo 2003). Vesicular-arbuscular mycorrhizae (VAM) occur in about 80 percent of all vascular plants (Raven et al. 1986), and the association is geographically widespread. Roots of *Astragalus missouriensis* var. *humistratus* have not been assayed for the presence of VAM symbionts. Both presence (e.g., Zhao et al. 1997, Barroetavena et al. 1998) and absence (Treu et al. 1995) of VAM has been reported in the genus *Astragalus*. In the endangered *A. applegatei*, Barroetavena et al. (1998) reported that colonization by VAM fungi from native soil was crucial to the survival of plants grown in a greenhouse.

Members of the pea family are well known for forming symbiotic relationships with *Rhizobium* bacteria that invade the cortical root swellings or nodules of root hairs. Through this mutually beneficial association, free air nitrogen is converted to fixed nitrogen that can be used by the plant. The ability to form nodules appears to be reasonably consistent within phylogenetic groups of Fabaceae. *Astragalus* species with nodules occur in almost all habitats, and nodules have been reported for at least 80 species (Allen and Allen 1981). *Astragalus missouriensis* var. *humistratus* has not been investigated for the presence of root nodules. Nodules have been reported for the closely related *A. missouriensis* var. *missouriensis* (Allen and Allen 1981), so it is likely that *A. missouriensis* var. *humistratus* also possesses the capacity to form nodules.

Hybridization

Although other genera in the Fabaceae (e.g., *Oxytropis* and *Lathyrus*) have been reported to exhibit hybridization, the phenomenon is not prevalent in *Astragalus*. Barneby (1964) speculated on the possible origin of *A. missouriensis* var. *humistratus* as a hybrid between *A. missouriensis* and *A. humistratus* var. *humistratus*, but this possibility has not been further investigated with modern phylogenetic techniques. There is no evidence that *A. missouriensis* var. *humistratus* engages in hybridization. Karron (1987) and Geer et al. (1995) report that sympatric *Astragalus* species can share pollinators. In these instances a mechanism to facilitate hybridization is available, but it is not known if it is actually occurring. *Astragalus missouriensis* var. *humistratus* is sympatric with two other varieties of *A. missouriensis*, as well as with several other *Astragalus* species (**Table 4**). Because pollination dynamics and potential barriers to hybridization in *A. missouriensis* varieties have not been investigated, the possibility remains open.

Demography

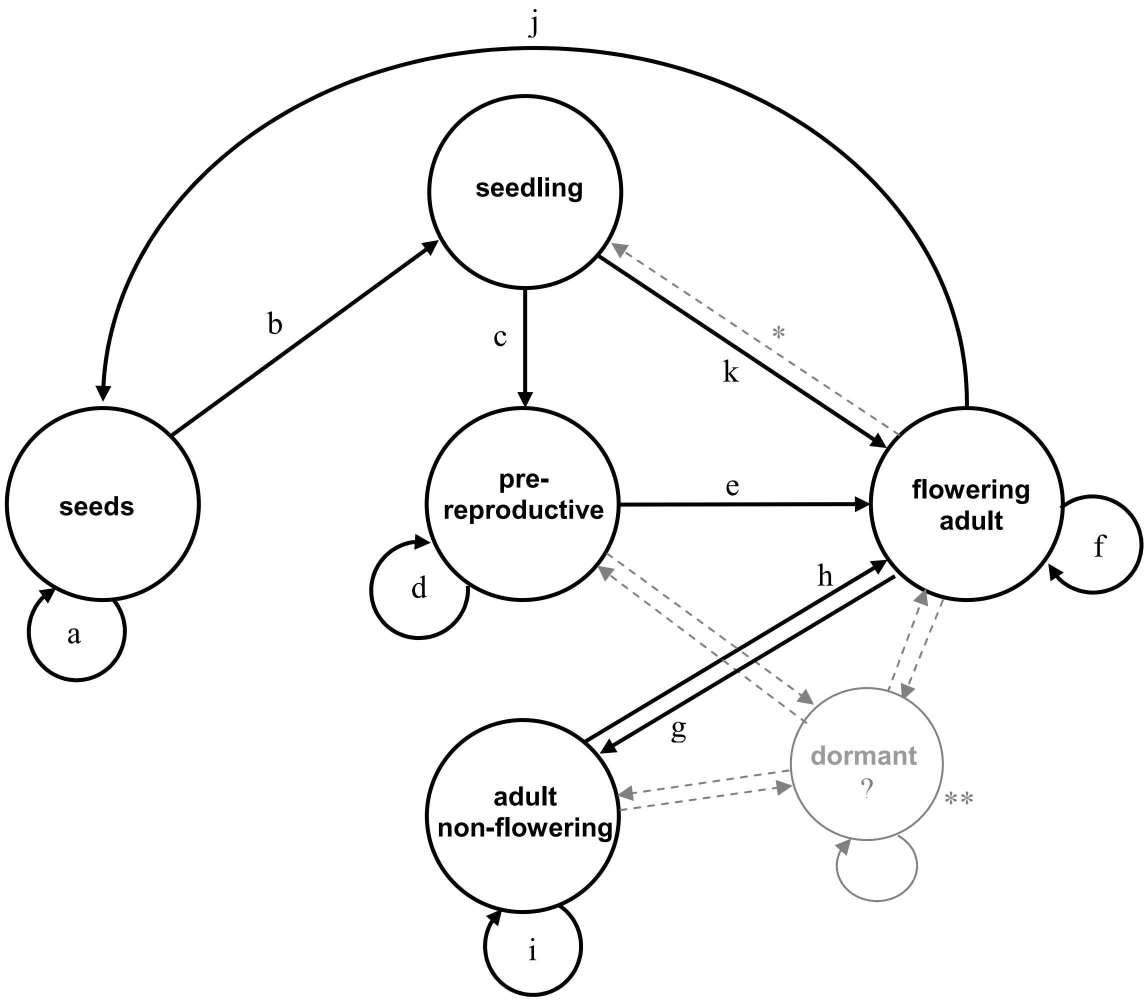
As an herbaceous perennial that is not monocarpic, *Astragalus missouriensis* var. *humistratus* exhibits overlapping generations. This characteristic is potentially important in the action of natural selection in that individuals of different ages will be exposed to slightly different selective processes (Harper 1977). Such selection can lead to temporal variation in population genetic structure, allowing seed banks to serve as reservoirs of genetic variation (Templeton and Levin 1979). Morris et al. (2002) found higher levels of genetic variation in the seed bank than in vegetative populations of the cedar glade endemic *A. bibullatus*. They suggest that the ability of the seed bank to preserve genetic diversity may depend on seed dormancy characters and on the relative size of the seed bank compared to the vegetative population. The investigation of these two factors could help to clarify genetic diversity issues for *A. missouriensis* var. *humistratus*.

Lesica (1995) conducted an eight year demographic study of *Astragalus* scaphoides, a long-lived perennial endemic to east-central Idaho and adjacent Montana. In this species, some plants would become dormant for one to several years, producing little or no aboveground vegetation. Dormant plants constituted about 10 percent of the population, and they could remain dormant for up to five years before reappearing. The possibility of a similar dormancy stage in *A. missouriensis* var. *humistratus* should be investigated. The lifespan of an *A. missouriensis* var. *humistratus* individual is not known, but plants probably have a normal lifespan of more than just a couple of years. In Lesica's (1995) study of *A. scaphoides*, 40 to 50 percent of individuals observed during the first year of the study were still alive eight years later.

Figure 7 shows a hypothetical life cycle diagram. Because there are no multi-year studies of *Astragalus missouriensis* var. *humistratus*, transition probabilities are left unquantified. Under the basic scenario shown, flowering plants produce seeds in early- to mid-summer. These seeds overwinter and germinate in the spring or remain dormant. Seedlings may flower in their first year, or they may require one to several years to reach reproductive size/age. Reproductive adults flower every year as conditions permit. The model assumes a transition interval of t = one year, and plants do not move between stages in intervals less than t.

Until demographic data are available for *Astragalus missouriensis* var. *humistratus*, it is impossible to conduct any kind of elasticity analysis to determine which demographic transitions are making the greatest contribution to population growth, and which might be most affected by management activities. An elasticity analysis of the extremely restricted Grand Canyon endemic *A. cremnophylax* var. *cremnophylax* (Maschinski et al. 1997) indicated that reproductive plants remaining within the same reproductive-size stage had the greatest influence on population growth. The size class making the largest contribution changed when the population was protected from trampling. Lesica (1995) found that although relative contributions of stages varied between years and sites, growth and survival of non-reproductive individuals of *A. scaphoides* was consistently important. Similar trends are possible for *A. missouriensis* var. *humistratus*.

Research on the concept of minimum viable populations (MVP) was initiated largely in response to requirements of the National Forest Management Act of 1976 that the USFS maintain "viable populations" of species found in each national forest. The theory of MVP was developed under the animal model of the sexually reproducing, obligate outcrossing individual, and it incorporated the effects of genetic stochasticity from elevated inbreeding coefficients in small populations (Soulé 1980, Shaffer 1981). The MVP is the smallest population that is predicted to have a very high chance of survival for the foreseeable future (Primack 1995). Shaffer (1981) emphasized the probabilistic nature of the definition of an MVP, noting that survival probabilities and expected duration may be set at various levels (e.g., 95%, 99% or 100%, 100, 1,000, or 10,000 years). Different estimates for MVP size have been suggested in response to the various types of uncertainty affecting populations (e.g., demographic stochasticity, environmental stochasticity, large scale natural catastrophe, genetic stochasticity; see Shaffer 1981). Suggested MVP numbers have ranged from 50 to buffer demographic stochasticity, to 500 to buffer genetic stochasticity (Franklin 1980), to a range of 1,000 to 1,000,000 in the case of environmental stochasticity and natural catastrophes (Menges 1991). This variation in estimates highlights the necessity



a. survival of dormant seeds in the seed bank
b. probability of seed becoming a seedling
c. survival of seedling to pre-reproductive stage
d. probability of individual remaining in pre-reproductive stage
e. probability of pre-reproductive becoming reproductive
f. probability of flowering adult flowering again next year
g. probability of flowering adult not flowering
h. probability of non-flowering adult flowering
i. probability of non-flowering adult remaining in non-flowering stage
j. seed production of flowering plants
k. probability of seedling flowering

* when do seeds germinate, i.e., are seedlings produced the same year?
** is there a dormant phase, and if so, probabilities of transition between this and other rosette stages?

Figure 7. Life cycle diagram for *Astragalus missouriensis* var. *humistratus* (after Caswell 2001).

for the development of Population Viability Analysis (PVA) models with robust parameters for each individual species. Such analyses, including numerical estimates of MVPs, require substantial empirical data and an understanding of the links among environmental variability, demography, and genetics in the species of interest (Menges 1991). There are currently no PVA models for *Astragalus missouriensis* var. *humistratus*, and our knowledge of the species is insufficient to provide appropriate parameters for such an analysis.

Although the concept of standardized estimates for MVP size is appealing for conservation managers, current consensus is that most general PVA models lack adequate data to be realistic. Moreover, although PVA may occasionally be essential for the conservation of a species, most species will be adequately protected by habitat preservation and conservation strategies based on available autecological information (Menges 1991). Land managers are often required to make a determination about whether a management action is likely to cause a trend toward federal listing or loss of viability, but they may find this difficult to do under time and funding constraints. Furthermore, land managers faced with repeated decisions must be aware of the potentially additive nature of their decisions. The combination of several smaller actions that do not individually cause a loss of viability may result in a significant impact on population trends that is not quickly apparent. In general, the most effective strategies are to avoid impacts to sensitive species whenever possible, and to preserve the highest population numbers possible, rather than rely on a generic formula for MVP numbers.

Community ecology

The community ecology of *Astragalus missouriensis* var. *humistratus* is poorly understood. A number of other rare species, including *Ipomopsis polyantha* (Pagosa ipomopsis), *Lesquerella pruinosa* (Pagosa Springs bladderpod), *Phlox caryophylla* (clove phlox), and *Townsendia glabella* (Gray's Townsend daisy) are also found in the Pagosa Springs area on similar habitats.

Herbivores

Astragalus species are often poisonous to livestock. This characteristic is due primarily to the sequestration of selenium in plant tissues, or to the production of nitro-toxins such as miserotoxin (Stermitz et al. 1969), cibarian, karakin, and hiptagin (Williams et al. 1975). These compounds are catabolized in the digestive tracts of ruminants and disrupt the central nervous system. *Astragalus* species containing nitro-toxins kill or permanently cripple thousands of sheep and cattle every year. Williams and Barneby (1977) analyzed leaflets of 505 *Astragalus* species for the presence of nitro-toxins, and they found varying levels of nitro-toxin in about 52 percent of the species that they examined. Presence and levels of nitro-toxins were fairly consistent among species belonging to the same taxonomic group. Although *A. missouriensis* var. *humistratus* was not among the species tested, varieties *missouriensis*, *amphibolus*, and *mimetes* all exhibited low levels of around 4 to 8 mg nitro-toxin per gram of plant. These results indicate that var. *humistratus* probably contains similarly low amounts of nitro-toxin.

Some species of *Astragalus* appear to be resistant to herbivory (e.g., Rittenhouse and Rosentreter 1994). Other species are subject to a variety of impacts from invertebrate herbivores. Anderson (2001) reported severe defoliation of *A. schmolliae* by larvae of the clouded sulfur butterfly. Aphids also appeared to have an impact on reproductive output (Anderson 2001). Lesica (1995) reported increased predation on inflorescences of *A. scaphoides* when livestock were present. Field observers report no sign of use by vertebrate herbivores on *A. missouriensis* var. *humistratus*.

Competitors

Community relationships of *Astragalus missouriensis* var. *humistratus* have not been investigated. Rare plants, in particular those that are characteristic of sparsely vegetated habitat types, are commonly thought to be poor competitors. However, studies investigating the relative competitive abilities of rare and common congeners have shown mixed results (Lloyd et al. 2002). *Astragalus missouriensis* var. *humistratus* plants are typically found in open, sometimes grassy areas, and they may have limited competitive abilities or tolerance of shading. A number of invasive species have been reported near sites where *A. missouriensis* var. *humistratus* occurs (see Threats section). However, there are no data available that would help to determine if any of these species will become a serious competitor of *A. missouriensis* var. *humistratus* in the future.

Parasites and disease

There are no reports of parasites or disease in *Astragalus missouriensis* var. *humistratus*. Field observers have not reported any obvious damage to foliage or fruits.

Symbioses

With the exception of the possible mycorrhizal relationships described above, there have been no reports of symbiotic or mutualistic interactions between *Astragalus missouriensis* var. *humistratus* and other species.

CONSERVATION

Threats

A primary consideration in evaluating threats to the long-term persistence of *Astragalus missouriensis* var. *humistratus* is the fact that very little is known about the species. Population sizes are unknown for the majority of locations, and the entire global range of *A. missouriensis* var. *humistratus* is small. Additive effects of threats to the metapopulation may be compounded by this restricted range.

Based on the available information, there are several threats to *Astragalus missouriensis* var. *humistratus*. In approximate order of decreasing priority these threats are effects of small population size, land development, surface disturbance, invasive species, air pollution, and global climate change. Many of these threats are pertinent to populations on the San Juan and Carson national forests. A lack of systematic tracking of population trends and conditions, and the lack of knowledge about its basic life cycle, habitat affinities, metapopulation extent, and demographics also contribute to the possibility that one or more of these factors will threaten the long-term persistence of the species. It is unlikely that the species could be suddenly decimated by anthropogenic activities, or that any single threat is sufficient to completely eliminate the species from its entire range. Without a range-wide monitoring of the species, however, individual populations could decline and disappear without notice, and the small global range of *A. missouriensis* var. *humistratus* means that there is less margin for error in protection.

About one fourth of the known locations of *Astragalus missouriensis* var. *humistratus* in Region 2, including the two largest known populations, are on the San Juan National Forest. However, as with other federal, state, and tribal lands, National Forest System lands have not been completely surveyed for occurrences, and it is difficult to assess the extent of impacts from the above threats for any undocumented locations. In the absence of a coordinated effort to monitor and maintain populations, ignorance of potential impacts could lead to a gradual erosion of habitat availability and increasing impacts from development and other forms of disturbance. Increased disturbance from human activity in the range of *A. missouriensis* var. *humistratus* is likely to have a slow but steady negative effect on habitats, populations, and individuals. These factors constitute the most likely immediate threats to the species. Without systematic monitoring of the species throughout its limited range, population levels could be severely reduced before anyone realizes the extent of the losses.

Small population size

Demographic stochasticity is the variation over time in vital rates such as recruitment and survival, and it is generally only a concern for very small populations. Reported numbers of individuals at two *Astragalus missouriensis* var. *humistratus* populations in Region 2 appear to be sufficient to buffer against the probability that a fluctuation in vital rates will take the population to the extinction threshold. However, numbers are either unknown or at about the generally accepted minimum of 50 for other populations.

Nothing is known about the population genetics of *Astragalus missouriensis* var. *humistratus*. Efforts to quantify genetic variability in *A. missouriensis* var. *humistratus* would be of interest due to the prediction of evolutionary theory that species with small ranges and few individuals will exhibit low levels of genetic polymorphism (Hartl and Clark 1989).

Environmental stochasticity generally refers to variation over time in the physical and biological environment. For a single population, this includes natural events happening at random intervals that cause the deaths of a large proportion of individuals in the population. Such events may occur very rarely yet still have a large impact on persistence of the population (Menges 1991). For *Astragalus missouriensis* var. *humistratus*, potentially important environmental events might include catastrophic fire, landslides, or long-term drought. Multiple populations can have a mitigating effect against the operation of environmental stochasticity. However, for disjunct populations, catastrophic local events have the potential to eliminate the species from part of a region.

Land development

About 43 percent of the area within the range of *Astragalus missouriensis* var. *humistratus* is public land, which makes the possibility of direct impacts from residential development and attendant road construction on that portion of its range relatively small. However, human population numbers continue to increase in the area, especially in Archuleta County (U.S. Census Bureau 2005), and this is likely to lead to an increase in anthropogenic effects to the environment. Virtually all private, non-tribal land in Archuleta County is designated for residential development of varying density (Archuleta County Planning Department 2005). The area around Pagosa Springs is expected to sustain high density development, both residential and industrial.

When development does take place, it can increase habitat fragmentation and edge effects. Edge is the outer boundary of an ecosystem that abruptly grades into another type of habitat (Forman and Godron 1986). Such boundaries are often created by naturally occurring processes such as floods, fires, and wind, but they can also be created by human activities such as roads, timber harvesting, agricultural practices, and rangeland. Human-induced edges are often dominated by plant species that are adapted to disturbance. As the landscape is increasingly fragmented by large-scale, rapid anthropogenic conversion, these edges become increasingly abundant. Through its effects on plant-insect interactions, habitat fragmentation tends to decrease the effective population size (Holsinger and Gottlieb 1991), may affect the foraging behavior of pollinators (Goverde et al. 2002), and potentially reduces seed set (Steffan-Dewenter and Tscharntke 1999). Fragmentation may also enhance the potential for spread of invasive species (With 2002).

Surface disturbance

Surface disturbances in addition to those associated with land development that have the potential to affect *Astragalus missouriensis* var. *humistratus* individuals and habitat include road building and maintenance, resource development, livestock grazing, recreational use, and fire. Many of the known populations in Colorado are in highway right-of-way or other environments near roads, trails, and parking areas. Road construction and maintenance directly threatens some populations, especially in the vicinity of Pagosa Springs, and may alter or destroy habitat for others. Energy resource development, in particular for coal bed methane (CBM), is extremely widespread just to the south and west of the known range of *A. missouriensis* var. *humistratus*, and there is some CBM well development in the area around Chromo. The total area disturbed for each well is estimated to be on the order of 3.5 acres (1.4 ha) (e.g., USDI Bureau of Land Management 1998, 1999), making this a potential threat to populations or habitat. *Astragalus missouriensis* var. *humistratus* is not known to be grazed by domestic livestock, but concentrations of animals during trailing are a potential source of surface disturbance that may impact some individuals or populations. Surface disturbance from recreational use is typically associated with off-road-vehicle use by all-terrain vehicles (ATVs), motorcycles, and mountain bikes. Both mountain biking and off-road vehicle use on the San Juan National Forest have increased in the past few years (USDA Forest Service, San Juan National Forest 1999). There is currently no information available that would allow land managers to identify the level of disturbance that will impact *A. missouriensis* var. *humistratus* occurrences.

Astragalus missouriensis var. *humistratus* presumably evolved under natural cycles of fire and regrowth, at least where it occurs in woodland or shrubland settings. The effect of fire suppression on habitat dynamics is unknown but potentially important in the persistence of suitable habitat. This threat may also interact with the effects of global warming on dominant vegetation. For instance, if fire-prone vegetation types increase in expanse, the frequency and intensity of fire in the range of *A. missouriensis* var. *humistratus* may also increase. Fire and fuels management activities may also involve surface disturbance that impacts individuals and habitat. These surface disturbing activities also greatly increase the ability of invasive species to move into new areas. In the balance, such disturbances are likely to weigh more heavily on the negative side for the species as a whole.

Invasive species

The mechanisms by which invasive or non-native species threaten rare plants or other native vegetation are not well understood. The replacement of native vegetation by non-native species is often observed, but documentation of direct competitive interactions with non-natives that are detrimental to rare species is sparse. Studies that have investigated these interactions indicate that negative effects of invasive species are often better explained by changes in disturbance regime or other habitat variables associated with invasive species presence rather than solely by the presence of invasive species (e.g., Gould and Gorchov 2000, Farnsworth 2004, Thomson 2005). For example, Thomson (2005) found that invasive grasses had a negative effect on the rare *Oenothera deltoides* ssp. *howellii* primarily through the inhibition of seedling germination due to thatch build-up. The potential for similar interactions between *Astragalus missouriensis* var. *humistratus* and non-native species is unknown. However, it is important to consider the possibility of negative impacts by invasive species on the viability of *A. missouriensis* var. *humistratus* populations.

In Region 2, the San Juan National Forest tracks 85 invasive species (USDA Forest Service, San Juan National Forest 2003). Of these, Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), and yellow toadflax (*Linaria vulgaris*) have been reported near documented locations of *Astragalus missouriensis* var. *humistratus* on USFS lands. These species are commonly treated by spraying with the herbicide Tordon® (picloram). Such treatments are likely to also kill *A. missouriensis* var. *humistratus* individuals that happen to be growing in the treated area, but there are no known instances where this has already happened. Additional non-native species reported occurring with *A. missouriensis* var. *humistratus*, but not tracked by the San Juan National Forest, include smooth brome (*Bromus inermis*), orchard grass (*Dactylis glomerata*), alfalfa (*Medicago sativa*), yellow sweet clover (*Melilotus officinalis*), Kentucky bluegrass (*Poa pratensis*), dandelion (*Taraxacum officinalis*), and salsify (*Tragopogon dubius*).

Air pollution

An additional environmental factor in the range of *Astragalus missouriensis* var. *humistratus* is the presence of several large power plants in northern New Mexico. The Four Corners Power Plant and nearby San Juan Generating Station are substantial emitters of sulfur dioxide (SO_2) and nitrogen oxides (NO_x), the primary causes of acid deposition. Nitrogen deposition may impact local and regional ecosystems in a variety of ways. Atmospheric deposition of nitrogen compounds and other pollutants can alter soil chemistry and concentrations of important soil nutrients. Forest or woodland ecosystems may be damaged when acidic ions in the soil displace calcium and other nutrients from plant roots, inhibiting growth. Excess nitrogen inputs may alter species diversity by allowing native plants that have adapted to nitrogen-poor conditions to be out-competed and replaced by more nitrogen-tolerant non-native species. Finally, very high levels of acid deposition can damage plant leaves and leach nutrients directly from foliage (Stolte 1991, U.S. Environmental Protection Agency 2002). The effect and intensity of these emissions in the range of *A. missouriensis* var. *humistratus* are generally unknown. However, both wet and dry nitrogen deposition are believed to be much higher in the surrounding higher elevation mountains than in the immediate area around the power plants (Nanus et al. 2003). Because populations of *A. missouriensis* var. *humistratus* are concentrated at the extreme northeastern edge of the San Juan Basin where elevations are higher, this factor may be important for this species.

Global climate change

The long-term survival of the species could be affected by habitat expansion or contraction induced by global climate change. Under two widely-used climate change models, as levels of atmospheric carbon dioxide (CO_2) increase, the predicted scenario for the Pagosa Springs area is an increase in both temperature and precipitation (National Assessment Synthesis Team 2000). Locally, this change is likely to drive an expansion of ponderosa pine woodland and a corresponding decrease in grassland and sparsely vegetated areas (National Assessment Synthesis Team 2000). Changes in dominant vegetation type may be beneficial or detrimental for *Astragalus missouriensis* var. *humistratus*, but with the current level of knowledge of its habitat requirements, it is impossible to predict the outcome. Although it is generally difficult or impossible to manage directly for this threat, land managers need to be aware of the possibility that interaction with the effects of global climate change may affect the severity of other threats.

Potential for overutilization

There are no known commercial uses for *Astragalus missouriensis* var. *humistratus*. In fact, although *Astragalus* is a very large genus, comparatively few species are of agricultural significance (Allen and Allen 1981). The prevalence of toxicity in the genus *Astragalus* greatly reduces their utility as forage. A variety of *Astragalus* species have served as a source of gum tragacanth, an insoluble carbohydrate gum that has been used for a variety of manufacturing and pharmaceutical purposes for hundreds of years (Allen and Allen 1981). At least one species of *Astragalus* (*A. membranaceous*, or Huang-qi) is widely used in Chinese medicine, where it is often listed merely as "Astragalus." It is generally described as an immune system booster and recommended for a variety of uses. There is no indication that *A. missouriensis* var. *humistratus* is likely to become a target of either of these types of commercial use.

Astragalus missouriensis var. *humistratus* is occasionally collected by botanists, but it has never been the subject of formal scientific investigation.

Survey and research should emphasize non-destructive methods until and unless population numbers are determined to be sufficient to support collections.

Effects of management activities

The effects of management activities or natural disturbances on habitat quality for *Astragalus missouriensis* var. *humistratus* have not been studied. However, it is obvious that activities in the Pagosa Springs area connected with land or resource development are contributing to habitat fragmentation for all native species, and that these activities can decrease habitat quality for *A. missouriensis* var. *humistratus*. Management activities such as road or trail construction and maintenance, timber harvest, livestock grazing, motorized recreation, and fire suppression are associated with soil disturbance, which may also have a detrimental impact on habitat quality and availability for *A. missouriensis* var. *humistratus*. Invasive species are most prevalent in areas disturbed by surface activities, and they may be either a symptom or a cause of decline in habitat quality.

In general, management activities or natural disturbances that affect habitats are likely to have similar or parallel effects on individuals or populations. In particular, surface disturbance associated with land and resource development or recreational use is likely to have a direct impact on individuals and populations of *Astragalus missouriensis* var. *humistratus*. Plants may be killed or damaged as a result of these activities, and population remnants may be unable to recolonize disturbed areas.

Conservation Status of Astragalus missouriensis var. *humistratus in Region 2*

There is no evidence that the distribution or abundance of *Astragalus missouriensis* var. *humistratus* is declining in Region 2. However, because most locations have not been repeatedly or recently observed and because no monitoring has been implemented, it is impossible to give an accurate tally of the total numbers of individuals of the species in existence, much less any sort of analysis of population trends. Furthermore, much of the probable range has not been surveyed for *A. missouriensis* var. *humistratus*, especially tribal lands. This lack of quantitative information is also applicable to the portion of the metapopulation that lies outside of Region 2 and makes it difficult to assign a conservation status with any degree of confidence.

Evidence presented in the previous sections indicates that the potential for a variety of habitat fragmenting or surface disturbing activities that may have a detrimental effect on *Astragalus missouriensis* var. *humistratus* populations is high throughout its range, especially in the Pagosa Springs area. Risks to populations from management activities may be somewhat ameliorated in Region 2 because the species shares habitat and locations with other rare and sensitive species. However, there are no conservation plans in place for the species anywhere in its range, so most populations cannot be considered secure for any reason other than historical lack of activity in their vicinity.

The patchwork of ownership patterns in the range of *Astragalus missouriensis* var. *humistratus* means that federal land managers must cooperate with a variety of state, tribal, and local entities to ensure the persistence of the species. In order to minimize the effects of the many different land uses in the area, land managers must continue to be aware that this small area of southern Colorado/northern New Mexico is the only place on earth where this species occurs, and that if it is not maintained here, it will be lost.

Management of Astragalus missouriensis var. *humistratus in Region 2*

Implications and potential conservation elements

Astragalus missouriensis var. *humistratus* is found in a variety of habitats and land management situations in its known range, and these differences are likely to have differential effects on the persistence of the species. Current evidence suggests that *A. missouriensis* var. *humistratus* populations are small and scattered. The dispersed nature of these populations may render them especially susceptible to environmental changes or management policies that introduce fragmentation into once continuous habitat. Surface disturbing activities such as land development, road building, and energy resource development are the primary sources of habitat change in the area.

Desired environmental conditions for *Astragalus missouriensis* var. *humistratus* include undisturbed and unfragmented tracts of habitat, especially areas of shaley substrate in Rocky Mountain Ponderosa Pine Woodland or Rocky Mountain Gambel Oak-Mixed Montane Shrubland ecological system types that are large enough to sustain natural ecosystem processes for both the plant and its pollinators. Landscape connectivity should be sufficient to allow metapopulation dynamics to function. From a functional standpoint, ecosystem processes on which *A. missouriensis* var. *humistratus* depends appear to remain largely intact on public lands in the area. Whether this will remain true as residential development increases on adjacent lands is unknown. Further research on the ecology and distribution of *A. missouriensis* var. *humistratus* will help to develop effective approaches to management and conservation.

It is likely that a thoughtful assessment of current management activities on lands occupied by *Astragalus missouriensis* var. *humistratus* would identify some opportunities for change that would be inexpensive and have minimal impacts on the livelihood and routines of local residents, ranchers, managers, stewards, and recreationists while conferring substantial benefits to *A. missouriensis* var. *humistratus*.

Tools and practices

Species inventory

Colorado Natural Heritage Program data and herbarium collections provide the majority of information on *Astragalus missouriensis* var. *humistratus* occurrences (**Table 3**). Because *A. missouriensis* var. *humistratus* is not tracked by the New Mexico Natural Heritage Program, New Mexico records are exclusively from herbarium specimens. While these sources present a generalized picture of the species' total range, the true extent and population numbers remain essentially unquantified. Thus, a priority for species inventory work is to focus on obtaining more complete data on the number and size of populations both in Colorado and New Mexico. A clearer picture of the relative abundance of *A. missouriensis* var. *humistratus* throughout its range would enable prioritization of any additional inventory and monitoring activities. In addition, inventory and monitoring of populations on USFS lands could focus on locations that are likely to be affected by implementation of management decisions.

Existing protocols for species inventory are primarily based on surveys for rare, threatened, or endangered species. Although not rigorously standardized, these methods all include the same basic principles. The following recommendations are adapted from U.S. Fish and Wildlife Service (2000), California Native Plant Society (2001), and Cypher (2002).

Surveys usually attempt to target all species of concern in an area. In the case of inventory for *Astragalus missouriensis* var. *humistratus*, this practice is particularly applicable since there are many other rare species in the area, including other Region 2 sensitive species. The most effective inventory techniques will attempt to maximize the potential discovery of the targeted species in the survey area by:

1. Identifying areas that are most likely to contain populations. Because detailed micro-site requirements (if any) are not known for *Astragalus missouriensis* var. *humistratus*, it may be difficult to refine search areas as other than "open areas with soils derived from Cretaceous shales and sandstones." Searchers can begin with areas similar to the habitat of known populations, but potential habitat should not be omitted just because it is not exactly like known habitat. The initial phase of species inventory should include the collection of more detailed information on the preferred habitats of *A. missouriensis* var. *humistratus*. This is likely to involve a preliminary field investigation to characterize habitats of some of the known occurrences in both New Mexico and Colorado in more detail. This information can then be used to determine the habitat specificity of *A. missouriensis* var. *humistratus* and to direct further inventory efforts.

2. Searching at the time when plants are most visible and identifiable. For *Astragalus missouriensis* var. *humistratus*, this time is during the flowering and fruiting periods, probably in late May to early July. Before beginning surveys in a given year, at least one member of the survey crew should visit a known population of *A. missouriensis* var. *humistratus* to confirm the current phenology of the target species. In addition, survey work should take into account the effects of drought conditions on the potential visibility of the plants; survey work is likely to be more successful in years with normal precipitation patterns.

3. Employing searchers who are familiar with the plant. Field survey crews should include at least one member who has seen *Astragalus missouriensis* var. *humistratus* growing in its natural habitat. Photographs and/or herbarium specimens may be used to familiarize other team members with the plant if necessary, but its similarity to other

A. missouriensis varieties in the area makes it advisable for all search team members to form a search-image directly from a living specimen in situ whenever possible. Surveys should be conducted by trained professionals who are familiar with the taxa in question. Surveyors should be able to distinguish between varieties of *A. missouriensis*. Collection of voucher specimens may be appropriate. Personnel for the initial survey should be familiar with detailed methods of soil and habitat characterization. Surveyors should use Global Positioning System (GPS) technology for quick and accurate data collection of location and population extent. Preparatory work should take into account the fact that although much of the habitat to be searched is federal land, access through private or tribal land is often required.

4. <u>Systematically covering the area to be searched</u>. In order to facilitate correct identification, survey efforts should take place during the period of flowering and fruiting. As in points 1 and 2 above, searchers should concentrate first on areas where habitats appear similar to those at known locations, potential search areas should not be eliminated merely because they do not possess the exact combination of habitat that is found in the known occurrence. Intensive, systematic survey may be required.

It is important to maximize return from the effort invested in species inventory by carefully documenting results, including negative results. Survey reports should document the location that was visited, the date of the visit, the number and condition of individuals in the population, habitat and associated species information, evidence of disease or predation, and any other pertinent observations. If a new population of *Astragalus missouriensis* var. *humistratus* is located, a completed element occurrence report form for the appropriate state, accompanied by a copy of the appropriate portion of a 7.5- minute topographic map with the occurrence mapped, should be submitted to the Colorado Natural Heritage Program. Population boundaries should be mapped as accurately as possible. If the population size permits, voucher specimens should be collected and submitted to regional herbaria. Regardless of population size, voucher photographs should be taken, and the location should be determined as exactly as possible. Populations located on USFS lands should be permanently marked in some way to facilitate population monitoring. The use of multiple markers (e.g., corner stakes) and GPS coordinates can be a great help in relocating populations. Records should also document areas that were searched unsuccessfully; however, negative results are not a guarantee that the plant is absent from an area.

Habitat inventory

Many of the techniques used in habitat inventory are similar to those described for species inventory. In fact, the habitat delineation component of species inventory provides the starting point for subsequent habitat inventory. The use of aerial photography, topographic maps, soil maps, and geology maps to identify inventory search areas is widely used and highly effective. This technique is most effective when basic knowledge of a species' substrate and habitat specificity is available. A variety of distribution modeling techniques may also be useful to identify the extent of potential habitat. Some techniques require the use of absence data as well as presence data, so it is important to document negative survey results for future use in distribution modeling. Models cannot completely substitute for on-the-ground inventory, but they may allow inventory efforts to focus on areas where potential habitat is most likely to be affected by management actions. In the case of *Astragalus missouriensis* var. *humistratus*, important factors to quantify during habitat inventory will include the degree of disturbance in the area, variation in surface soil composition, associated species, habitat structure, and any additional factors identified by surveyors during species inventory.

Population monitoring

Since there is currently no information on population numbers over time, population monitoring is among the highest priorities for research on *Astragalus missouriensis* var. *humistratus*. A minimal level of effort at permanently established monitoring plots could provide an ongoing qualitative awareness of population trends. Even presence/absence monitoring of known locations could give early warning of declining population trends. This data could be collected yearly at established stations that are easily accessed. Ideally, these stations would coincide with locations already visited by agency personnel in the course of other duties. With a little additional effort, broad population estimates could be made at each station (see Elzinga et al. 1998), and photographs could provide an idea of habitat condition. Such efforts may be especially important if drought is having a large impact on populations.

Quantitative data on the dynamics of subpopulations and the population as a whole are almost entirely lacking. One of the most useful methods would involve monitoring marked individuals over the course of several years. This would require the establishment of permanent plots or transects in areas with sufficient numbers of individuals to provide decent sample sizes. Lesica (1987) and Van Buren and Harper (2003) describe possible methods. Ideally, marked individuals in permanent quadrats or transects would form a core study area for a surrounding population that was also censused annually for total plant numbers. Plots should be large enough to contain a reasonable sample size and to remain useful as plants die and are recruited. Sample sizes may need to be greater than one or two hundred plants. Rittenhouse and Rosentreter's (1994) study of *Astragalus amblytropis* used three nonrandomized transects to obtain initial sample sizes of 105, 63, and 40 plants. Over the course of one year, these sample sizes declined to 19, 6, and 6 plants, respectively. Although this type of decline may be extreme, it highlights the need to ensure that original sample size is sufficient to maintain the study. Plots in large populations could cover a portion of the population while those in smaller populations might contain the entire local occurrence.

At first, monitoring would need to be sufficiently frequent to determine the appropriate time to measure growth and reproduction. Natural variability in growth, flowering, and seed set means that observations that are too infrequent can result in data that are difficult to interpret (e.g., plants that had no flowers at observation time 1 have abundant fruit at observation time 2). The first year of monitoring should concentrate on establishing the timing of critical seasonal elements such as flowering and fruit set, and determining the most useful and practical data collection protocols. Subsequent years could concentrate on collecting data at these established times.

Quantitative studies are time consuming and expensive. Although *Astragalus missouriensis* var. *humistratus* does not appear to merit such levels of study from management personnel at this time, it is important to keep it in mind as a potential research subject for other investigators. Area residents such as Fort Lewis or San Juan College students and faculty, or federal agency researchers should be alerted to the possibility of such studies. Efforts to enlist the help of other researchers in future studies of *A. missouriensis* var. *humistratus* could greatly enhance our knowledge of this species.

Habitat monitoring

Habitat monitoring may need to be conducted on a broader scale than that of population monitoring. This decision will be driven by the results of species inventory and monitoring, and by the habitat characteristics identified during inventory. If habitat monitoring is not possible, or if it is deemed unnecessary, documenting habitat characters, associated species, evidence of current land use and management, disturbance impacts, and so forth for monitored populations would contribute to our knowledge of the species. However, until more is known about the species' habitat requirements, it is possible that monitoring the habitat of only a few known populations will risk missing important trends.

The use of photo points for habitat monitoring is described in Elzinga et al. (1998). Practical details of photographic monitoring are covered exhaustively in Hall (2001). This is a powerful technique that can be done quickly in the field. Although it does not provide detailed cover or abundance data, it can help to elucidate patterns observed in quantitative data.

Beneficial management actions

The linking of *Astragalus missouriensis* var. *humistratus* to management of other local rare and sensitive species is perhaps the most useful conservation strategy, since they are frequently found in similar habitats. The fact that over 40 percent of the known range of this species is on federal land places federal land managers in a good position to establish and perpetuate such a strategy. In general, management actions that minimize the impacts of surface disturbance and promote natural levels of connectivity between subpopulations will tend to benefit populations of *A. missouriensis* var. *humistratus*. Wherever possible, road and trail construction or timber harvesting activities can be located so as to avoid *A. missouriensis* var. *humistratus* populations. Monitoring and control of construction activities and off-road vehicle travel should be combined with practices that prevent the spread of weeds into *A. missouriensis* var. *humistratus* populations. These practices might include public educational outreach about the invasive species problem, periodic monitoring of areas most at risk for infestation, efforts to minimize disturbance and limit dispersal, and the maintenance of healthy native vegetation (see Colorado Natural Areas Program 2000 for additional information). If infestation by noxious weeds cannot be prevented, it is best to use control methods that will not impact *A. missouriensis* var. *humistratus* individuals growing in the area.

Tools available to the USFS for conservation of *Astragalus missouriensis* var. *humistratus* in Region 2 include its continued listing as a sensitive species, regulating the use of USFS lands where it occurs, and increasing the protective level of management area designations for *A. missouriensis* var. *humistratus* occurrences. In some instances, it may be possible for the USFS to contribute to the conservation of *A. missouriensis* var. *humistratus* by identifying and proposing land exchanges or purchases that will lead to the protection of additional occurrences. The USFS can also provide opportunities for the collection of *A. missouriensis* var. *humistratus* material for storage or propagation of off-site populations. Implementation of these and other tools largely depends on the acquisition of better information on known or suspected occurrences.

Seed banking

No seeds or genetic material are currently in storage for *Astragalus missouriensis* var. *humistratus* at the National Center for Genetic Resource Preservation (Miller personal communication 2005). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2002).

Information Needs

At this time our knowledge regarding the extent of *Astragalus missouriensis* var. *humistratus* distribution is accurate only on a broad scale. Within the known distribution, accurate information on the real abundance of the species, especially on tribal lands, is needed. It will be difficult to formulate conservation strategies for Region 2 without clarifying this issue. More complete information on the environmental characters influencing the distribution patterns would also be invaluable in formulating management strategies.

The dynamics of the broad habitat types where *Astragalus missouriensis* var. *humistratus* is found are reasonably well documented. However, the specific position of *A. missouriensis* var. *humistratus* within these ecological systems is not well understood. Furthermore, although the species has been casually observed in the field by a variety of workers, there are no multi-year observations that would contribute to an understanding of the species' life cycle and population trends. Some inferences can be made from other *Astragalus* species, but members of this genus often exhibit restricted ranges, which may indicate local adaptation and differentiation.

Repeated observations of marked individuals in several populations would greatly clarify the population dynamics of *Astragalus missouriensis* var. *humistratus*. In particular, it would be useful to identify the time of germination and onset of flowering, germination requirements, life expectancy, seed bank dynamics, and transition probabilities for different life-cycle stages.

The effects of environmental variation on the reproductive rates, dispersal mechanisms, and establishment success of *Astragalus missouriensis* var. *humistratus* have not been investigated. The same is true for its relationship with herbivores, pollinators, and exotic species. As a consequence, the effects of both fine- and broad-scale habitat change in response to management or disturbance will be difficult to evaluate. Better information on the habitat requirements of *A. missouriensis* var. *humistratus* would facilitate better understanding of the potential effects of disturbance and management actions in these habitats. In particular, investigation of the response of the species to soil disturbances produced by management activities would be beneficial. Because these disturbances can easily be followed by an increase in invasive species, additional information on the effects of these invaders on the habitat and life cycle of *A. missouriensis* var. *humistratus* is also needed. The effects of grazing on the habitat and pollination ecology of *A. missouriensis* var. *humistratus* are also of interest.

The apparent tendency of *Astragalus missouriensis* var. *humistratus* to occur in scattered, small populations may mean that metapopulation dynamics are especially important to the survival of the species. However, virtually nothing is known about the metapopulation structure and processes of *A. missouriensis* var. *humistratus*. It would be most useful for baseline studies to collect data on migration, colonization, and extinction rates, as well as on environmental factors contributing to the maintenance of inter-population connectivity. Until this information is available, we cannot realistically predict the likelihood of *A. missouriensis* var. *humistratus* persisting at either the local or regional scale.

As with metapopulation dynamics, current demographic information is also not sufficient to enable a good analysis of the persistence of *Astragalus missouriensis* var. *humistratus*. The most useful demographic information would include 1) the determination of whether individual and population numbers are increasing, declining, or stable; 2) the identification of which life cycle stages have the greatest influence on population trends; and 3) the determination of what biological factors are influencing those stages identified as being important (Schemske et al. 1994). Lesica's (1995) long-term study of *A. scaphoides* provides a good model for similar work on *A. missouriensis* var. *humistratus*. Collection of useful demographic data will require the investment of two to three years at a minimum, ideally more. While providing useful data, short-term studies can miss important demographic events that reoccur at intervals longer than the study period (Coles and Naumann 2000). A variety of population monitoring methods could be easily adapted to the tracking of *A. missouriensis* var. *humistratus*. Pilot studies may be required to adapt some methods to the particular growth and distribution patterns of *A. missouriensis* var. *humistratus*.

It may be of interest to investigate the phylogenetic relationships within the *Astragalus missouriensis* group, as well as to investigate the potential hybrid origin of *A. missouriensis* var. *humistratus*.

Restoration methods have not been explicitly developed for this species. Existing reclamation and restoration guidelines for resource extraction activities such as timber harvest and well drilling do not have specific provisions for the restoration of *Astragalus missouriensis* var. *humistratus* populations.

The primary information need for *Astragalus missouriensis* var. *humistratus* is the determination of total population numbers and trends over time for known populations. It would also be useful to survey for additional populations, especially on public lands. Basic life-history information, including pollination dynamics and possible impacts on pollinators, rates of recruitment and survival, dispersal, and metapopulation dynamics would contribute to conservation and restoration efforts. Finally, quantification of the effects of land management practices on the survival and persistence of the species would greatly facilitate management decisions for this species.

Some additional information on population locations and habitats may be available from herbarium specimens not consulted for this document. In addition, Volume 10 / 11 (Magnoliophyta: Rosidae, part 3 & 4) of the *Flora of North America*, which will contain the treatment of *Astragalus*, has not yet been released.

DEFINITIONS

Acaulescent: without a stem, or the stem so short that the leaves are apparently all basal (Harris and Harris 1994).

Ascending: growing obliquely upward; usually curved (Harris and Harris 1994).

Caulescent: with an obvious leafy stem rising above the ground (Harris and Harris 1994).

Compound leaf: a leaf separated into two or more distinct leaflets; a pinnately compound leaf has leaflets arranged on opposite sides of an elongated axis (Harris and Harris 1994).

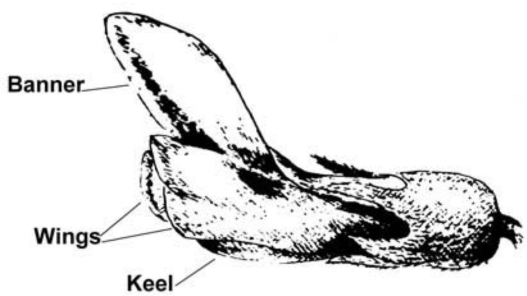
Connate: fused.

Dehiscence: the opening at maturity of fruits and anthers (Harris and Harris 1994).

Fragmentation: The breaking up of once continuous tracts of habitat into smaller, disconnected pieces, generally resulting in a loss of habitat and connectivity between habitat patches.

Monocarpic: A plant that dies after flowering although it may take several years to flower; synonymous with semelparous (Silvertown and Lovett Doust 1993).

Papilionaceous: of flowers, butterfly-like, with a banner petal, two wing petals, and two (fused) keel petals (Harris and Harris 1994).



Adapted from Faegri and van der Pijl 1979

Pubescent: hairy.

Raceme: an elongated inflorescence with a single main axis along which single, stalked flowers are arranged (Harris and Harris 1994).

Rank: used by Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe. Global imperilment (G) ranks are based on the range-wide status of a species. State-province imperilment (S) ranks are based on the status of a species in an individual state or province. State-province and Global ranks are denoted, respectively, with an “S” or a “G” followed by a character (NatureServe 2005). **These ranks should not be interpreted as legal designations**.

Ruderal: of plants, tending to inhabit disturbed areas.

Seleniferous: referring to soil or ore containing selenium.

Stipules: A pair of leaf-like appendages at the base of the leaf stalk in some leaves (Harris and Harris 1994).

Sympatric: applied to species whose habitats (ranges) overlap (Allaby 1998).

Vesture (also vestiture): the epidermal coverings of a plant (Harris and Harris 1994).

Zygomorphic: having bilateral symmetry; a line through the middle of the structure will produce a mirror image on only one plane (Harris and Harris 1994).

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