Astragalus anisus M.E. Jones (Gunnison milkvetch): A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

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Astragalus anisus (Gunnison milkvetch). Photograph by Barry Johnston. Used with his permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ASTRAGALUS ANISUS*

Status

Astragalus anisus (Gunnison milkvetch) is a local endemic whose global distribution is limited to the upper Gunnison Basin in Gunnison County, Colorado. About 75 percent of the documented occurrences are on federal lands, but only 10 to 15 percent are on USDA Forest Service (USFS) land of the Gunnison National Forest. This species is fairly common within the basin, and the population numbers are thought to be stable. However, due to its small global distribution, NatureServe and the Colorado Natural Heritage Program rank this species as G2S2 (imperiled because of rarity or other factors). The Rocky Mountain Region (Region 2) of the USFS does not currently list *A. anisus* as a sensitive species although it was listed as such prior to November 2003. *Astragalus anisus* is included on the Bureau of Land Management (BLM) Colorado State Sensitive Species List in the Gunnison Field Office. 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

Although *Astragalus anisus* is locally common and appears to have a stable population, its entire global range is contained within the upper Gunnison Basin. Additive effects of threats to the population may be compounded by this restricted range. Based on the available information, there are several tangible threats to *A. anisus*. In order of decreasing priority, these are road building, off-road vehicle use, non-motorized recreation, non-native species invasion, grazing, residential development, fire suppression, resource extraction, and global climate change. A lack of systematic tracking of population trends and conditions and a lack of knowledge about the species' basic life cycle also contribute to the possibility that one or more of these factors will threaten its long-term persistence.

Primary Conservation Elements, Management Implications and Considerations

Habitat and populations of *Astragalus anisus* in the upper Gunnison Basin are primarily on public lands. Documented occurrences include nine sites on USFS lands of the Gunnison National Forest, and 64 sites on BLM holdings of the Gunnison Field Office. Consequently, public land managers are in the best position to ensure the continued survival and persistence of this species. Efforts by USFS and BLM personnel to perform basic population monitoring and to maintain a basin-wide awareness and interest in *A. anisus* will contribute greatly to the knowledge and preservation of the species. This level of awareness should contribute to ensuring that management actions do not adversely affect the species' persistence.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Astragalus anisus* (Gunnison milkvetch) is the focus of an assessment because it is a local endemic and was designated a sensitive species in Region 2 from 1993 to 2003. It is not currently so designated (USDA Forest Service 2003). Within the National Forest System, a sensitive species is a plant or and animal whose population viability is identified as a concern by a regional forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species or a species of concern may require special management so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Astragalus anisus* throughout its range, all of which is in Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of assessment

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public a thorough discussion of the biology, ecology, conservation status, and management 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 but provides the ecological background upon which management must be based. However, it does focus on the consequences of changes in the environment that result from management (i.e. management implications). Furthermore, it cites management recommendations proposed elsewhere and, when management recommendations have been implemented, the assessment examines the success of the implementation.

Scope of Assessment

This assessment examines the biology, ecology, conservation, and management of *Astragalus anisus*. Although some, or even a majority, of the literature on related species cited herein may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *A. anisus* 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 placed in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. There are no refereed publications devoted entirely to *Astragalus anisus*, although it is mentioned in a variety of sources. Because basic research has not been conducted on many facets of the biology of *A. anisus*, literature on its congeners was used to make inferences. The refereed and non-refereed literature on the genus *Astragalus* and its included species is somewhat more extensive and includes many endemic or rare species. Not all publications that include information on *A. anisus* or other *Astragalus* species are referenced in the assessment. Material treating common or non-native species of *Astragalus* was generally omitted, as was material that included only brief mention of *A. anisus* without providing new information. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism. Some non-refereed literature was used in the assessment, however, due to the lack of refereed material directly pertaining to *A. anisus*. Non-refereed literature included reports prepared by and for state and federal agencies, online articles, and student research. Unpublished data (e.g. Natural Heritage Program records, Bureau of Land Management survey data) were important in estimating the geographic distribution of the species. These data required special attention because of the diversity of persons and methods used in their collection.

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. However, 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). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations,

inference, good 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 use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly it facilitates 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 Process have been peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, employing at least two recognized experts in 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 anisus is not currently considered a sensitive species in Region 2 of the USFS, and because it occurs only in Colorado, it is not included on any other USFS special status listings in the United States. It is listed on the Sensitive Species List for the BLM Gunnison Field Office. About 75 percent of the documented occurrences are on federal lands that are either owned or managed by the Gunnison Ranger District of the Gunnison National Forest or the Gunnison Field Office of the BLM (**Figure 1**). Of the nine USFS occurrences, only the one in the West Elk Wilderness Area is on land protected from some man-made threats (e.g. motorized vehicle use). Of the 64 occurrences on BLM land, nine are on lands that receive protection as part of the West Antelope Creek and South Beaver Creek Areas of Critical Environmental Concern (ACEC). None of these lands are specifically managed for the conservation of *A. anisus*. This species was also listed as Rare in 1997 IUCN Red List of Threatened Plants (Walter and Gillett 1998), but it is not included in the most recent version of the Red List (International Union for Conservation of Nature and Natural Resources 2003).

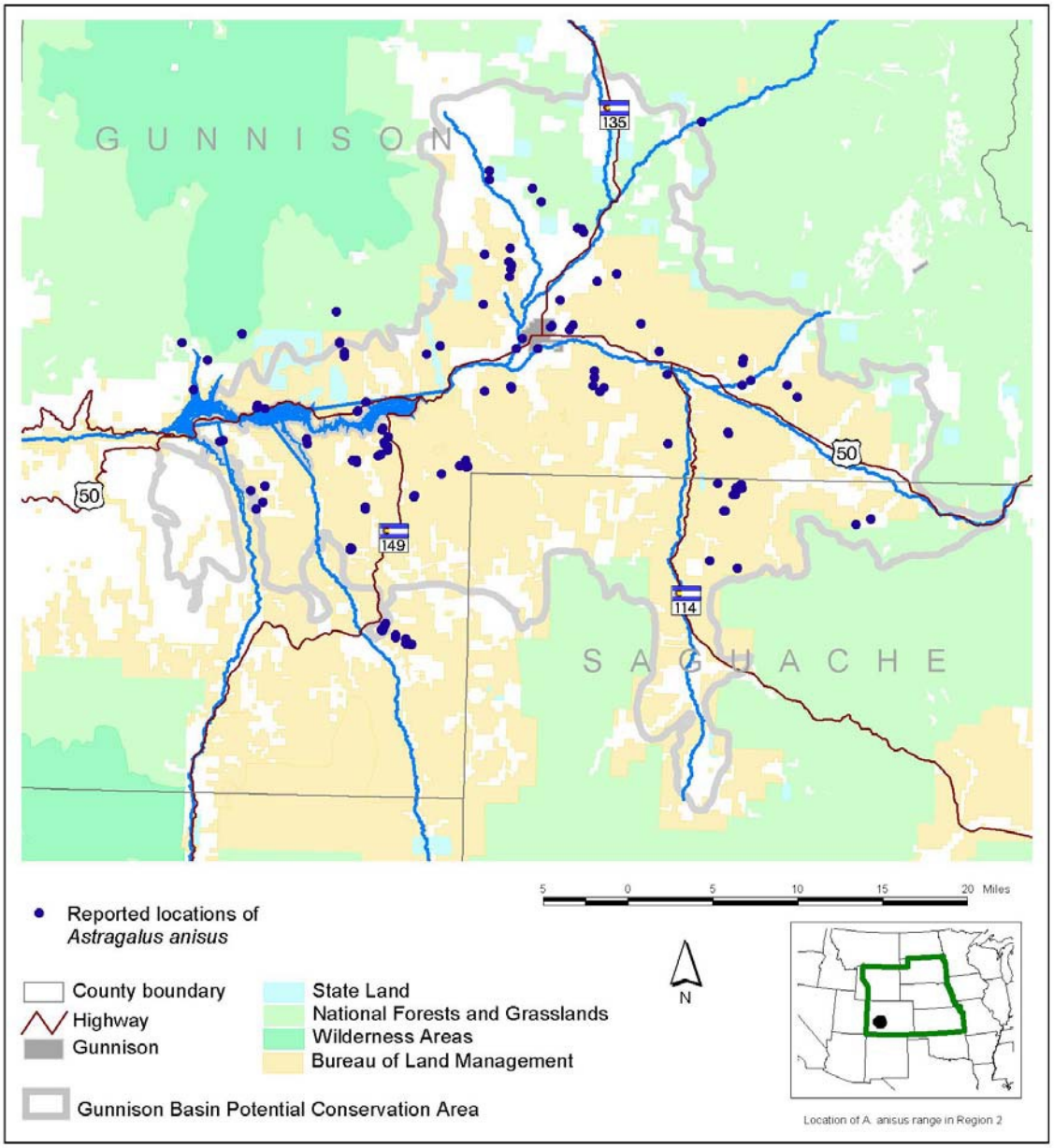


Figure 1. Distribution of *Astragalus anisus* and land ownership of the Gunnison Basin.

The NatureServe and Colorado Natural Heritage Program (NHP) ranks for *Astragalus anisus* are G2 and S2, respectively. The global (G) rank is based on the status of a taxon throughout its range. This species is ranked G2, imperiled globally, because of its rarity (6 to 20 occurrences) or because of other factors demonstrably making it very vulnerable to extinction throughout its range. The state (S) rank is based on the status of a taxon in an individual state. In Colorado, this species is ranked S2, imperiled in state, because of its rarity (6 to 20 occurrences) or because of other factors demonstrably making it very vulnerable to extirpation from the state. The factor weighing most heavily in the rankings of *A. anisus* is its small global distribution, and thus its vulnerability to extinction; the number of known occurrences is a secondary consideration in this case.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Astragalus anisus is not listed as threatened or endangered in accordance with the Endangered Species Act, and therefore there are no laws concerned specifically with its conservation. As of this writing, neither the USFS nor any other federal agency has written a conservation strategy for this species at a national or regional level. Almost all occurrences of *A. anisus* on USFS and BLM holdings in the Gunnison Basin are on lands managed for multiple uses.

Almost all known occurrences of *Astragalus anisus* fall within the Gunnison Basin Potential Conservation Area (PCA), designated by the Colorado NHP as having natural heritage significance (Rocchio et al. 2003; Appendix). The Gunnison PCA encompasses federal, state, and private lands (**Figure 1**) and is considered to have irreplaceable biodiversity significance. It is assigned a B1 ranking by the Colorado NHP. PCA boundaries do not confer any regulatory protection of the site, nor do they automatically exclude all activity. Colorado NHP staff hypothesize that some activities will prove degrading to the elements or the ecological processes on which the PCA is based, while other activities will not. PCA boundaries represent the best professional estimate of the primary area supporting the long-term survival of the targeted species or plant associations and are presented for planning purposes. They delineate ecologically sensitive areas where land-use practices should be carefully planned and managed to ensure that they are compatible with protection of natural heritage resources and sensitive species. PCA boundaries are based primarily on factors relating to the ecological systems, not on an analysis of human context and potential stresses. All land within the PCA planning boundary should be considered an integral part of a complex economic, social, and ecological landscape that requires wise land-use planning at all levels (Rocchio et al. 2003).

A primary consideration influencing the extent and boundaries of the Gunnison Basin PCA is the Gunnison sage grouse (*Centrocercus minimus gunnisonii*), a species of special concern in Colorado and a candidate for listing under the federal Endangered Species Act. The Gunnison sage grouse also serves as an indicator species for the sagebrush shrublands and steppe habitat of the Gunnison basin where *Astragalus anisus* occurs (Young 1994, Young 2003), and it is a Management Indicator Species for the Grand Mesa, Uncompahgre, and Gunnison National Forests. The long-term decline in the grouse population has been attributed to the loss of suitable habitat. Habitat overlap for the sage grouse and the milkvetch is primarily in leks, which are the breeding grounds for the grouse (Johnston personal communication 2003). Management activities intended to improve grouse habitat will not automatically have a positive impact on *A. anisus*. However, any attention directed to the sagebrush habitat on a basin-wide level is likely to ensure that impacts and changes to *A. anisus* habitat are also noted as a side effect. The basin is a Colorado Division of Wildlife Colorado Species Conservation Partnership target area (Colorado Division of Wildlife 2003).

Adequacy of current laws and regulations

There is currently no evidence to suggest that populations of *Astragalus anisus* are anything but stable. However, in the absence of formal laws, regulations or a detailed conservation strategy, assessing the adequacy of current management practices is difficult due to the lack of quantitative information on population trends for *A. anisus*. There is no way to know whether current management practices on lands supporting *A. anisus* populations will be effective in protecting the species in the long term.

The single USFS occurrence in the West Elk Wilderness Area and the nine locations within BLM ACEC boundaries are likely to be somewhat better protected than occurrences on lands where more use is permitted. On a regional-landscape scale, protection and improvement of sage grouse habitat are also likely to help protect *Astragalus anisus* (e.g. through control of livestock grazing, control of invasive species, restoration of native species). However, the real impacts of sage grouse protection efforts for individuals

or populations of *A. anisus* have not been explicitly investigated.

Adequacy of current enforcement of laws and regulations

There have been a few known instances in which populations of *Astragalus anisus* have been extirpated by human activities, and it is possible that other populations have been obliterated without notice. One known occurrence (Johnston and Lucas 1978) was eliminated by the creation of Blue Mesa Reservoir. Another population that occurred on uranium mine tailings (Anderson 1990) was destroyed when the tailings were removed (J. Coles as communicated to Lucy Jordan, quoted in memo from Keith Rose, 20 July 1993, Colorado NHP files). These isolated incidents do not appear to have threatened or endangered the persistence of the species. However, a steady but gradual loss of individual populations over time through a variety of causes could go largely unnoticed for many years.

The primary factor impeding the protection of *Astragalus anisus* populations is the lack of a systematic awareness of the impacts of development, disturbance (e.g. road construction and maintenance, herbicide application), and other habitat loss on the species, both as individual plants and as populations in a basin-wide context. It is unlikely that the species could be suddenly decimated by anthropogenic activities, but without basin-wide monitoring of the species, individual populations could decline and disappear without much fanfare.

Biology and Ecology

Classification and description

Astragalus anisus 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). The Papilionoideae 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 five or more leaflets), of which it is the largest member, comprising some 1600 to 2000 species worldwide (Smith 1977, Zomlefer 1994). The worldwide distribution of *Astragalus* is cosmopolitan outside the tropics and Australia, and the largest center of distribution for *Astragalus* is southwestern Asia (Allen and Allen 1981). 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 our species are endemic to some degree (Barneby 1964).

The origin of the generic name *Astragalus* is thought to be the Greek word *astragalos* (αστράγαλος), meaning ankle-bone. These bones were apparently once used as a form of dice, and the rattle of dry seeds in the pod of *Astragalus* mimics the sound of dice in the cup (Barneby 1964, Allen and Allen 1981).

As a modern genus, *Astragalus* was first delineated in 1700 by Tournefort (cited in Barneby 1964), who separated a group within the Leguminoseae by its bilocular (two-chambered) pod. Ever since that time, this character has been highly influential in the taxonomy of *Astragalus*. Early monographic studies of *Astragalus* were Eurasian in focus (Pallas 1800 and DeCandolle 1802, as cited in Barneby 1964), and it was not until the first half of the 19th century that the North American species received systematic treatment. Beginning with *Flora of North America* (Torrey and Gray 1838), North American *Astragalus* species 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.

During the period between Torrey and Gray and Barneby, the two most important and disputatious monographers of North American *Astragalus* were Marcus Eugene Jones and Per Axel Rydberg. Jones lived and worked in Salt Lake City for many years, in one of the centers of *Astragalus* speciation. He explored the Colorado Plateau and the Great Basin, collecting and describing many of our species. His self-published revision of the genus (Jones 1923), which draws on materials from his own work as well as from the California Academy of Sciences (CAS), Brandegee collections and others, presents 30 sections of *Astragalus* with 273 species and 144 subordinate varieties (Barneby 1964). Working at about the same time as Jones, Per Axel Rydberg produced a monograph for North American Flora (1929). Rydberg breaks *Astragalus* into 28 genera and 564 species. Rydberg had a perhaps unreasonable aversion to the use of variety and subspecies, always "preferring a binomial name to a trinomial for the sake of convenience" (Rydberg 1923). Critics have since pointed out that his treatment falls apart due to a rigid adherence to a system of fruiting characters without any recognition of the dynamic evolutionary processes operating on such characters (Barneby 1964).

The monumental revision of Barneby (1964) presents one genus with 368 species and 184 varieties, for a total of 552 taxa, and it supercedes previous revisions. Isely's (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. Taxonomically isolated species are characteristic of *Astragalus* (Barneby 1964), and *A. anisus* appears to follow this tendency.

History of knowledge

Astragalus anisus is somewhat unusual among its congeners in that it has remained under the same name since its description, throughout the anfractuous revisions of the genus previously mentioned. In part, this taxonomic stability may be due to the fact that it was known only from the type specimen for many decades.

Astragalus anisus was first described by Jones (1893) from a specimen "collected at Pueblo, Colorado, by Miss A. P. Lansing, and communicated by Miss Alice Eastwood". Jones (1928) described it as "a unique species … never found but once, and then only in fruit, near Pueblo Colorado, Lower Temperate life zone". The holotype was originally deposited at Pomona College, now merged with Rancho Santa Ana (RSA-POM) where it is accession number POM-45945, with a collection date of 1892. Duplicates of this collection (isotypes) are at California Academy of Sciences (CAS), where the collection date is listed as 1888, at University of California (UC), and at the New York Botanical Garden (NYBG) with a collection date of 1891.

Barneby (1964) recounts from his communication with Miss Eastwood that Miss Alida Lansing was a student of Miss Eastwood when she taught at Denver High School. Miss Eastwood's description of the collector, although discreet, gives the impression that Miss Lansing was not a meticulous record-keeper, and perhaps more interested in pressing pretty wildflowers than in rigorous botanical collection. At any rate, some mistake in recording the collection location appears to have resulted in an error of location for the type specimen, which resulted in the species disappearing from collectors' view for over half a century. Rydberg (1906) gives its habitat as "dry mesas of Colorado", without further citation.

Astragalus anisus was eventually rediscovered in its true range near Gunnison in 1949 by William A. Weber (1949). Continued searches in the Pueblo vicinity have failed to turn up any evidence that *A. anisus* ever occurred there (Colorado Native Plant Society 1997). The species has been infrequently but regularly collected in the past 50 years or so. In an ironic twist, a specimen at the University of Colorado Museum Herbarium (COLO) collected in 1898 near Sapinero and originally identified as *A. shortianus*, then annotated to *A. iodopetalus*, was recently reannotated as *A. anisus* (Lederer personal communication 2003). This specimen could have served to identify the true locale of *A. anisus* only a few years after Miss Lansing's incorrectly labeled collection. In addition to the type specimens at RSA, CAS, UC, and NYBG, specimens are housed at COLO, the Rocky Mountain Herbarium (RM), Colorado State University (CS), Western State College (R. Bingham personal communication 2003), and possibly other locations.

A brief investigation of the classification of *Astragalus anisus* is enough to reveal that the internal phylogenetic relationships of *Astragalus* as a genus are still somewhat roughly delineated. Although *A. anisus* has remained under the same name through the revisions of Jones, Rydberg, Barneby, and Isely, and although it has remained in approximately the same position in the organization of the genus as a whole, its neighbors within the subgroup Argophylii have not remained constant. Barneby (1964) places *A. anisus* in

the large-flowered Piptolobi, under section Argophylii, subsection Anisi, where it is most closely allied with subsection Missourienses. These two groups share the characteristic dolabriform hairs and persistent pods. Recent phylogenetic research (Sanderson 1991, Sanderson and Doyle 1993, Wojciechowski et al. 1999) has tended to confirm the basic structure of Barneby's classification.

Much of the more recent knowledge of the species is due to the work of federal agency personnel in the Gunnison Basin and to the investigations of Dr. Robin Bingham's students at Western State College in Gunnison.

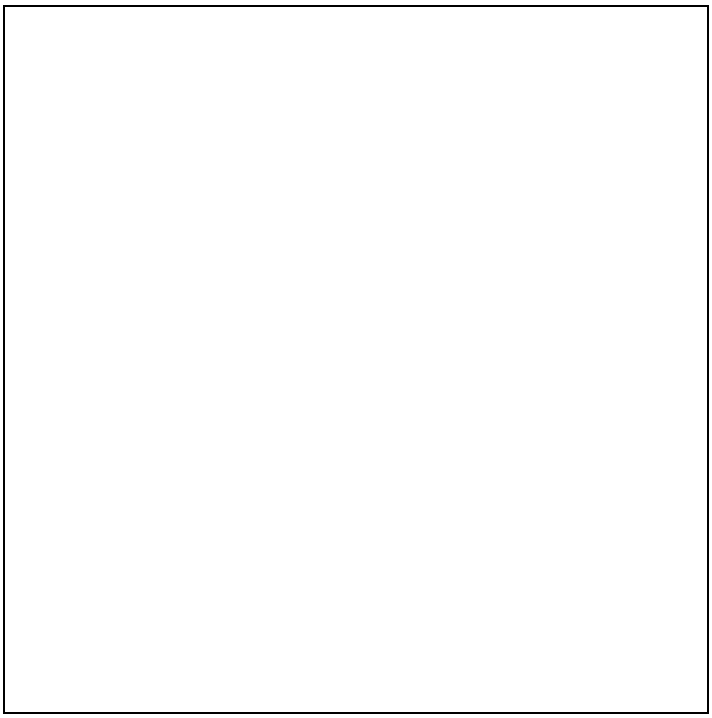
Description

As described by Barneby (1964), *Astragalus anisus* is a short, tufted perennial with basal leaves that arise from a very short stem above a woody taproot. The caudex, or stem base, often shows the thatched remains of old leaves. The leaves are pinnately compound, up to 7 cm long, with 11 to 15 leaflets. The entire plant appears silvery-gray due to the presence of numerous hairs of a characteristic dolabriform (ax or pick-shaped) shape. *Astragalus anisus* flowers from May to June. Flowers are borne on short racemes and are typically pink-purple in color. The pods (fruits) are short (1.3 to 1.8 cm in length) and almost round, though somewhat compressed from front to back, and of a fleshy texture with flat-lying hairs. Fruits are originally green in color, becoming brown with maturity. Each fruit contains 28 to 40 ovules. Seeds are smooth, black, and small (2.0 to 2.4 mm in length). The fruit is bilocular (has two chambers), often appears red or orange when inflated, and splits into two sections when dry.

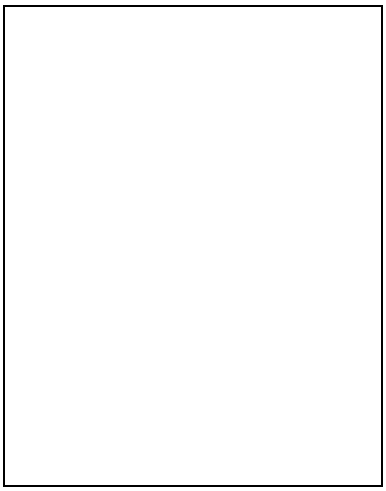
Johnston et al. (2001) list 29 other species of *Astragalus* that occur in the Gunnison Basin. Most are not easily confused with *A. anisus*. The characteristic silvery-gray foliage, dwarf habit, and nearly round fruits make the species relatively easy to distinguish. Fruiting individuals are easily identified by the pods trailing out from underneath the foliage (Henretty 1994). Of the similar species in the area, *A. alpinus* has long, pendant fruits instead of nearly globular pods. *Astragalus aboriginum* is generally much taller, with longer leaflets and smaller flowers, and it is usually found at higher elevations (Spackman et al. 1997). *Astragalus iodopetalus* is also low-growing and silvery-gray, but has blue flowers and glaucous fruits.

Published descriptions and other sources

Complete technical descriptions are available in Jones (1893, 1923), Barneby (1964), and Isely (1984, 1998). Of these, Barneby is the most complete, and his Atlas is available in most herbaria and university libraries. Isely's (1998) description, although more recent, is much abridged, and the longer version published in the Iowa State Journal of Research (Isely 1984) is not widely available. Good drawings of *Astragalus anisus* are harder to find. The only illustration of a complete specimen is from Spackman et al. (1997), and is somewhat simplistic in detail (see **Figure 2a**), especially of the fruit. Jones (1923) includes a better drawing of a fruit and a leaflet **Figure 2b**), but does not illustrate the complete plant. Furthermore, the self-published edition of his monograph and plates is not readily available. An excellent photograph showing the fruits is available in *Rare Plants of Colorado* (Bill Jennings in Colorado Native Plant Society 1997), and a good photograph showing the plant in flower (by Barry Johnston, Gunnison NF) is readily available in the *Colorado Rare Plant Field Guide*, in both online and print versions (Spackman et al. 1997) (**Figure 3**).



(a)



(b)

Figure 2. Drawings of *Astragalus anisus*. Illustration (a) by Gemma Delfinado, and illustration (b) by M.E. Jones. Used with permission.

photos by Barry Johnston

Figure 3. Photographs of *Astragalus anisus* by Barry Johnston, used with permission.

Distribution and abundance

Discussions of endemism in the literature have highlighted the imprecision with which the term is often used (e.g., Krukeberg and Rabinowitz 1985, Anderson 1994). For instance, although *Astragalus anisus* and *A. microcymbus* are both described as endemic to the Gunnison area, it is clear that *A. anisus* has a much larger range and is more common in the area than *A. microcymbus*. *Astragalus anisus* is perhaps best described as a local endemic; it is known only from East-Taylor, Tomichi, and Upper Gunnison watersheds in the Gunnison River Basin (Gunnison and Saguache counties).

Assuming that the type locality of Pueblo is incorrect, the current and historical ranges of *Astragalus anisus* are probably roughly synonymous. The global, regional, and statewide distribution of *A. anisus* lies entirely in an area within approximately a 35 mile radius of the town of Gunnison, Colorado and may encompass as much as 600 square miles (**Figure 1**).

Astragalus anisus has been reported as far west as Soap Creek, although documented occurrences there are thought to be extirpated. The eastern-most known locations are in Saguache County southeast of Doyleville. An isolated single report at the USFS One-Mile Campground in Taylor Canyon (Marotti et al. 1996) is the northernmost occurrence, but with the exception of this one, the lower 10 miles of the Ohio Creek drainage are the more well-defined northern extent. Occurrences in the Powderhorn area mark the southernmost extension currently known. See **Table 1** for a summary of documented occurrences of *A. anisus*.

Within the Gunnison Basin, *Astragalus anisus* is found throughout much of the sagebrush shrubland habitat. Because it is so common within the area, field workers tend to stop recording instances after a while (Austin personal communication 2003, Capodice personal communication 2003, Johnston personal communication 2003), so the reported locations probably do not reflect the complete extent of its distribution. There are nine known occurrences on the Gunnison National Forest (Johnston personal communication 2003), including one on the West Elk Wilderness Area, and there are perhaps another 60 to 70 additional documented locations on other federal, state, or private land (**Table 1**), depending on whether some reports in fact constitute separate populations. Johnston (personal communication 2003) estimated that there could be as many as 500 occurrences. About 75 percent of the documented occurrences are on federal lands, but only 10 to 15 percent are USFS land.

Population sizes reported by Wasson (1998) range from 4 to 760+ individuals, in areas ranging from 0.025 to 130 acres. Mean population size is 72 plants in an area of about 20 acres. One population that may be as large as 5000+ individuals has been reported (Johnston personal communication 2003), although it is not known if this refers to any of the occurrences listed in **Table 1**. The numbers of plants is highly correlated with total population area (r= 0.91), but it is quite variable. Within a population, plants are typically distributed in clusters of 3 to 10 individuals, and the clusters are widely scattered (Wasson 1998). For smaller populations (less than 250 plants), the average number of plants is slightly less than 2 per acre. Population sizes for occurrences on USFS lands are largely unquantified, but numbers of 2, 21, and 50 to 100 plants are reported for three locations (**Table 1**).

Table 1. Documented occurrences of *Astragalus anisus*. Occurrences are arranged by location (Township, Range, Section) and are arbitrarily numbered. With the exception of record 1, which is in the 6th principle meridian, all TRS locations are in the 21st principle meridian. Some occurrences as listed here may be combined as a single occurrence when more information is available, but they were kept separate here to retain distinct habitat information. Sources include Colorado Natural Heritage Program data (CNHP), Johnston survey (vegetation plots collected for Johnston et al. 2001), BLM survey records (CNHP files), and herbarium labels. ID information is from the source. CNHP ID's are either Element Occurrence Records (of the format EOR00), or unprocessed raw data from CNHP files (RDB00). Johnston survey sample numbers and BLM site codes are also given in parenthesis. Counties: GUNN = Gunnison, SAGU = Saguache. Ownership: BLM = Bureau of Land Management, Colorado = State of Colorado, USFS = USDA Forest Service.

	County	Ownership	Date of Last Observation	Location	Elevation (ft)	Habitat	Population size	Source (ID)
1	GUNN	USFS Gunnison NF	6/10/1996	15.0S 84.0W Sec22 –One-mile Campground.	8,400	Surrounding area occupied by patches of sagebrush meadow and blue spruce forest on floodplain. Disturbed gravel roadside. Open to partial shade.	2 plants	CNHP (EOR19)
2	SAGU	BLM Gunnison FO	8/13/1998	47.0N 2.0E Sec10	Not available (NA)	Big sagebrush-sparse Utah serviceberry-pine needlegrass-sparse snowberry community. Aspect: 14. Slope 12 %.	Present	Johnston survey (Sample 988029)
3	SAGU	BLM Gunnison FO	8/20/1998	47.0N 2.0E Sec11	NA	Big sagebrush-Kentucky bluegrass-yarrow-dandelion community. Aspect: 294. Slope 16%.	Present	Johnston survey (Sample 988030)
4	GUNN	BLM Gunnison FO	7/8/1998	47.0N 2.0W Sec5	8,620 to 8,680	S/SW slopes, rocky area, sandy, granitic gravels. Black sage and big sage.	5 plants	BLM survey (GAT01) CNHP (RDB112)
5	GUNN	BLM Gunnison FO	8/18/1993	47.0N 2.0W Sec34	8,360	Bitterbrush-big sagebrush-muttongrass-Arizona fescue and Big sagebrush-bitterbrush-muttongrass-pine needlegrass communities. Aspect: 289 and 275. Slope: 24% and 22%.	Present	CNHP (EOR12) Johnston survey (Samples 933075 & 933076)
6	GUNN	BLM Gunnison FO	7/6/1998	47.0N 2.0W Sec34	8,650	SW slopes, rocky areas, sandy, granitic gravels. Black sage, big sage.	35 plants	BLM survey (POW01/02) CNHP (RDB94)
7	GUNN	BLM Gunnison FO	7/21/1998	47.0N 2.0W Sec34	8,760 to 8,950	SW slopes, rocky areas, sandy, granitic gravels. Black sage and big sage-on either side of the roadway.	23 plants	BLM survey (POW03) CNHP (RDB95)
8	GUNN	BLM Gunnison FO	7/21/1998	47.0N 2.0W Sec35	8,775	SW slopes, rocky areas, sandy, granitic gravels. Black sage and big sage growing on either side adjacent to the roadway.	4 plants	BLM survey (POW04) CNHP (RDB96)
9	GUNN	BLM Gunnison FO	7/21/1998	47.0N 2.0W Sec35	8,800 to 8,900	SW slopes, rocky areas, sandy, granitic gravels. Black sage and big sage adjacent to the roadway.	6 plants	BLM survey (POW05) CNHP (RDB97)
10	GUNN	BLM Gunnison FO	7/21/1998	47.0N 2.0W Sec35	8,800 to 8,900	SW slopes, rocky areas, sandy, granitic gravels. Black sage and big sage adjacent to the roadway.	10 plants	BLM survey (POW06) CNHP (RDB98)
11	GUNN	BLM Gunnison FO	6/15/1998	48.0N 1.0W Sec7	8,540 to 8,580	S/W/SW slopes, rocky areas, sandy, granitic gravels. Black sage, big sage.	11 plants	BLM survey (BMS11) CNHP (RDB92)
12	GUNN	BLM Gunnison FO	6/15/1998	48.0N 1.0W Sec7	8,540 to 8,580	S/W/SW slopes, rocky areas, sandy, granitic gravels. Black sage, big sage.	19 plants	BLM survey (BMS12) CNHP (RDB93)
13	GUNN	BLM Gunnison FO	5/20/1999	48.0N 1.5W Sec12	8,740	Habitat type: black sagebrush-pine needlegrass-muttongrass. Aspect: northeast. Slope: 2%. Soil texture: sandy/gravelly.	30 to 40 plants	CNHP (EOR33)
14	GUNN	BLM Gunnison FO	6/28/1995	48.0N 2.0E Sec6	8,420	Aspect: 265. Slope: 8%.	Present	Johnston survey (Sample 955023)
15	SAGU	BLM Gunnison FO	7/9/1993	48.0N 2.0E Sec13	9,330	Arizona fescue-junegrass-pingue community. Aspect: 249. Slope: 7%.	Present	Johnston survey (Sample 933013)

	County	Ownership	Date of Last Observation	Location	Elevation (ft)	Habitat	Population size	Source (ID)
16	SAGU	BLM Gunnison FO	6/22/1995	48.0N 2.0E Sec13	9,360	Arizona fescue-junegrass-pingue community. Aspect: 266. Slope: 17%.	Present	Johnston survey (Sample 955016)
17	SAGU	BLM Gunnison FO	7/5/1995	48.0N 2.0E Sec13	9,360	Arizona fescue-junegrass-pingue community. Aspect: 241. Slope: 20%.	Present	Johnston survey (Sample 955027)
18	SAGU	BLM Gunnison FO	7/5/1995	48.0N 2.0E Sec13	9,340	Black sagebrush-Arizona fescue-junegrass-pingue community. Aspect: 219. Slope: 16%.	Present	Johnston survey (Sample 955025)
19	SAGU	BLM Gunnison FO	7/31/1998	48.0N 2.0E Sec13	9,200 to 9,360	SW slopes, rocky areas, sandy, granitic gravels. Black sage, big sage.	129 plants	BLM survey (HGL03) CNHP (RDB88)
20	SAGU	BLM Gunnison FO	6/22/1995	48.0N 2.0E Sec14	9,100	Black sagebrush-bottlebrush squirreltail-pine needlegrass.	Present	Johnston survey (Sample 955015)
21	SAGU	BLM Gunnison FO	7/31/1998	48.0N 2.0E Sec14	9,100 to 9,300	SW slopes, rocky areas, sandy, granitic gravels. Black sage, big sage.	51 plants	BLM survey (HGL02) CNHP (RDB87)
22	SAGU	BLM Gunnison FO	8/1/1997	48.0N 2.0E Sec15	8,640	Flat area with sandy gravel and some gullies. Sagebrush and very sparse dryland grasses.	12 plants	BLM survey (HGL05) CNHP (RDB101)
23	SAGU	BLM Gunnison FO	7/31/1998	48.0N 2.0E Sec23	9,100 to 9,320	SW slopes, rocky areas, sandy, granitic gravels. Black sage, big sage.	100 plants	BLM survey (HGL04) CNHP (RDB89)
24	SAGU	BLM Gunnison FO	8/7/1998	48.0N 2.0E Sec26	8,700 to 8,750	SW slopes, rocky areas, sandy, granitic gravels. Black sage, mountain big.sage.	6 plants	BLM survey (HGL07) CNHP (RDB90)
25	GUNN	BLM Gunnison FO	5/22/1998	48.0N 2.0W Sec3	7,780 to 8,380	SW slopes, rocky areas, sandy, granitic gravels. Black sage, mountain big sage.	>234 plants	BLM survey (BMS03) CNHP (RDB111)
26	GUNN	BLM Gunnison FO	8/6/1996	48.0N 2.0W Sec4	7,960	Big sagebrush-pine needlegrass community. Aspect: 193. Slope: 10%.	Present	Johnston survey (Sample 961010)
27	GUNN	BLM Gunnison FO	8/7/1996	48.0N 2.0W Sec4	7,960	Big sagebrush-sparse bitterbrush community. Aspect: 233. Slope: 17%.	Present	Johnston survey (Sample 961011)
28	GUNN	BLM Gunnison FO	5/21/1998	48.0N 2.0W Sec8	8,020 to 8,040	SW slope, rocky area, sandy, granitic gravels. Black sage, big sage.	17 plants	BLM survey (BMS08) CNHP (RDB109)
29	GUNN	BLM Gunnison FO	5/21/1998	48.0N 2.0W Sec8	8,000	SW slope, rocky area, sandy, granitic gravels. Black sage, big sage.	100 plants	BLM survey (CPR07) CNHP (RDB110)
30	GUNN	BLM Gunnison FO	8/2/1994	48.0N 2.0W Sec20	8,730	Arizona fescue-fringed sage-sparse. Aspect: 331. Slope: 34%.	Present	CNHP (EOR10) Johnston survey (Sample 944222)
31	GUNN	BLM Gunnison FO	7/15/1997	48.0N 2.0W Sec23	8,340	Mature sagebrush. S/SW slope, disturbed area along fenceline and down cattle trail.	52 plants	BLM survey (BMS07) CNHP (RDB91)
32	SAGU	USFS Gunnison NF	6/19/1998	48.0N 3.0E Sec25	8,740	*Artemisia nova/Poa fendleriana* community. Aspect: northeast. Slope: 1%. Rolling uplands. Soil texture: sandy.	20 plants	CNHP (EOR31)
33	GUNN	BLM Gunnison FO	7/29/1994	48.0N 3.0W Sec2	8,330	Indian ricegrass-bottlebrush community. Aspect: 264. Slope: 28%.	1.5% cover	CNHP (EOR09) Johnston survey (Sample 944065)
34	GUNN	Private	6/2/1997	48.0N 3.0W Sec16	NA	Not available (NA)	Present	Johnston survey (Sample 972067)
35	GUNN	BLM Gunnison FO	6/5/1997	48.0N 3.0W Sec17	NA	NA	Present	Johnston survey (Sample 972064)

	County	Ownership	Date of Last Observation	Location	Elevation (ft)	Habitat	Population size	Source (ID)
36	GUNN	Private	6/10/1997	48.0N 3.0W Sec21	NA	NA	Present	Johnston survey (Sample 972093)
37	GUNN	Private	6/4/1997	48.0N 3.0W Sec29	NA	NA	Present	Johnston survey (Sample 972096)
38	SAGU	BLM Gunnison FO	8/1/1998	48.0N 4.0E Sec30 - Southeast of Doyleville	8,440 to 8,780	*Artemisia/Poa* community: Soil texture: sandy.	36 plants	CNHP (EOR21)
39	SAGU	BLM Gunnison FO	8/1/1998	48.0N 4.0E Sec30 - Southeast of Doyleville	8,540	Associated plant community: black sage, big sage. Southwest slopes, rocky areas, sandy, granitic gravels.	16 plants	CNHP (EOR32)
40	GUNN	BLM Gunnison FO	7/30/1992	48.0N 4.0W Sec1	8,460	Black sagebrush-big sagebrush-sparse Arizona fescue. Aspect: 249. Slope: 13%.	Present	CNHP EOR08 Johnston survey (Sample 922016)
41	GUNN	BLM Gunnison FO	6/2/1998	49.0N 1.0E Sec16	8,000 to 8,100	SW slope, rocky area, sandy, granitic gravels. Black sage, big sage.	80 plants	BLM survey (SLP05/06) CNHP (RDB107)
42	GUNN	BLM Gunnison FO	6/2/1998	49.0N 1.0E Sec22	8,100 to 8,200	SW slope, rocky area, sandy, granitic gravels. Black sage, big sage.	76 plants	BLM survey (SLP08) CNHP (RDB108)
43	GUNN	Private	5/16/1990	49.0N 1.0W Sec1 - South of Gunnison airport, uranium tailings pile	7,600	With sagebrush and crested wheatgrass.	Extirpated	Herbarium label Welsh & Anderson #24437 at RM
44	GUNN	Private	5/16/1990	49.0N 1.0W Sec2 - West of Gunnison	7,680	Gravel flat.	Not available (NA)	CNHP (EOR05)
45	GUNN	Private	6/6/1951	49.0N 1.0W Sec3 - Roadside, 1 mile w. of Gunnison	7,600	NA	NA	Herbarium label Pendland & Hartwell #4124 at RM CNHP (RDB115)
46	GUNN	BLM Gunnison FO, South Beaver Creek ACEC	7/11/1997	49.0N 1.0W Sec20 - Hartman Rocks	7,800	Hillsides in U-shaped draw. Sagebrush, dryland grasses.	14 plants	BLM survey (INW01) CNHP (RDB99)
47	GUNN	BLM Gunnison FO, South Beaver Creek ACEC	7/11/1997	49.0N 1.0W Sec22	8,000 to 8,075	SW slope, rocky area, sand and granitic gravels. Sagebrush.	19 plants	BLM survey (INW02) CNHP (RDB100)
48	GUNN	BLM Gunnison FO, South Beaver Creek ACEC	7/11/1997	49.0N 1.0W Sec22	8,000 to 8,075	SW slope, rocky area, sandy, granitic gravels. Sagebrush.	18 plants	BLM survey (GUN09) CNHP (RDB106)
49	GUNN	BLM Gunnison FO	10/3/1995	49.0N 2.0E Sec6	7,920	Wyoming sagebrush-sparse community. Aspect: 176. Slope 13%.	Present	Johnston survey (Sample 951017)
50	GUNN	BLM Gunnison FO	7/27/1997	49.0N 2.0E Sec12 - Northeast of Parlin	8,400 to 8,520	Sagebrush - mature stands and black sagebrush-pine needlegrass community. Aspect: south/southwest. Slope: 5-25%. Soil texture: sandy gravel.	~200 plants	CNHP (EOR29) Johnston survey (Sample 955003)
51	GUNN	BLM Gunnison FO	7/15/1998	49.0N 2.0E Sec13 - Parlin vicinity	8,000 to 8,670	Sagebrush community. South/southwest slopes. Rocky, sandy soil.	225 plants	CNHP (EOR25)

	County	Ownership	Date of Last Observation	Location	Elevation (ft)	Habitat	Population size	Source (ID)
52	GUNN	BLM Gunnison FO	7/15/1998	49.0N 2.0E Sec13 - Parlin vicinity	8,000 to 8,020	Southwest slopes, rocky areas, sandy, granitic gravels. Associated plant community: low growing sagebrush.	4 plants	CNHP (EOR28)
53	GUNN	BLM Gunnison FO	7/15/1998	49.0N 2.0E Sec13 - Parlin vicinity	8,000 to 8,020	Associated plant community: low growing sagebrush. Habitat type: southwest slopes, rocky areas, sandy, granitic gravels.	21 plants	CNHP (EOR30)
54	GUNN	BLM Gunnison FO	5/23/1978	49.0N 2.0E Sec18 - Rocky ridges just S of old gravel pit along Colorado highway 114	NA	NA	NA	Herbarium label Johnston & Lucas #1514 at RM
55	GUNN	BLM Gunnison FO	8/7/1998	49.0N 2.0E Sec35	7,690	SW slopes, rocky areas, sandy, granitic gravels. Black sage, mountain big sage.	4 plants	BLM survey (HGL06) CNHP (RDB102)
56	GUNN	BLM Gunnison FO, West Antelope Creek ACEC	5/27/1998	49.0N 2.0W Sec1 SW¼. - Northern Gunnison Basin: ca 6 air mi W of Gunnison.	7,950	South-facing sagebrush slope.	NA	Herbarium label Taylor #5358 at COLO
57	GUNN	BLM Gunnison FO, West Antelope Creek ACEC	5/18/1998	49.0N 2.0W Sec11 N½. - Northern Gunnison Basin: ca 6.5 air mi WSW of Gunnison.	7,950	Sagebrush meadow and drainage.	NA	Herbarium label Taylor #4950 at COLO
58	GUNN	BLM Gunnison FO, West Antelope Creek ACEC	6/8/1949	49.0N 2.0W Sec19 - 12 mi. E of Gunnison	NA	Sandy clay loam, sagebrush hillside.	NA	Herbarium label Weber #4706 at COLO & RM CNHP (RDB113)
59	GUNN	BLM Gunnison FO	7/26/1993	49.0N 2.0W Sec30	7,690	Wyoming sagebrush-sparse Indian ricegrass. Aspect: 245. Slope: 7%.	0.6% cover	CNHP (EOR11) Johnston survey (Sample 933039)
60	GUNN	BLM Gunnison FO	5/13/1998	49.0N 2.0W Sec32	7,900	Habitat type: *Artemisia nova/Stipa pinetorum* and Wyoming sagebrush-sparse Indian ricegrass. Rolling uplands. Aspect: 298. Slope: 5%. Gravelly/ rocky soil.	40 to 50 plants	CNHP (EOR23) Johnston survey (Sample 961001)
61	GUNN	BLM Gunnison FO	8/7/1998	49.0N 3.0E Sec17 - East of Parlin	8,380	Habitat type: SW slopes, rocky areas, granitic gravels. Black sage, mountain big sage, grasses.	85 plants	CNHP (EOR24)
62	GUNN	BLM Gunnison FO	6/30/1964	49.0N 3.0E Sec21 - Parlin vicinity	8,300	With sagebrush on sandy loam soil. Aspect: SW; Slope: 15%.	NA	CNHP (EOR04)
63	GUNN	BLM Gunnison FO, West Antelope Creek ACEC	9/12/1995	49.0N 3.0W Sec1	9,430	Arizona fescue-pingue-needle-and-thread community. Aspect: 269. Slope: 16%.	Present	CNHP (EOR26) Johnston survey (Sample 955223)
64	GUNN	BLM Gunnison FO, West Antelope Creek ACEC	9/13/1995	49.0N 3.0W Sec12	9,220 to 9,430	Arizona fescue-junegrass-pingue and Blue grama-sedge-needle-and-thread-sparse Arizona fescue communities. Aspect: 260-269. Slope: 16-25%.	Present	CNHP (EOR15 & EOR27) Johnston survey (Samples 955071 & 955072)

	County	Ownership	Date of Last Observation	Location	Elevation (ft)	Habitat	Population size	Source (ID)
65	GUNN	BLM Gunnison FO	6/17/1994	49.0N 3.0W Sec30	7,660	Wyoming sagebrush-Hood's phlox community. Aspect: 268, 119. Slope: 17%, 9%.	Present	CNHP (EOR13) Johnston survey (Samples 944009 & 944011)
66	GUNN	USFS Gunnison NF West Elk WA	6/13/1997	49.0N 4.0W Sec1 NE¼. - Northern Gunnison Basin: ca 18 air mi W of Gunnison.	8,950 to 9,450	Narrowleaf cottonwood drainage.	NA	Herbarium label Taylor #1345 at RM
67	GUNN	USFS Gunnison NF	9/17/1996	49.0N 4.0W Sec10 - Coal Creek	7,880	*Artemisia tridentata/Poa fendleriana* community. Aspect: W; Slope: 3-4%. Soil: old thick colluvial landslide deposit - clay loam?	Two sub-sites: 17 plants and 4 plants	CNHP (EOR18)
68	GUNN	BLM Gunnison FO	5/24/1978	49.0N 4.0W Sec21 - Soap Creek	7,400	East facing clay hills.	extirpated	CNHP (EOR07)
69	GUNN	BLM Gunnison FO	7/8/1994	50.0N 1.0E Sec15	8,450	Black sagebrush-pine needlegrass community. Aspect: 275. Slope: 11%.	Present	Johnston survey (Sample 944202)
70	GUNN	BLM Gunnison FO	5/30/1997	50.0N 1.0E Sec16 S1/2- Northern Gunnison Basin: ca 3.5 air mi NE of Gunnison.	7,800 to 8,000	Sagebrush meadow.	NA	Herbarium label Taylor #714 at RM
71	GUNN	Private	6/5/1994	50.0N 1.0E Sec19 - Cranor Hill Road	7,840	Sagebrush-indian rice grass community. Soil: gravelly clay loam.	5 to 7 plants	CNHP (EOR17)
72	GUNN	BLM Gunnison FO	7/25/1997	50.0N 1.0E Sec31 - Gunnison Cemetery	7,800	Gravelly slope. Sagebrush with dryland grasses in sparse clumps, assorted xeric forb species.	40 plants	BLM survey (GUN06)
73	GUNN	BLM Gunnison FO	6/9/1995	50.0N 1.0E Sec36	8,670	Black sagebrush-pine needlegrass. Aspect: flat. Slope 0%.	Present	Johnston survey (Sample 955303)
74	GUNN	BLM Gunnison FO	8/22/1997	50.0N 1.0W Sec3 - Maggie Gulch	8,400 to 8,540	Very windy hillside spilling down S/SW slopes into more vegetation; very stoney and gravelly in most locations. Rugged terrain. Stunted sagebrush.	761 plants	BLM survey (GUN01/02/03) CNHP (RDB103)
75	GUNN	Private	6/5/1994	50.0N 1.0W Sec8 - Maggie Gulch	8,280	Sagebrush/bitterbrush and sagebrush/pine needlegrass communities. Aspect: flat; Slope: 0%. Soil: clay loam.	15 plants	CNHP (EOR16)
76	GUNN	BLM Gunnison FO, West Antelope Creek ACEC	5/27/1998	50.0N 1.0W Sec29 NE¼. - Northern Gunnison Basin: ca 3.5 air mi NW of Gunnison.	8,075	Sagebrush hills.	NA	Herbarium label Taylor #5308 at COLO
77	GUNN	Private	7/1/1997	50.0N 1.0W Sec36 - Escalante Hill	7,700	S/SW hillside, rocky, gravelly on disturbed areas. Sagebrush with dryland grasses in sparse clumps, lichens.	10 plants	BLM survey (GUN05) CNHP (RDB105)
78	GUNN	USFS Gunnison NF	6/20/1998	50.0N 3.0W Sec26 SE¼. - Northern Gunnison Basin: ca 12.5 air mi WNW of Gunnison.	9,575	Aspen forest and sagebrush meadow.	NA	Herbarium label Taylor #7046 at COLO

	County	Ownership	Date of Last Observation	Location	Elevation (ft)	Habitat	Population size	Source (ID)
79	GUNN	USFS Gunnison NF	9/18/1998	51.0N 1.0E Sec32	NA	Black sagebrush-pine needlegrass community. Aspect: 96. Slope: 5%	Present	Johnston survey (Sample 988107)
80	GUNN	USFS Gunnison NF	6/8/1993	51.0N 1.0E Sec32	8,100	Big sagebrush-sparse Utah serviceberry-rabbitbrush-sparse snowberry-Indian ricegrass community. Aspect: 49. Slope: 18%.	1.5% cover	CNHP (EOR20) Johnston survey (Sample 931005)
81	GUNN	Colorado	6/9/1967	51.0N 1.0W Sec16 - Ohio Creek, Mountain Meadow Research Center, CSU.	8,100	Assoc taxa: sage.	NA	CNHP (EOR01)
82	GUNN	USFS Gunnison NF	9/22/1998	51.0N 1.0W Sec23	NA	Big sagebrush-snowberry-muttongrass community. Aspect: 221. Slope: 8%.	Present	Johnston survey (Sample 988110)
83	GUNN	USFS Gunnison NF	8/31/1998	51.0N 1.0W Sec25 - Forest Service Road 863	8,600	Habitat type: *Artemisia tridentata/Stipa pinetorum*. Rolling uplands, clay soil.	50 to 100 plants	CNHP (EOR22)

Population trend

Population trends of *Astragalus anisus* are not known. There have been no rigorous multi-year population census efforts that would give an accurate description of population trends. After being rediscovered in 1949, the species was at first thought to be quite rare, but it has since been regularly reported as scattered but common in the Gunnison Basin (e.g., Harrington 1954, Barrell 1969, Weber and Wittmann 2001). Subpopulations appear to fluctuate dramatically between years, perhaps depending on the weather (Wasson personal communication 2003), but there has been no systematic observation of overall population trends for *A. anisus* in the upper Gunnison Basin as a whole.

Habitat

Astragalus anisus is broadly associated with the Sagebrush Shrublands and Sagebrush Shrub Steppe ecological system types (Rondeau 2001) in the Gunnison Basin. These ecological systems are described as matrix-forming communities, which 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).

Both the Sagebrush Shrublands and Sagebrush Shrub Steppe ecological systems are typically found on flat to rolling hills with well-drained clay soils slopes between 7,000 to 10,000 feet in elevation and are characterized by a dense shrub cover with a significant herbaceous understory (Rondeau 2001). In the Gunnison Basin, Sagebrush Shrubland associations are typically dominated by *Artemisia tridentata* (ssp. *tridentata*, *vaseyana* or *wyomingensis*) or *A. cana*, while Sagebrush Shrub Steppe associations are characterized by *A. nova* or *A. arbuscula*.

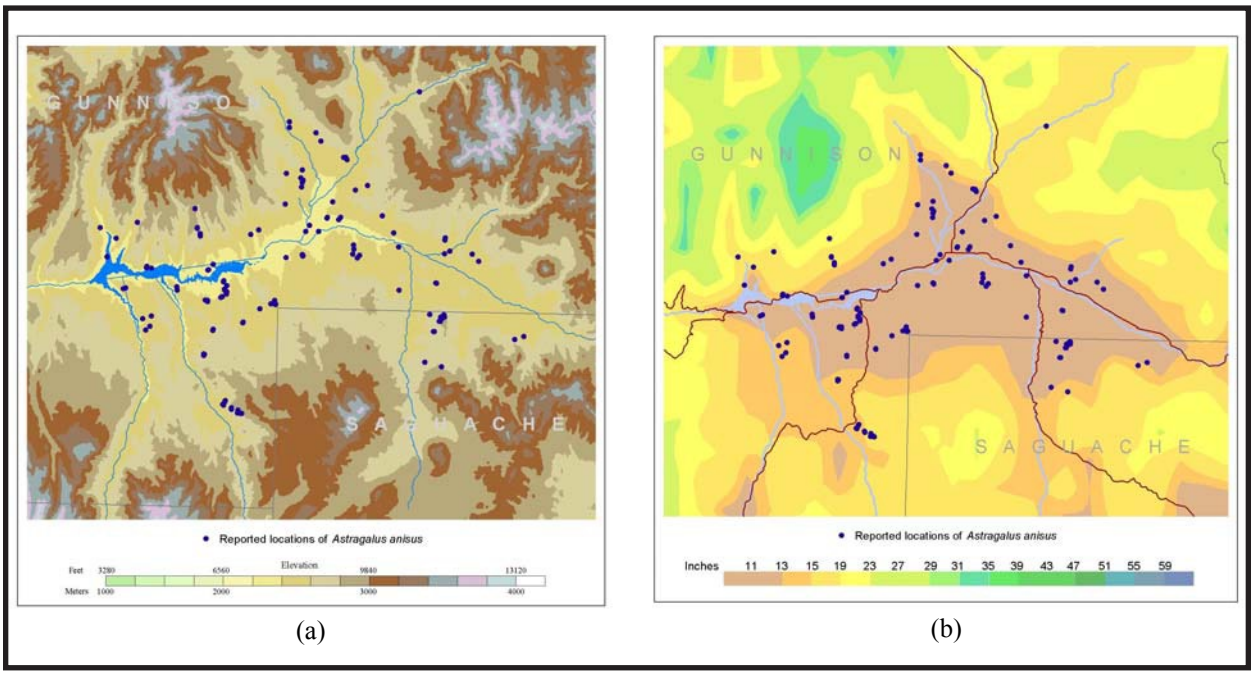
Associations dominated by *Artemisia tridentata* ssp. *wyomingensis* and *A. nova* correspond to the Dry Sagebrush Shrublands ecological type of Johnston et al. (2001), those dominated by *A. tridentata* ssp. *tridentata* fall into the Big Sagebrush Shrublands type, and associations dominated by *A. tridentata* ssp. *vaseyana*, *A. arbuscula*, or *A. cana* comprise the Subalpine Sagebrush Shrublands type (Johnston et al. 2001).

Astragalus anisus is primarily found in the Dry Sagebrush Shrubland type, which dominates the lower elevations of the Gunnison Basin (Johnston personal communication 2003). Habitat information from a variety of sources is summarized in **Table 1**. Data from specimen labels and element occurrence records show *A. anisus* occurring with the associated species shown in **Table 2** (most commonly reported associates are in bold).

Table 2. Species reported to be associated with *Astragalus anisus*. Most common affiliates in bold.

Shrubs/Subshrubs:	Graminoids:
Amelanchier utahensis	*Achnatherum hymenoides* (=*Oryzopsis hymenoides*)
Artemisia frigida	***Bouteloua* (=*Chondrosom*) *gracilis***
Artemisia nova	*Carex* spp.
Artemisia tridentata	*Elymus elymoides*
Chrysothamnus depressus	*Koeleria macrantha*
Chrysothamnus viscidiflorus	*Pascopyrum smithii*
Krascheninnikovia lanata	***Poa fendleriana***
Picradenia richardsoni (=*Hymenoxys richardsonii*)	*Poa secunda*
Purshia tridentata	*Stipa comata* (=*Hesperostipa*)
Symphoricarpos rotundifolius	***Stipa pinetorum***
Tetradymia canescens	
Yucca glauca	
Forbs:	**Other:**
Cactus spp.	lichens
Packera multilobata	
Phlox hoodii	
Stenotus acaulis	
Tetraneuris torreyana	

Elevations of reported occurrences range from 7,675 to 9,430 feet (2,340 to 2,875 meters; **Figure 4a**). From 1900 to 2000, annual rainfall reported in Gunnison averaged 10.44 inches per year (Western Regional Climate Center 2003). Precipitation in the Gunnison Basin increases at higher elevations (**Figure 4b**). Precipitation amounts are fairly evenly distributed throughout the seasons, with somewhat more moisture being received during the "monsoon" season of July and August. Precipitation in winter and spring falls primarily in the form of snow. Temperatures can dip below freezing during any month of the year, and the basin acts as a cold air sink. Cold air drainage in the upper Gunnison Basin can be a stronger influence on temperature than elevation (United States Department of Agriculture 1975). *Astragalus anisus* is clearly adapted to the temperature swings of its range, since it is already flowering in May, when mean daily minimum temperatures are still below freezing (Western Regional Climate Center 2003).



(a) (b)

Figure 4. Elevations of *Astragalus anisus* occurrences and precipitation patterns in the Gunnison Basin.

Within the upper Gunnison Basin, *Astragalus anisus* does not appear to be restricted to one soil type, although it is usually reported as occurring on sandy to gravelly granitic soils. The majority of occurrences are on soils of the Parlin-Lucky-Hopkins Association (generalized as the Cheadle group in **Figure 5**), although the plant also occurs on all other major associations in the lower elevations of the basin. The Parlin-Lucky-Hopkins Association is the primary association of the upland hills, slopes, and swales of the upper Gunnison Basin at elevations from 7,500 to 9,000 feet. Soils are characterized as "deep and moderately deep, moderately sloping to steep, well-drained channery loams and gravelly sandy loams on hills, mountains, ridges and benches" (USDA Soil Conservation Service 1975). Parent materials of these soils are rhyolite, tuff, gneiss, and schist.

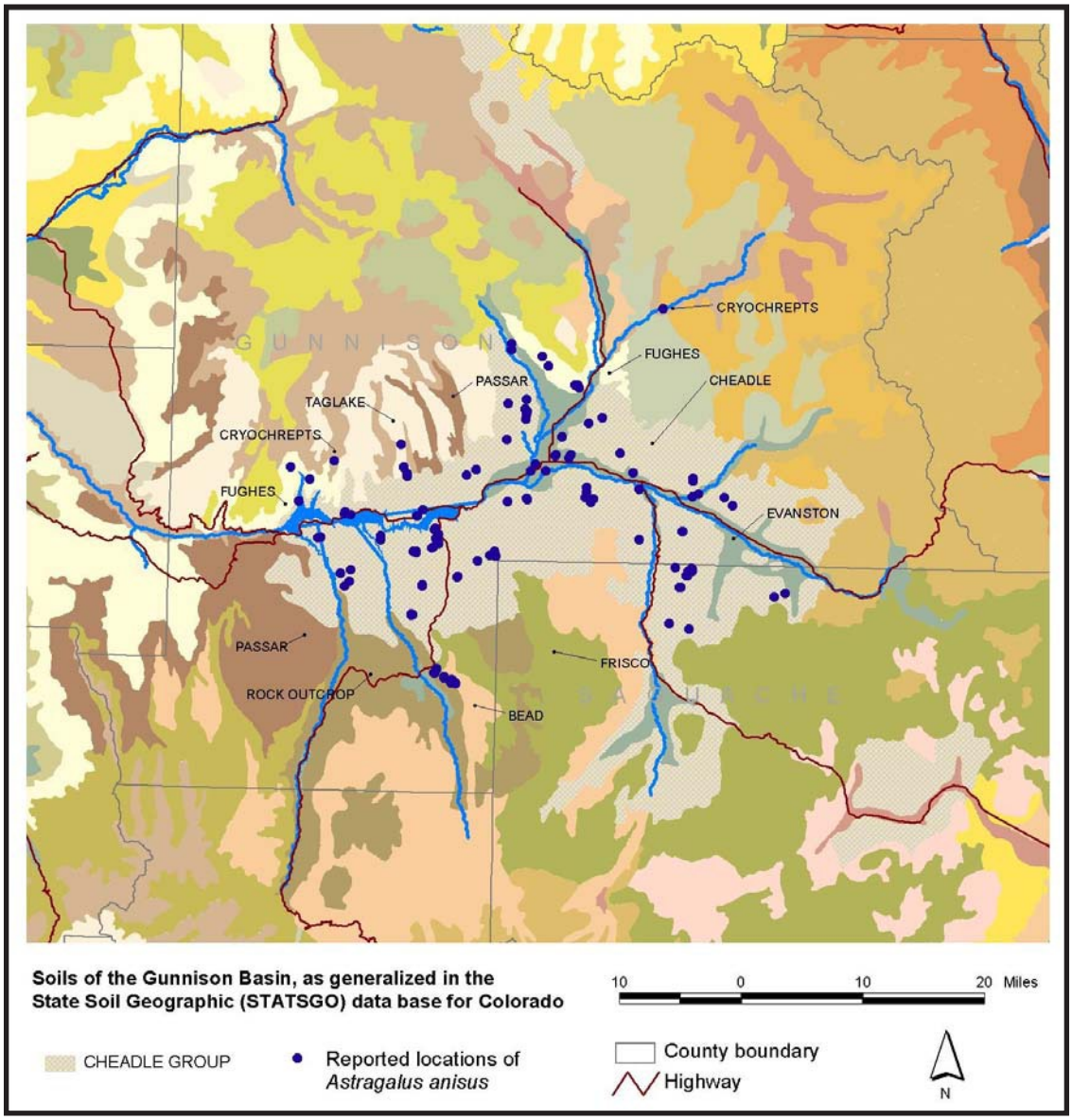


Figure 5. Soil groups with *Astragalus anisus* occurrences.

The sagebrush shrublands of the Gunnison Basin have been grazed for the past 120 to 150 years, and grazing was often heavy prior to 1970 (Johnston et al. 2001). In the past, many areas have been subject to mechanical and chemical removal of sagebrush, and these areas were often reseeded with non-native forage species such as *Agropyron cristatum* (crested wheat), *Bromus inermis* (smooth brome), and *Melilotus* spp. (sweet clovers). In the past 20 years burning has become the most common sagebrush removal technique (Johnston et al. 2001). Sagebrush removal and conversion to forage cultivation has probably resulted in the loss of some *Astragalus anisus* habitat (Capodice personal communication 2003). Other changes in the Gunnison Basin that have affected *A. anisus* habitat include the closing of Blue Mesa Dam and the subsequent filling of Blue Mesa Reservoir in 1965, and the general increase of low-density residential development in the area.

Astragalus anisus is most often found in fairly open sites, where sagebrush shrubs do not form a closed canopy. Occurrence sites are characterized by the absence of trees, moderate shrub cover, moderate understory cover, and extensive bare ground (**Figure 6**). For 26 occurrences reported by Wasson (unpublished data, Colorado NHP files), the average percent cover for six cover classes is shown in **Table 3**.

Figure 6. Examples of *Astragalus anisus* habitat. Photographs by April Wasson, used with permission.

Table 3. Cover classes for *Astragalus anisus* occurrences. From data for 26 occurrences reported by Wasson (unpublished data, Colorado NHP files).

Cover type	Percent Cover
Tree	0
Shrub	20
Forb	7
Graminoid	7
Moss/Lichen	4
Bare ground	57

Johnston et al. (2001) reported for 29 samples that slopes range from 0 to 34 percent with an average of 17.3 percent, and that site aspects are usually more or less west-facing (range 222° to 309°) tightly clustered around an average of 266°.

Under the assumption that *Astragalus anisus* habitat consists primarily of sagebrush shrublands below 9,430 feet, a rough map of potential habitat is shown in **Figure 7**. Light green areas are Sagebrush community (sagebrush with rabbitbrush, bitterbrush) and Sagebrush/Grass mix (co-dominate sagebrush shrubland and perennial grassland). Vegetation cover data are from basin-wide mapping (Colorado Division of Wildlife). Within this area, the most favorable aspect (215° to 324°) and slope (less than 35 percent) combinations are shown as darker green. Unfortunately, there is no way to distinguish where sagebrush shrublands are suitably open without the use of ground survey or aerial photo interpretation. USFS lands account for 10 to 15 percent of both potentially suitable and optimal habitat shown in **Figure 7**.

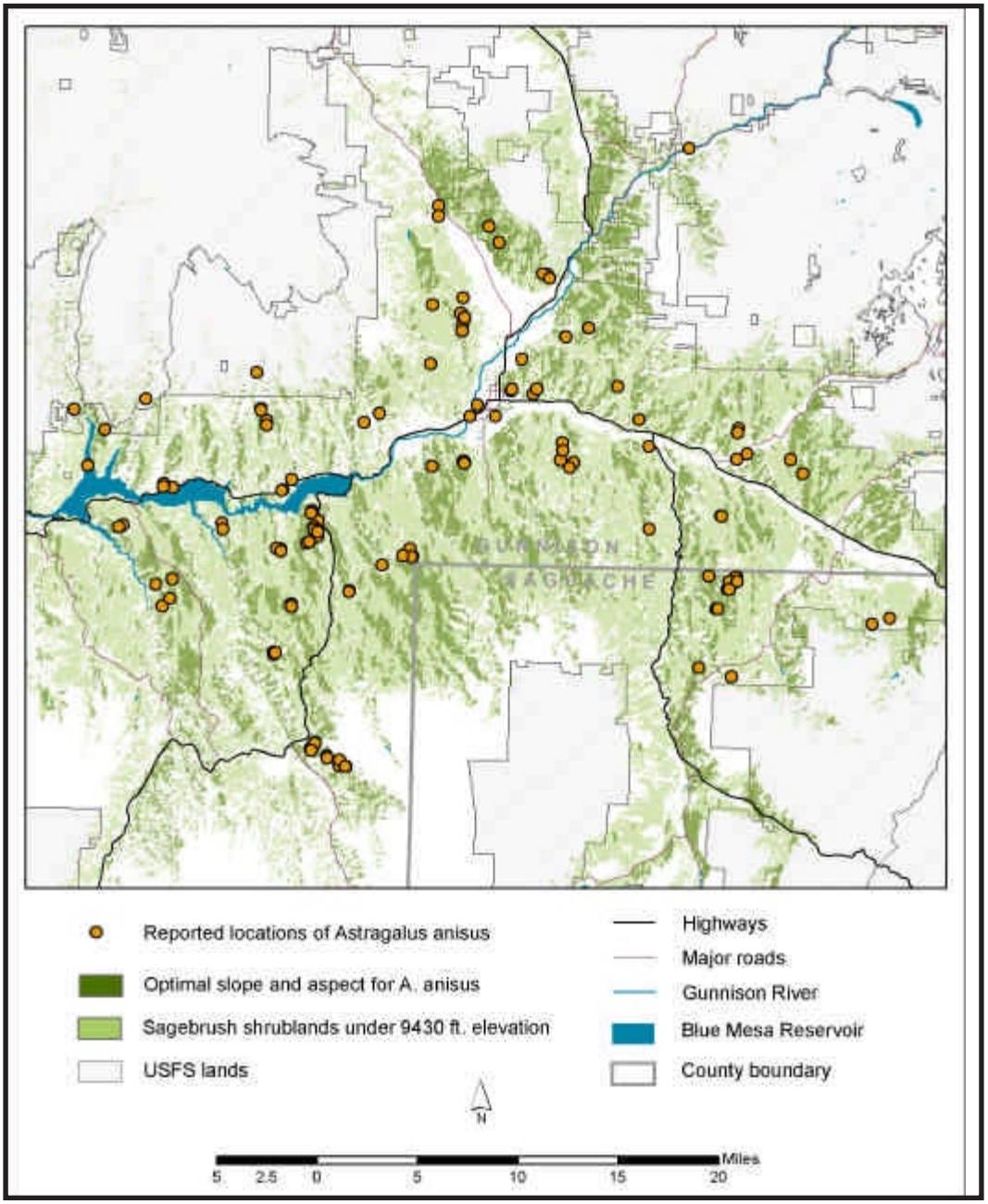


Figure 7. Potential suitable habitat for *Astragalus anisus*.

Reproductive biology and autecology

Using the C-S-R (Competitive/Stress-Tolerant/Ruderal) model of Grime (2001), the reduced stature, unpalatability, and potentially long lifespan of *Astragalus anisus* tend to indicate that it is a stress-tolerator. Stress for perennials in this low-rainfall habitat stems from nutrient limitation rather than competition (Grime 2001).

Although not otherwise a typical ruderal species, there is also some evidence that *Astragalus anisus* is tolerant of disturbance. Field observers have reported plants growing in road margins or in the center of two-tracks (Cudlip personal communication 2003, Wasson personal communication 2003). One reported population occurred on uranium tailings (record 43 in **Table 1**), and another occurred along a campground road at the USFS One-Mile Campground on the Taylor River (record 1 in **Table 1**).

As a perennial species that probably devotes one or more years to vegetative growth before reproducing, *Astragalus anisus* can be regarded more or less as a *k*-selected species (using the classification scheme of MacArthur and Wilson 1967), albeit more towards the *r*-selected end of the spectrum than many species. Although individuals can flower profusely under some environmental conditions, normal relative proportions of reproductive to total biomass are probably not large.

Reproduction

Astragalus anisus reproduces only by seed, not vegetatively or clonally. As with all *Astragalus* species, flowers of *A. anisus* contain both male and female reproductive organs. The mating system and the degree of self-compatibility for *A. anisus* have not been investigated. 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 *Astragalus* species (*A. linifolius* and *A. osterhouti*) and one widespread *Astragalus* species (*A. lonchocarpus*) 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, although the selfed seedlings of the restricted species showed evidence of inbreeding depression.

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

Pollinators and pollination ecology

As do all members of the subfamily Papilionoideae, *Astragalus anisus* 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 "trip mechanism" of papillonaceous 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. A bee typically alights on the landing platform provided by the wings and pushes its 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 anisus* 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 *A. montii*, *A. kentrophyta*, and *A. miser*. *Osmia* species 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

Plants typically begin flowering in May and continue into the first half of June. Fruits are generally mature by the end of July (Wasson personal communication 2003) and are shed from the plant. Some seeds germinate without scarification (Austin personal communication 2003), which suggests that it is possible for seeds to germinate the same year they are produced. Wasson observed small plants in early October that may have been seedlings that germinated in the late summer/early fall. Other field observers have not noticed possible late-germinating seedlings (Capodice personal communication 2003, Johnston personal communication 2003). It is not known if such seedlings overwinter successfully. Plants may also germinate in the spring.

There is no information about germination site requirements for *Astragalus anisus*. Johnston (personal communication 2003) described angular rock fragments common in the soils of the area. These may provide microsites for seed establishment in soils that are otherwise of an almost concrete-like consistency.

Fertility and propagule viability

Individuals observed by Wasson began flowering in early May and continued flowering through the first half of June. Fruits began filling in June and were mature by the end of July. Large flowering individuals of *Astragalus anisus* produced a dozen or more inflorescences, but for all flowering plants, the average was between four and five.

Each inflorescence produces 3 to 7 flowers (Barneby 1964), and of these, fewer than 15 percent will produce fruits. Wasson (1998) observed that 2 to 10 fruits per plant are common. The average number of viable seeds per fruit is not known. In *Astragalus australis* var. *olympicus*, Kaye (1999) found that 70 to 90 percent of ovules were unfertilized, aborted, or damaged by insects. Successful fruit and seed production in *A. anisus* are likely to be influenced by pollen availability, resource limitation, and predispersal insect herbivory, but the relative importance and spatial variability of these factors are unknown.

Austin (personal communication 2003) reported germination success of about 16 percent in a small sample of seeds sprouted on damp paper towels. There are no data available for germination percentages under natural conditions.

Dispersal mechanisms

The probability of dispersal of seeds and other propagules decreases rapidly as distance from the source increases (Barbour et al. 1987). The majority of seeds will remain close to the parent plant; very few long-distance dispersals occur. Dispersal of split fruits that still retain seeds may offer the best opportunity for increasing dispersal distance in *Astragalus anisus*.

Pods typically separate into two halves upon dehiscence, but seeds may remain in the half-legume for some time and may be dispersed some distance from the parent plant before escaping from the pod chamber. During this stage, it is possible that pods are dispersed by water, wind, gravity, or animal action. Soil permeability is low for much *Astragalus anisus* habitat (Johnston et al. 2001), increasing the potential for run-off and subsequent dispersal by pods or seeds being washed along the surface. Rittenhouse and Rosentreter (1994) observed pods of *A. amblytropis* rolling downslope under very light wind conditions, and rolling upslope under very windy conditions. Individual seeds are fairly small (2 to 2.4 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 (Friedlander 1980, Clement and Miller 1982, Nelson and Johnson 1983, Rittenhouse and Rosentreter 1994, Lesica 1995). Wasson and others have observed insect damage on fruits of *A. anisus*, but the source of damage has not been identified. Pods were observed with neat round holes in the middle of one or both lobes. These were interpreted as exit holes of seed-eating larvae (Wasson personal communication 2003). Seed predation is very common; field observers report that most fruits show some evidence of predation (Austin personal communication 2003, Wasson personal communication 2003). Predation may vary between years; Wasson observed more predated seed pods in 1997 than in 1998. The bilocular pod ensures that seed predators in one half do not necessarily destroy ovules in the entire pod.

Seed predation is a potential source of high mortality in the life cycle of *Astragalus anisus*. Lesica (1995) found that seed predation from weevils varied between years and locations for *A. scaphoides*, although it was consistently present. Insect seed predation accounted for losses of 0 to 33 percent, with a mean of 18 percent. When combined with herbivory on inflorescences, loss of fecundity ranged from 19 to 90 percent. Nelson and Johnson (1983) found that although

larger seeds were more likely to be preyed upon by bruchid seed beetles in three *Astragalus* species, smaller seeds did not germinate well. This stabilizing selection for intermediate size seeds is likely to occur in many *Astragalus* species where seed predators are present.

Cryptic phases

Seed bank dynamics and seed longevity have not been investigated for *Astragalus anisus*. Bowles et al. (1993) successfully germinated seeds from herbarium specimens of two rare *Astragalus* species (*A. neglectus* and *A. 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. anisus* seeds under natural conditions may remain viable for many years.

The numbers of *Astragalus anisus* seeds in seed banks have not been investigated. Some other *Astragalus* species appear to maintain variable but potentially large seed banks. Ralphs and Cronin (1987) reported a mean density of 394 seeds/m^2 of soil for *A. lentiginosus* var. *salinas* (salt milkvetch) 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 4346 seeds/m^2, and they hypothesized that the seed bank was sufficient to allow "population outbreaks" (un-quantified) in years with favorable environmental conditions. Morris et al. (2002) reported densities from 24 to 753 seeds/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*, and the possibility should be investigated for *A. anisus*.

Phenotypic plasticity

Field observers indicate that *Astragalus anisus* does not exhibit much phenotypic plasticity or variation over its restricted range (Cudlip personal communication 2003, Wasson personal communication 2003). Wasson (1998) reported no significant difference in mean plant size among three populations. One exception to the general lack of phenotypic differentiation among populations is the "musaform", or banana-shaped, pods reported on some individuals of some subpopulations by Johnston (personal communication 2003). He estimates that perhaps 1 percent of the total population exhibits this variation. It is not known what effect this variation has on individual fitness, if any.

Mycorrhizal relationships

Endomycorrhizal fungi of the type called vesicular-arbuscular mycorrhizae (VAM) occur in about 80 percent of all vascular plants (Raven et al. 1996). VAM fungi belong to a group of non-descript soil fungi (Glomales) that are difficult to identify because they seldom sporulate (Fernando and Currah 1996). They are the most abundant type of soil fungi (Harley 1991) and infect up to 90 percent of all angiosperms (Law 1985). VAM fungi are generally thought to have low host specificity, but there is increasing evidence for some degree of specificity between some taxa (Rosendahl et al. 1992, Sanders et al. 1996). While this group has not previously been thought of as particularly diverse, recent studies suggest that there is unexpectedly high diversity at the genetic level (Sanders et al. 1996, Varma 1999) and at the single plant root level (Vandenkoornhuyse et al. 2002). As root endophytes, the hyphae of these fungi enter the cells of the plant roots where water and nutrients are exchanged in specialized structures.

Roots of *Astragalus anisus* have not been assayed for the presence of vesicular-arbuscular mycorrhizal symbionts. Both presence (Barroetavena et al. 1998, Zhao et al. 1997) and absence (Treu et al. 1995) of VAM have 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 anisus* has not been investigated for nodulization. However, nodules have been reported for several other species in the subgroup Argophylii (*A. crassicarpus*, *A. missouriensis*, *A. mollissimus*, and *A. purshii*), so it is possible that *A. anisus* also possesses this ability.

Hybridization

There is no evidence of hybridization in *Astragalus anisus*. Although other genera in the Fabaceae (e.g., *Oxytropis* and *Lathyrus*) have been reported to exhibit hybridization, the phenomenon is not prevalent in *Astragalus*. 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. Because pollination dynamics and potential barriers to hybridization in *A. anisus* have not been investigated, the possibility remains open.

Demography

As an herbaceous perennial that is not monocarpic, *Astragalus anisus* 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 clarify the genetic diversity issues for *A. anisus*.

Little is known about the population genetics of *Astragalus anisus*. It is not known whether the species is capable of self-pollination. Some species of *Astragalus* are self-compatible, while others are obligate outcrossers (Karron et al. 1988). Preliminary efforts by students at Western State College to measure the genetic variability of *A. anisus* were not entirely successful (Bingham personal communication 2003), but they may indicate that the species has more variability than reported for other narrow endemics. Further efforts to quantify genetic variability in *A. anisus* 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).

Karron et al. (1988) studied the genetic structure of four *Astragalus* species, two locally endemic and two geographically widespread. In common with *A. anisus*, all species were herbaceous perennials growing in sparsely vegetated, arid habitats. Although the restricted species had lower levels of enzyme polymorphism than one of the widespread species, they were by no means genetically depauperate. Preliminary work by Moran and Bingham (2001) indicates that this may also be true for *A. anisus*.

The demographic information for *Astragalus anisus* presented below is primarily taken from work done by April Wasson (1998) while a student at Western State College. Wasson collected data on the size-class distribution and reproductive output of plants from three populations during the summer of 1998. She recorded plant diameter, flower stalk number, number of flowers per stalk, and fruit production for a total of 54 plants. The size of *A. anisus* individuals ranged from 1 to 12 cm diameter; distribution is shown in **Figure 8**.

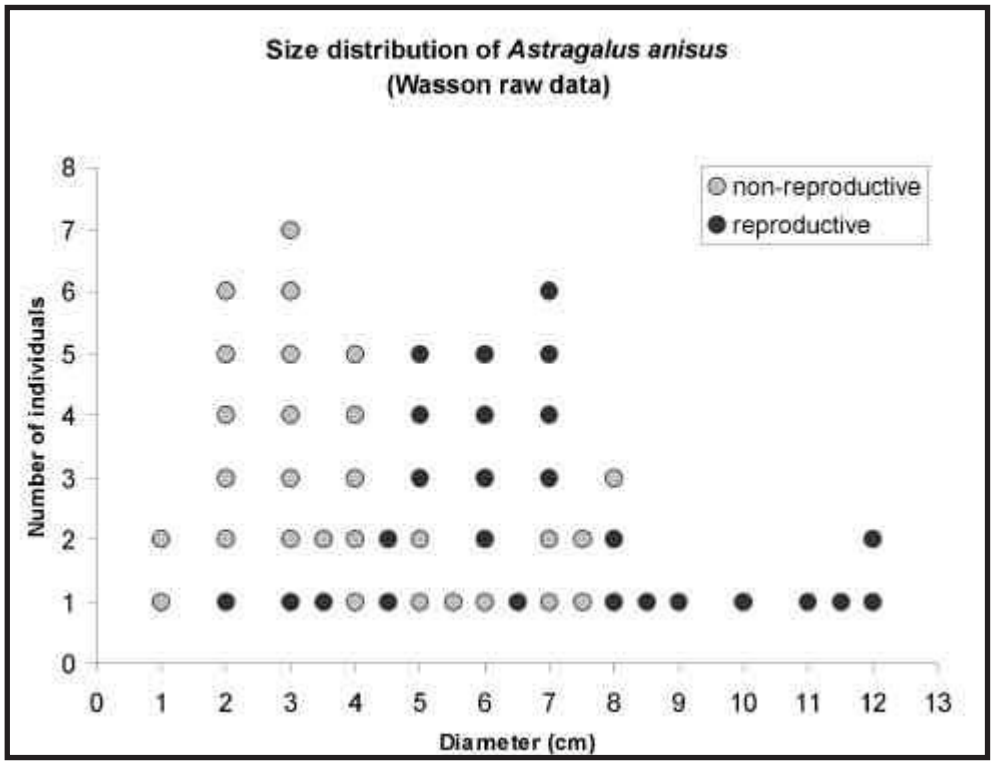


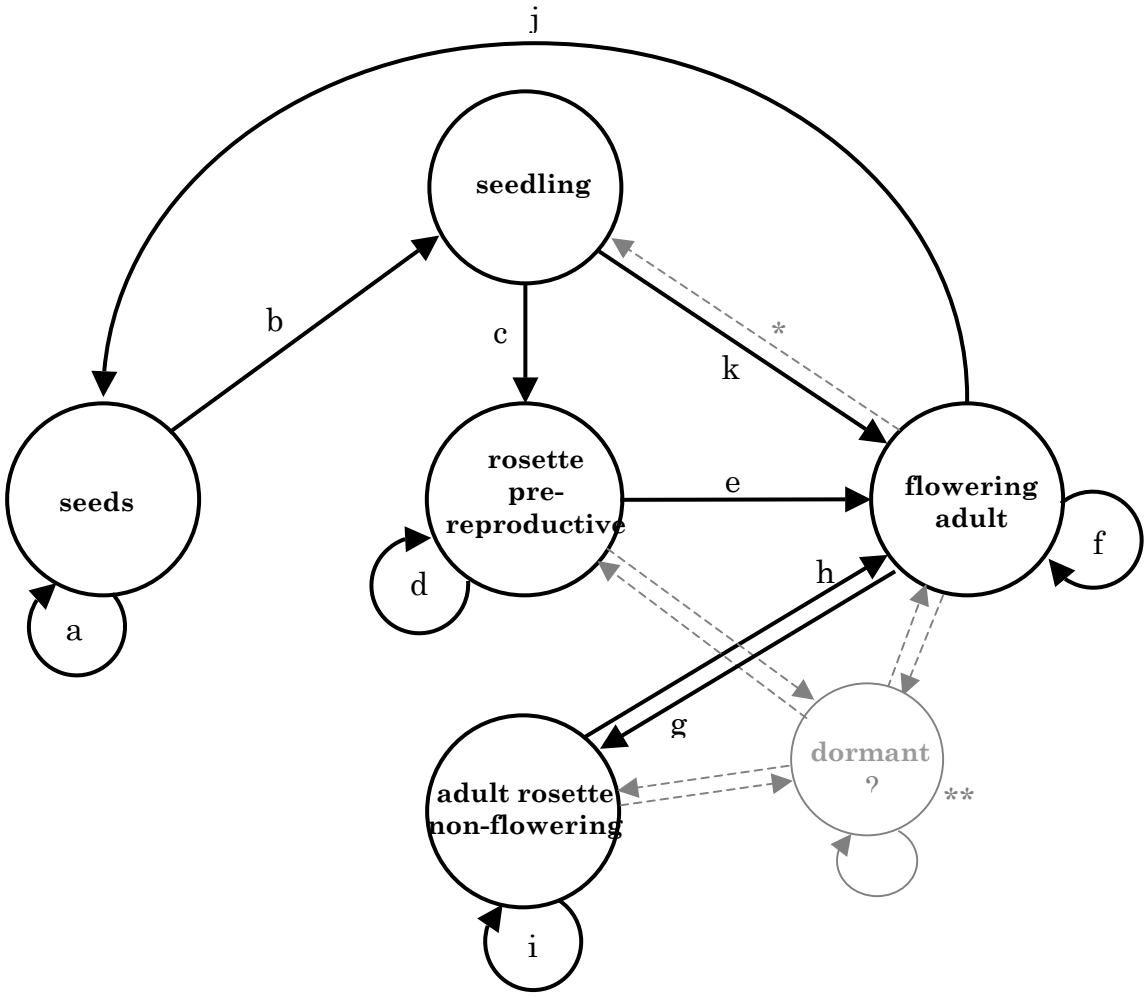
Figure 8. Size distribution of *Astragalus anisus*.

Data on flower production indicate that plants normally must reach a certain size before they commence flowering. Most plants that produced flowers were at least 5 cm in diameter. Among flowering plants, there were positive correlations between plant size and flower production and between flower production and fruit production, but size clearly does not explain all of the variation in flower and fruit production. A correlation between fruit production and plant size is less clear. Although there is certainly some degree of correlation between fruit production and reproductive success, the utility of this character as a measure of fitness is not very well quantified.

Lesica (1995) conducted an eight-year demographic study of *Astragalus scaphoides*, a long-lived perennial endemic to east-central Idaho and adjacent Montana. It occurs in sagebrush steppe (*Artemisia tridentata/Pseudoroegneria spicata*). In *A. scaphoides*, 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 plants could remain dormant up to five years before reappearing. The possibility of a similar dormancy stage in *A. anisus* should be investigated.

The lifespan of an *Astragalus anisus* individual is not known, although plants may be capable of living 20 years or more (Johnston personal communication 2003). In Lesica's study of *A. scaphoides*, 40 to 50 percent of individuals observed during the first year of the study were still alive eight years later. Longevity in *A. anisus* could be investigated by looking for growth rings in the root crown.

Figure 9 shows a hypothetical life cycle diagram. Because there are no multi-year studies of *Astragalus anisus*, transition probabilities are left unquantified. Under the basic scenario shown, flowering plants produce seeds in mid- to late-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.



a. survival of dormant seeds in the seed bank
b. probability of seed becoming a seedling
c. survival of seedling to rosette (juvenile) stage
d. probability of rosette remaining in pre-repro stage
e. probability of pre-reproductive rosette 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 9. Life cycle diagram for *Astragalus anisus* (after Caswell 2001).

Until better demographic data are available for *Astragalus anisus*, it is impossible to conduct any kind of elasticity analysis to determine which demographic transitions make the greatest contribution to population growth. 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* were consistently important. Similar trends are possible for *A. anisus*.

There are no Population Viability Analysis (PVA) models available for *Astragalus anisus*. Morris et al. (1999) discuss general classes of data sets and methods suitable for PVA including:

1) Count-based extinction analysis: requires counts of individuals in a single population from censuses performed a minimum of 10 years (preferably more).

2) Multi-site extinction analysis: requires counts from multiple populations, including a multi-year census from at least one of those populations.

3) Projection matrix modeling: requires detailed demographic information on individuals collected over three or more years (typically at only one or two sites).

There is clearly a trade-off in the years required versus intensity of data collection. Currently there are no data sets available that could be used for PVA of *Astragalus anisus*. Although population levels appear to be stable and the species is not in obvious danger of extinction, the identification of a minimum viable population could assist in the formation of quantitative management objectives (Brackley 1989).

Community ecology

Herbivores

Astragalus species are often poisonous to livestock. This is due primarily to the sequestration of selenium in plant tissues or to the production of nitro-toxins such as miserotoxin, cibarian, karakin, and hiptagin. *Astragalus anisus* is not a selenium-absorbing species. Williams and Barneby (1977) analyzed leaflets of 505 *Astragalus* species for the presence of nitro-toxins. These compounds are catabolized in the digestive tracts of ruminants and disrupt the central nervous system. *Astragalus* species that contain nitro-toxins kill or permanently cripple thousands of sheep and cattle every year. Williams and Barneby (1977) found varying levels of nitro-toxin in about 52 percent of the species they examined. The presence and levels of nitro-toxins were fairly consistent among species belonging to the same taxonomic group. Although *A. anisus* was not among the species tested, results from other species in the Argophylii subgroup indicate that *A. anisus* probably contains low amounts of nitro-toxin.

Some species of *Astragalus* appear to be resistant to herbivory (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 little sign of use by vertebrate herbivores on *A. anisus*. Invertebrate herbivory appears to be primarily confined to fruits.

Competitors

The tendency of *Astragalus anisus* to prefer areas with a large percentage of bare ground indicates that it is not a strong competitor. Since plants often grow in loose clumps, intraspecific competition may be more important than interspecific competition. Plants appear to be intolerant of shading by sagebrush shrubs. Associated species are few and tend to be found in areas where moisture is less available (Johnston et al. 2001). The possibility that *Bromus tectorum* (cheatgrass) will become a serious competitor of *A. anisus* in the future is unknown.

Parasites and disease

The presence of invertebrate larvae as seed parasites is suggested by the reports of “exit holes” in seed pods. Individual seeds have not been examined for such damage. There are no reports of disease in *Astragalus anisus*. Field observers have not reported any obvious damage to foliage.

Symbioses

With the possible exception of the mycorrhizal relationships described above, there have been no reports of symbiotic or mutualistic interactions between *Astragalus anisus* and other species. Barneby (1964) notes that some xerophytic *Astragalus* species of the Intermountain West often grow in close association with sagebrush species (*Artemisia arbuscula* or *A. tridentata*), which provide shelter for seedlings and protect the foliage from grazing animals. This interaction has frequently been referred to in the literature as the "nurse plant syndrome," and it has been well studied in the saguaro cactus (*Cereus gigantea*) (Niering et al. 1963). However, this type of association has not been observed for *A. anisus* and appears unlikely since plants apparently do not tolerate shading.

A generalized envirogram for *Astragalus anisus* is shown in **Figure 10**. An envirogram is a graphical representation of pathways of influence between components in the direct environment of an organism and factors that indirectly affect or modify the direct environment (Andrewartha and Birch 1984). Objects in the direct environment, or centrum, are traditionally grouped under the headings of resources, mates/reproduction, predators, and malentities. In the absence of more detailed information on the biology and community ecology of *A. anisus*, the primary utility of this diagram is to remind land managers of the potential impacts of their actions in various aspects of the species environment and to suggest potential topics for research.

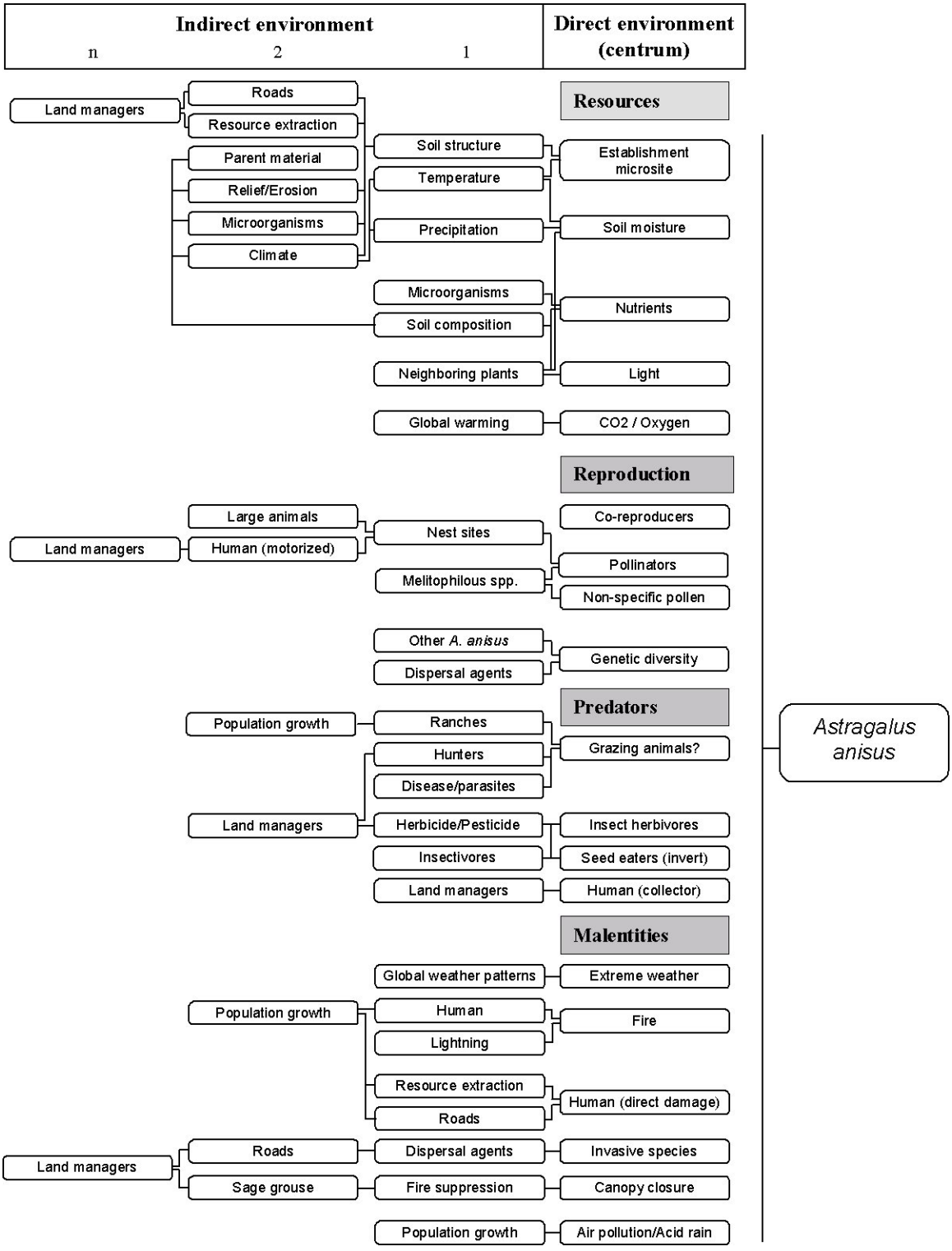


Figure 10. Envirogram for *Astragalus anisus*.

CONSERVATION

Threats

Although *Astragalus anisus* is locally common and appears to have a stable population, its entire global range is contained within the upper Gunnison Basin. Such a restricted range could compound any effects of threats to the population, and based on the available information, there are several tangible threats to *A. anisus*. In order of decreasing priority, these threats are road building, off-road vehicle use, non-motorized recreation, non-native species invasion, grazing, residential development, fire suppression, resource extraction, and global climate change. Many of these threats are pertinent to at least some populations on the Gunnison National Forest. A lack of systematic tracking of population trends and conditions and lack of knowledge about its basic life cycle also contribute to the possibility that one or more of these factors will threaten the long-term persistence of the species.

Road construction and maintenance have probably destroyed both individual plants and suitable habitat. This is especially true for the population on USFS land at One-Mile Campground, which occurs on disturbed gravel road shoulders. Because paving or grading operations could easily destroy the two plants observed here, this population is considered to have poor viability (Colorado Natural Heritage Program 2003). Furthermore, a proliferation of roads and trails often degrades habitat connectivity, with a potential for detrimental effects on pollinators. While some individual plants have been able to take advantage of the increased moisture usually available at road edges (Cudlip personal communication 2003, road construction likely weighs more heavily on the negative side for the species as a whole.

Off-road vehicle use and non-motorized recreation, especially when they result in the creation of social trails, could negatively affect populations of *Astragalus anisus*. Current travel restrictions on the Gunnison National Forest restrict motorized travel to designated routes only. Enforcement of this policy would protect *A. anisus* populations from potential impacts. Interpretation of the threat posed by roads is complicated by the fact that most documented occurrences are near roads. The single occurrence in the West Elk Wilderness Area is also the only USFS occurrence that is farther than one mile from a road. Populations that are not near roads may remain undocumented, but condition of and threats to those populations will also remain unknown.

Road proliferation greatly increases the ability of invasive species to move into new areas. Competition from invasive species, especially *Bromus tectorum*, has the potential to affect population levels as well as to alter habitats enough to affect the persistence of *Astragalus anisus*. Please see the discussion below for additional information on the possible impacts of *B. tectorum* on *A. anisus*.

Livestock grazing is unlikely to threaten populations or the species as a whole, as *Astragalus anisus* is not generally palatable to cattle or horses. Individuals are somewhat resistant to trampling. However, trampling by large concentrations of livestock could be detrimental to pollinators, as well as some individual plants. While grazing in many areas was much heavier in the early and mid 20th century than it is today, the legacy of this overgrazing persists in many areas. Grazing reduces the cover of perennial bunchgrasses and forbs in sagebrush shrublands and steppes, opening them for invasion by *Bromus tectorum* and other exotic species. Erosion increases when the native understory species are gone (West and Young 2000). Much of the public land in the Gunnison Basin has active grazing allotments, and *A. anisus* is exposed to grazing on both USFS and BLM lands. *Astragalus anisus* has been documented on the Taylor Park (record 1 in **Table 1**), Slate River (records 79 through 83 in **Table 1**) Needle (record 32 in **Table 1**), Rainbow (record 78 in **Table 1**), and Soap Creek (records 67 and 68 in **Table 1**) allotments on the Gunnison National Forest. At the time of this writing, these allotments were all active and were grazed by cow-calf pairs for various amounts of time (Austin personal communication 2004).

The bulk of the species' habitat falls on public lands, which makes the possibility of direct impacts from residential development on much of its range relatively small. When development does take place, it can increase habitat fragmentation and edge effects. Edges are the outer boundaries of ecosystems that abruptly grade into other types 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 livestock grazing. 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. The overall reduction of large landscapes jeopardizes the existence of specialist species, may increase non-native species, and limits the mobility of species that require large

landscapes or a diversity of landscapes for their survival (Rocchio et al. 2003). The proliferation of subdivisions and ranchettes in the Gunnison Basin could lead to increasing habitat fragmentation, pollinator decline, and disruption of subpopulation interconnectivity. For populations on USFS lands, this is most likely to occur in the Ohio Creek and lower East River areas where USFS lands with potential habitat for *Astragalus anisus* abut privately owned areas. This includes the occurrences on the Slate River allotment (records 79 through 83 in **Table 1**), as well as other potential undocumented populations in the area. However, at this time this factor does not constitute an immediate threat to the persistence of *A. anisus*.

Astragalus anisus presumably evolved under natural cycles of fire and regrowth, and these dynamics are likely to be important in the persistence of suitable habitat. Fire suppression, if it leads to an increase in sagebrush density, will have the effect of gradually eliminating suitable habitat for *A. anisus*.

Resource extraction is not likely to directly threaten the persistence of the species, as its preferred habitat is unlikely to yield worthwhile timber. Gravel mining or other large-scale earthmoving (e.g. mine tailings removal, landfills) could destroy some populations and habitat, but it is unlikely to affect the entire population. However, road proliferation associated with extractive activities in neighboring areas could impact portions of *Astragalus anisus* habitat.

The long-term survival of the species could be affected by habitat expansion or contraction induced by global climate change. Global climate change is likely to have wide-ranging effects in the near future. Projections based on current atmospheric CO_2 trends suggest that average temperatures will increase while precipitation will decrease in Colorado (Manabe and Wetherald 1986). This will have significant effects on nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. A temperature increase could cause vegetation zones to climb 350 feet in elevation for every degree F of warming (U.S. Environmental Protection Agency 1997). Because the habitat for *Astragalus anisus* is already xeric, lower soil moistures in the growing season induced by decreased precipitation could have serious impacts. *Astragalus anisus* currently occupies habitat confined to the lower parts of the Gunnison Basin. If Wyoming sagebrush shrublands were able to extend to higher elevations under warming conditions, available habitat could expand. Conversely, if conditions led to a contraction of this lower elevation habitat, *A. anisus* might be unable to escape the "bottom of the bowl" as its habitat is eliminated.

It is unlikely that any single threat is sufficient to eliminate the species completely from its entire range. However, for species with small global ranges, there is less margin for error in protection. USFS lands on the Gunnison National Forest support 10 to 15 percent of known occurrences of *Astragalus anisus*, and similar proportions of potentially suitable and optimal habitat. As with other federal lands, however, the forest has not been completely surveyed for occurrences. For any undocumented occurrences on USFS or other federal lands, it is difficult to assess the extent of impacts from the above threats. In the absence of a coordinated inter-agency effort to monitor and maintain populations wherever they are found, our ignorance could lead to a gradual erosion of habitat availability and to an increase in impacts from development and other forms of disturbance. Increased disturbance from human activity in the Gunnison Basin is likely to have a slow but steady effect on habitats, populations, and individuals of *A. anisus*, as well as its pollinators. These effects cannot be mitigated by USFS management practices alone. Without systematic monitoring of the species throughout its limited range, including USFS lands, population levels could be severely reduced before anyone realizes the extent of the losses. Ongoing inter-agency communication regarding knowledge of occurrences, monitoring efforts, and awareness of management practices that could impact *A. anisus* and its habitat would greatly enhance protection for this species.

Influence of management activities or natural disturbances on habitat quality

There have been no studies of the effects of management activities or natural disturbances on *Astragalus anisus* itself. However, some inferences can be drawn from our knowledge of its preferred niche within the sagebrush shrublands habitat. *Astragalus anisus* is clearly intolerant of heavy sagebrush cover, and it relies to some extent on the earlier seral stages of sage development. Whether natural or anthropogenic, low to moderate levels of disturbance that maintain a mosaic of sparse shrub cover within the potentially dense shrubland will probably act to maintain shifting subpopulations at a reasonable level. Management practices that increase canopy cover (e.g. fire suppression) will tend to decrease habitat for *A. anisus*. Moreover, activities or disturbances that result in habitat fragmentation (e.g., road creation) are likely to isolate subpopulations, have a negative impact on

local pollinators, and increase the potential for local extinction. Public lands of the Gunnison Basin, including USFS lands, are widely used for recreation and hunting. Impacts to *A. anisus* habitat from these activities are generally minimal, especially under current USFS and BLM travel guidelines restricting all-terrain vehicle and motorcycle use to designated routes.

Although *Astragalus anisus* does not occur in habitat suitable for timber harvesting, logging access roads through some habitat are a potential threat. In particular, timber sales have the potential to increase threats from access roads. However, at the time of this writing, there were no proposed actions on the Gunnison National Forest that would affect known *A. anisus* populations (USDA Forest Service 2004). Throughout the Gunnison Basin, road proliferation also increases the threat of impacts from invasive species. Although the effect of fire suppression has not been quantified for *A. anisus*, any tendency of sagebrush cover to increase under such a management regime would tend to eliminate habitat for *A. anisus*.

Influence of management activities or natural disturbances on individuals

In general, management activities or natural disturbances that affect habitats are likely to have similar or parallel effects on individuals or subpopulations. Current management of motorized and non-motorized recreation in the Gunnison Basin is likely to help prevent destruction of individuals and habitat. In particular, the regulations restricting motorized travel on federal lands to established routes and the efforts to direct and confine mountain-biking use to established trails will help to mitigate the effects of these activities. However, with the exception of one location in the West Elk Wilderness Area, the other eight documented occurrences on USFS land are either near roads or in Inventoried Roadless Areas of Category 1C, where road construction and reconstruction is not prohibited (USDA Forest Service 2000).

Maschinski et al. (1997) found that although population levels of *Astragalus cremnophylax* var. *cremnophylax* at Grand Canyon National Park fluctuated after protection from trampling, modeling suggested that the post-protection population would stabilize, in contrast to the declining unprotected population. Although plants were able to tolerate some trampling, the trampling also increased the individual plant's vulnerability to poor climatic conditions. Seedlings were able to reach the reproductive stage more quickly after protection from trampling. Sugden (1985) found that sheep grazing endangered ground nesting bees that were responsible for pollinating *A. monoensis* in California. These results tend to suggest that populations of *Astragalus* species are more stable under conditions where disturbance is limited and of a type and intensity under which the species has evolved.

Interaction of the species with exotic species

As of this writing, *Astragalus anisus* habitat was largely free of invasive non-native plant species. However, Johnston et al. (2001) documented some 28 species of non-native plants of concern in the Gunnison Basin. Most of these are not likely to have a severe impact on the overall population of *A. anisus*. As with many *Astragalus* species, *A. anisus* is somewhat of a specialist in barren, semi-desert habitats. Many invasives that are a problem in the Gunnison Basin, such as *Cirsium arvense* (Canada thistle), *Leucanthemum vulgare* (oxeye daisy), and *Linaria vulgaris* (butter-and-eggs), favor more mesic habitats and do not pose an extensive threat to *A. anisus*.

Although *Bromus tectorum* is not currently widespread in the upper Gunnison Basin, the possibility of its increase does pose a threat. *Bromus tectorum* is common to the east in the Front Range foothills and to the west in the Grand Junction and Montrose areas. In western Colorado *B. tectorum* is dominating some rangelands and has replaced native grasses and shrubs within the last 50 years. Fifteen years ago *B. tectorum* was rare on BLM land in the upper Gunnison River Basin, but in the year 2000 it was common along many roads at elevations below 9,000 feet (Hayes and Scott 2001). USFS lands in the area are generally at higher elevations and are less likely to exhibit extensive invasion by *B. tectorum*.

Extensive invasion by *Bromus tectorum* can alter the natural fire dynamics of the sagebrush shrublands. A natural fire regime in such habitats is a cycle of 25 to 75 years, but areas dominated by *B. tectorum* can burn every 3 to 5 years (Hayes and Scott 2001). Although frequent fires would reduce the sagebrush canopy cover, they would probably also drastically reduce *Astragalus anisus* populations if fire cycles are shorter than the expected lifespan of an individual.

Bromus tectorum can establish quickly where the soil surface has been disturbed, and it often first appears along roadsides. Hayes and Scott (2001) reported that Highway 50 in the Gunnison Basin has *B. tectorum* over much of its length and that there are patches along Highway 149 from Highway 50 to

Lake City. *Bromus tectorum* is more abundant in the western half of the basin. Areas that currently have significant infestations away from roads are Elk Creek and Red Creek campgrounds within Curecanti National Recreation Area, on areas of the Sapinero Mesa that are associated with domestic sheep bedding grounds and a wildfire, and in the Big Gulch area west of Quartz Creek. *Astragalus anisus* occurrences are known near all these areas.

Threats from over-utilization

There are no known commercial uses for *Astragalus anisus*. 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 *Astragali* 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* (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 is recommended for a variety of uses. There is no indication that *A. anisus* is likely to become a target of either of these types of commercial use.

Selenium-absorbing species of *Astragalus* have been used in the detection and mapping of seleniferous and uranium-bearing areas, and they are a major source of livestock poisoning. *Astragalus anisus* is not a selenium-absorbing species, but its unpalatibility due to other toxins has not been investigated.

Astragalus anisus is regularly collected in botanical surveys and has been the subject of some scientific investigations by students of Dr. Robin Bingham at Western State College in Gunnison. Available evidence indicates that population levels are sufficient to support collection and research at similar levels in the future.

Conservation Status of the Species in Region 2

Is distribution or abundance declining in all or part of its range in Region 2?

The numbers of plants in individual populations of *Astragalus anisus* have been observed to fluctuate dramatically between years (Wasson personal communication 2003), but there are no data that would allow distribution and abundance trends to be quantified. No fluctuations have been documented for populations on USFS lands. In the absence of evidence to the contrary, the population is believed to be stable (Johnston personal communication 2003).

Do habitats vary in their capacity to support this species?

Habitats do appear to vary in their capacity to support the species. *Astragalus anisus* is found throughout the dry sagebrush shrublands of the lower elevations in the Gunnison Basin. However, this type of habitat is spatially variable throughout the basin. From occurrence records, it is clear that *A. anisus* finds some sagebrush habitat more suitable than others. *Astragalus anisus* tends to occur within the sagebrush shrubland mosaic primarily in areas where bare ground is abundant and aspects are westerly. Such areas are often found on the windward side of north-south trending ridges (Johnston et al. 2001). Moreover, the highly variable population sizes reported suggest that there are as yet unidentified microsite factors that affect local habitat quality. USFS lands appear to support proportionally the same amount of potential habitat as do lands under other ownership in Region 2.

Vulnerability due to life history and ecology

Astragalus anisus is vulnerable to impacts that degrade its sagebrush shrubland habitat. Ecological perturbations that result in greater stand closure might impact *A. anisus*. Current information about the life history and ecology of *A. anisus* is insufficient to

determine whether it is especially vulnerable to other habitat or environmental changes. *Astragalus anisus* does not appear to be a narrow habitat specialist, and there are no readily identifiable threats from current management practices to its persistence. Habitat quality for pollinators of *A. anisus* is a critical but unknown factor that may contribute to the vulnerability of the species.

Evidence of populations in Region 2 at risk

Colorado Natural Heritage Program records indicate that the primary threat to *Astragalus anisus* reported by field observers is roads. A population on USFS land at Soap Creek was probably destroyed by a new road and erosion from the road (Colorado Natural Heritage Program 2003). Other occurrences that were thought to be at risk from the proximity of roads were on BLM land near Parlin and Barret Creek, and on USFS land at One-Mile Campground (Colorado Natural Heritage Program 2003).

Approximately 75 percent of the acreage that encompasses the currently known distribution of *Astragalus anisus* is public land (**Figure 1**). This ownership pattern helps to ensure that habitat loss to residential development is not a primary threat. However, land management policies of federal and state agencies (especially BLM) have the greatest potential to influence the persistence of the species. At this time, the management policies and activities of the USFS and other federal agencies do not appear to be placing *A. anisus* populations at risk. In order to continue to minimize risk to the species, land managers must continue to be aware that the upper Gunnison Basin is the only place on earth where this species occurs, and that if it is not maintained here, it will be lost.

Management of the Species in Region 2

Implications and Potential Conservation Elements

Low elevation sagebrush shrublands of the Gunnison Basin, dominated primarily by *Artemisia nova* and *A. tridentata* ssp. *wyomingensis*, constitute the optimal habitat for *Astragalus anisus*. Within these types, *A. anisus* prefers open, relatively flat areas with a westerly exposure. In pre-settlement times, the sagebrush shrublands and steppes of western North America followed a cycle of succession driven by wildfire, climate fluctuation, and outbreaks of *Aroga* moth. The advent of widespread human activities, livestock grazing, weed invasion, pesticide use, and other range improvement practices have often dramatically altered the community structure and composition (West and Young 2000).

Desired environmental conditions for *Astragalus anisus* include sufficiently large areas where the natural ecosystem processes on which it depends can occur, permitting *A. anisus* to persist unimpeded by human activities and their secondary effects, such as weeds. This includes a satisfactory degree of ecological connectivity between populations to provide corridors and other nectar resources for pollinators. From a functional standpoint, ecosystem processes on which *A. anisus* depend appear to remain largely intact. Whether this will remain true at the human population densities projected for the area is uncertain. Further research on the ecology and distribution of *A. anisus* will help to develop effective approaches to management and conservation, and to potentially forestall any conflicts that may arise from sage grouse management activities.

It is likely that a thoughtful assessment of current management practices on lands occupied by *Astragalus anisus* 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 recreationalists while conferring substantial benefits to *A. anisus*. See the Tools and practices section of this document for potentially beneficial management actions relative to *A. anisus*.

Tools and practices

Species inventory

Numerous reports of *Astragalus anisus* occurrences, as well as some survey work (e.g., Henretty), have resulted in a reasonably good picture of the range and relative abundance of the species. However, the true range and population numbers remain essentially unquantified. Thus, future species inventory work should focus on obtaining better population size data. Even rough population estimates, using size categories such as 1 to 10, 10 to 100, 100 to 1000, etc., could greatly increase our knowledge of true population numbers. Workers could concentrate on quickly censusing known and new populations rather than on producing highly accurate counts and maps. Based on an analysis similar to that presented in **Figure 7**, further inventory work could concentrate on establishing the outer edges of the range this species and on identifying environmental factors that may control its distribution

(e.g., soil type, community condition). Although much of the habitat to be searched is on federal land, access through private land is often required, and this may involve additional field preparation. Species inventories are simple, inexpensive, and effective, and necessary for developing a sufficient enough understanding of the target species to create a monitoring program. Contracting experts on this species to search for more occurrences and to update historic records would contribute greatly to our knowledge of *A. anisus*.

Habitat inventory

The Colorado Natural Heritage Program routinely uses aerial photography, topographic maps, soil maps, and geology maps to refine search areas when conducting inventories of large areas. This approach has been highly effective in Colorado and elsewhere. It is most effective for species about which we have a basic knowledge of its substrate and habitat specificity, so that we can deduce distribution patterns and potential search areas. In particular, the combination of aerial photography with the sort of modeling of suitable habitat presented in **Figure 7** could allow the identification of sagebrush shrublands with canopy cover low enough to favor *Astragalus anisus* population persistence.

In addition, although the influence of edaphic factors on the distribution of *Astragalus anisus* has not been formally investigated, most occurrences are confined to the Parlin-Lucky-Hopkins Association (shown as the Cheadle group in STATSGO; USDA Soil Conservation Service 1994). This type covers most of the Gunnison Basin and lower Cochetopa drainage, and it is found in smaller patches in the East River drainage above Crested Butte and in the Saguache Creek drainage west of the town of Saguache (**Figure 5**). *Astragalus anisus* has not been reported from these last two areas. The East River area may be too high, and *A. anisus* may simply have been unable to disperse to the Saguache Creek drainage through intervening unsuitable habitat. However, a quick survey of the disjunct occurrences of the Cheadle soil group could provide confirmation of these areas as possible *A. anisus* habitat.

Population monitoring

Population monitoring is among the highest priorities for research on *Astragalus anisus*. A minimal level of effort could provide an ongoing qualitative awareness of population trends. Since population numbers appear to be stable, presence/absence monitoring could give early warning of declining population trends. These data could be collected yearly at established stations that are easily accessed. Ideally, 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.

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. See Lesica (1997) for one possible method. Ideally, marked individuals in permanent plots 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 or 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 non-randomized 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 insure that the 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 least 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). In the first year of monitoring observers should concentrate on establishing the timing of critical seasonal elements, such as flowering and fruit set, and on determining the most useful and practical data collection protocols. During subsequent years observers could concentrate on collecting data at these established times.

The rosette growth form of *Astragalus anisus* lends itself to easier measurement than that of rhizomatous species. Once established, size classes could be quickly distinguished by overlaying a series of circular cut-outs, or by a similar inexpensive method. Seed predators might be identified by collecting pods of

A. anisus before they are shed from the plant, keeping them in sealed bags, and observing what emerges. Within the broader demographic monitoring, it would be useful to establish concurrent, smaller, focused studies to examine pollination dynamics and seed production/dispersal.

Qualitative studies are time consuming and expensive. Although *Astragalus anisus* does not appear to merit such levels of study from management personnel at this time, it is important to keep them in mind as potential research subjects for other investigators. Other Gunnison Basin area residents such as Western State College students or Rocky Mountain Biological Laboratory researchers should be alerted to the possibility of such studies. Efforts to enlist the help of other researchers in future studies of *A. anisus* could greatly enhance our knowledge of this species. *Astragalus anisus* is an ideal subject because it is both "rare" as a local endemic and plentiful enough in its restricted range to allow collection and manipulation of individuals.

Habitat monitoring

For sites that are occupied by *Astragalus anisus*, habitat monitoring should be conducted concurrently with population monitoring. Documenting habitat attributes, disturbance regime, and associated species during all population monitoring efforts will greatly augment our present understanding of the habitat requirements and management needs of this species. This could be incorporated into the field forms used for the quantitative sampling regimen described above. If carefully selected environmental variables are quantified during monitoring activities, they will help explain observations of population change. Habitat monitoring of known populations will alert managers of new impacts, such as weed infestations and damage from human disturbance and grazing. Making special note of signs of degradation from overgrazing may help managers prevent serious degradation proactively by implementing changes in the grazing regime. Change in environmental variables might not cause observable demographic repercussions for several years, so re-sampling the chosen variables may help to identify underlying causes of population trends. Evidence of current land use practices and management are important to document while monitoring populations.

Observer bias is a significant problem with habitat monitoring (Elzinga et al. 1998). Thus, habitat monitoring is usually better at identifying new impacts than at tracking change in existing impacts. For estimating weed infestation sizes, using broad size classes helps reduce the effects of observer bias. To assess trampling impacts, using photos of impacts to train field crews will help them to rate the severity of the impact consistently.

The use of photopoints 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 establishment of an institutional awareness of *Astragalus anisus* is perhaps the most useful conservation tool. The fact that about 75 percent of its known range is on federal land places federal land managers (especially BLM) in the best position to establish and perpetuate such a strategy.

In general, management actions that tend to maintain the mosaic of dry sagebrush shrublands, especially with moderate to sparse cover, and to preserve some open patches that prevent disturbance of pollinator activities and promote natural levels of connectivity between subpopulations will tend to benefit populations of *Astragalus anisus*. Past grazing practices and sage-clearing activities have probably resulted in an increase of this type of condition throughout the Gunnison Basin (Johnston personal communication 2003). Although grazing is not detrimental to individual plants and may lead to some habitat improvement, it also has the potential to harm pollinator populations. Fire suppression throughout the basin could lead to increased sage cover, and thus reduce habitat suitable for *A. anisus*.

Although individual plants are resistant to trampling, such activity can depress the ability of individuals to tolerate stressful climatic conditions, and it can change the life cycle contributions of different size/age classes (Maschinski et al. 1997). Management actions that minimize trampling and disturbance from motorized and non-motorized recreation will tend to allow the species to maintain its evolved tolerance mechanisms and population dynamics in the face of natural disturbance. Control of off-road vehicle travel should be combined with practices that prevent the spread of weeds into *Astragalus anisus* populations. These practices should include providing public education about the problem, periodic monitoring of areas most at risk for infestation, minimizing

disturbance and limiting dispersal, and maintaining healthy native vegetation (see Colorado Natural Areas Program 2000 for additional information).

Seed banking

No seeds or genetic material are currently in storage for *Astragalus anisus* at the National Center for Genetic Resource Preservation (Miller personal communication 2003). It is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2002). Since the species is locally common, seeds should be collected and submitted for such storage.

Information Needs

Distribution

At this time our knowledge regarding the extent of *Astragalus anisus* distribution is reasonably complete, although this could be systematically confirmed through inventory efforts at the edges of its known distribution, and within suitable habitat where the species has not previously reported. The reported type locality at Pueblo has almost certainly been eliminated as a mistake in record keeping, and decades of botanical work have failed to turn up evidence that the species' range extends beyond the Gunnison Basin. However, since it has been described as a Gunnison Basin endemic, collectors may not look for it at edges of the currently known range or in nearby but distinctly separate areas.

Within the known distribution, accurate information on the real abundance of the species is needed. Information on possible range extensions and the influence of soil type on distribution are secondary needs.

Life cycle, habitat, and population trend

The habitat of *Astragalus anisus* is better understood than its life cycle and population trends. Survey and classification work by Barry Johnston (2000) has quantified the extent and character of sagebrush shrublands throughout the range. Furthermore, conservation efforts for the Gunnison sage grouse have contributed to the understanding of sagebrush shrubland dynamics and threats. However, potential conflicts exist between sagebrush shrubland dynamics that benefit the grouse and those that benefit *A. anisus*. The location and extent of any sagebrush control for grouse management on USFS lands should be monitored for its effect on *A. anisus* populations, if present.

In contrast, although the species has been casually observed in the field for many years 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 that may indicate local adaptation and differentiation.

Repeated observations of marked individuals in several populations would greatly clarify the population dynamics of *Astragalus anisus*. In particular, it would be useful to identify the time of germination, germination requirements, life expectancy, seed bank dynamics, and transition probabilities for different life-cycle stages. The development of an elasticity analysis could identify the critical stages of the life cycle and aid in the identification of threats to the persistence of *A. anisus*. Similarly, multi-year censusing or tracking efforts for some populations would greatly facilitate the quantification of population trends for the species as a whole. The species is sufficiently abundant to allow this type of research without significantly impacting the population as a whole.

Response to change

Rates of reproduction, dispersal, and establishment and the effects of environmental variation on these parameters have not been investigated in *Astragalus anisus*. Thus, the effects of various management options cannot be assessed during project planning. As a long-lived perennial with a dwarf growth form, *A. anisus* is not likely to be able to respond quickly to environmental changes.

Understanding the breeding system of *Astragalus anisus* will assist managers by determining the importance of pollinators for reproduction and population genetics. At this time, it is not known how management changes that affect insect visitors will affect *A. anisus*.

The specific responses of *Astragalus anisus* to disturbance are not clear and warrant further investigation. *Astragalus anisus* appears to be tolerant of some disturbance, but anthropogenic disturbance is unlikely to benefit *A. anisus* in natural settings, where it is likely to cause erosion and exacerbate problems from weeds. Information on the effects of the invasion of its habitat by *Bromus tectorum* and other exotic species is needed to manage populations of *A. anisus* properly. The effects of grazing on the habitat and pollination ecology of *A. anisus* also warrant careful study.

Metapopulation dynamics

Research on the population ecology of *Astragalus anisus* has not been done to determine the importance of metapopulation structure and dynamics to its long-term persistence at local or regional scales. Migration, extinction, and colonization rates are unknown for *A. anisus*. Baseline population dynamics and viability must first be assessed. *Astragalus anisus* could be an excellent subject for metapopulation studies since it appears to occur in numerous subpopulations throughout the Gunnison Basin.

Demography

Some initial work has been done that identified size classes and preliminary reproductive potential (Wasson 1998). However, much remains to be done to provide sufficient data to allow meaningful demographic analysis and to determine the likelihood of persistence at local or regional scales. 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 important stages (Schemske et al. 1994). Lesica's (1995) long-term study of *Astragalus scaphoides* provides a good model for similar work on *A. anisus*. Collection of useful demographic data will require the investment of two to three years at a minimum, ideally more. While they can provide useful data, short-term studies can also miss important demographic events that reoccur at intervals longer than the study period (Coles and Naumann 2000). See the Population monitoring section under Tools and practices for more detailed information on demographic monitoring.

Population trend monitoring methods

A variety of population monitoring methods could be easily adapted to the tracking of *Astragalus anisus*. See the Population monitoring section under Tools and practices for details.

Restoration methods

Restoration methods have not been explicitly developed for this species. However, the successful propagation of seeds by Gay Austin (Austin personal communication 2003) bodes well for the potential to raise *Astragalus anisus* individuals for restoration efforts, should that become necessary. Under current conditions in the Gunnison Basin, the species appears to be sufficiently stable and abundant that restoration methods are not a critical priority.

Research priorities for Region 2

Research priorities for *Astragalus anisus* are, in order of importance, population monitoring, studying pollination dynamics and possible impacts on pollinators, implementing demographic studies sufficient to perform elasticity analyses, identifying critical habitat factors, if any, and quantifying the effects of land management practices on the survival and persistence of the species.

Additional research and data resources

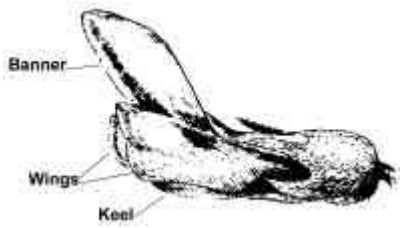
Some additional information on population locations, sizes, and habitats may be contained in the Gunnison Office files of retired BLM Wildlife Biologist, Joe Capodice. At the time of this writing, the vacancy left by his retirement had not been filled, and the extent of this information could not be confirmed. There may also be some useful data contained in uncompleted or unreported work by students of Dr. Robin Bingham at Western State College. Finally, additional herbarium specimens that could increase the known distribution of *Astragalus anisus* may exist at other locations not reported here.

Definitions

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

Monoecious: A plant the bears male and female reproductive structures in the same flower, or separate male and female flowers on the same plant (Allaby 1998).

Papilionaceous: Of flowers, butterflylike, with a banner petal, two wing petals, and a keel petal (Harris and Harris 1994).



Adapted from Faegri and van der Pijl 1979

Perfect: Flowers that include both male and female structures; bisexual (Weber and Wittmann 2001)

Potential Conservation Area: A best estimate of the primary area supporting the long-term survival of targeted species or natural communities. PCAs are circumscribed for planning purposes only (Colorado Natural Heritage Program Site Committee 2001)

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. These ranks should not be interpreted as legal designations. *Astragalus anisus* is ranked G2/S2: Imperiled globally/state-province because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.

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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APPENDIX

Gunnison Basin Potential Conservation Area

(from Rocchio et al. 2003)

Biodiversity Rank: B1. Irreplaceable biodiversity significance. The Gunnison Basin Potential Conservation Area (PCA) supports very good (B-ranked) occurrences of the globally- and state- critically imperiled (G1 S1) Gunnison Sage Grouse (*Centrocercus minimus*), designated a species of special concern by the Colorado Division of Wildlife and a candidate for listing under the Federal Endangered Species Act. This site represents the largest and most likely to succeed population of the Gunnison Sage Grouse. (That is, there are no remaining A-ranked occurrences). This site also supports nearly the entire world's population of the Gunnison milkvetch (*Astragalus anisus*) (G2 S2).

Protection Urgency Rank: P2. Very high urgency. Protection actions are urgently needed to secure the long-term survival of the Gunnison Sage Grouse. Although much of the land is federally owned, numerous important brood rearing and lek sites for the grouse are under private ownership with potential for development.

Management Urgency Rank: M1. Very high urgency. Although current management in many parts of this site is good to excellent, there are many areas that require management action. One of the most urgent management actions is to increase canopy cover and height of grasses and forbs under the sagebrush as well as in the riparian areas used for brood rearing.

Location: Gunnison and Saguache counties. The Gunnison Basin PCA encompasses sagebrush shrublands extending over 40 miles from north to south and 30 miles east to west, centered near the town of Gunnison.

U.S.G.S. 7.5-min. quadrangles: Cochetopa Park, Cold Spring Park, Sargents Mesa, West Baldy, Razor Creek Dome, Sawtooth Mountain, Spring Hill Creek, Sargents, Doyleville, Houston Gulch, Iris, Iris NW, Pitkin, Parlin, Signal Peak, Gunnison, Crystal Creek, Almont, Flat Top, Cement Mountain, Crested Butte, Powderhorn, Gateview, Poison Draw, Big Mesa, Carpenter Ridge, Sapinero, McIntosh Mountain, West Elk Peak SW, Little Soap Park, Squirrel Creek.

Legal Description:

T15S R84W, T15S R85W, T15S R 86W, T15S R87W, T45N R2E, T46N R1E, T46N R2E, T47N R1E, T47N R1W, T47N R1.5W, T47N R2E, T47N R2W, T47N R3E, T47N R3W, T47N R4E, T47N R4W, T48N R1E, T48N R1W, T48N R1.5W, T48N R2E, T48N R2W, T48N R3E, T48N R3W, T48N R4E, T48N R4W, T48N R5E, T49N R1E, T49N R1W, T49N R2E, T49N R2W, T49N R3E, T49N R3W, T49N R4E, T49N R4W, T50N R1E, T50N R1W, T50N R2E, T50N R2W, T50N R3E, T51N R1E, T51N R1W, T51N R2E, T51N R2W.

Elevation: 7,500 to 11,465 ft.

Size: Approximately 552,900 acres

General Description: The Gunnison Basin site is best characterized as rolling hills of sagebrush shrublands with dissecting rivers and creeks. Many of the hilltops are windblown free of snow and represent a more xeric landscape dominated by either dwarf sagebrush shrublands (sagebrush steppe) or montane grasslands. All of these ecological systems are extremely important for the Gunnison Sage Grouse, a sagebrush specialist. The sagebrush shrublands are winter and nesting habitat, while the xeric hilltops are lek sites, and the rivers and creeks are brood-rearing habitat. This site represents the world's largest remaining habitat and population for the Gunnison Sage Grouse (Gunnison Sage Grouse Working Group 1997), one of Colorado's rarest birds.

Numerous species of sagebrush dominate these shrublands, but Wyoming sagebrush (*Artemisa tridentata* ssp. *wyomingensis*) is usually the dominant below 8,500 feet in elevation, while mountain sagebrush (*A. tridentata* ssp. *vaseyana*) is the dominant above 8,500 feet. The dwarf sagebrush shrublands on the windswept slopes and ridges may be black sagebrush (*A. nova*) or low sagebrush (*A. arbuscula*). The dominant grasses in the grasslands vary with elevation as well.

The riparian areas along the creeks and rivers vary significantly depending on elevation, stream gradient, stream volume, and floodplain width. The most significant riparian areas within this site are those dominated by shrubs, including willows (*Salix* spp.), and alders (*Alnus incana*) that also have high grass and

forb cover during the summer months when grouse are present.

Biodiversity Rank Justification: This area represents the best remaining site for the Gunnison Sage Grouse (G1). This grouse was recently described as a distinct species and has a high potential for being federally listed as an endangered species due to a declining population. Within the Gunnison Sage Grouse range (i.e., southwest Colorado), only Gunnison County has a secure population (Gunnison Sage Grouse Conservation Plan 1997). In 1995, the spring population of sage grouse in the Gunnison Basin was about 2200 birds (Gunnison Sage Grouse Working Group 1997). Factors clearly implicated in the long-term decline of sage grouse are habitat loss; habitat fragmentation caused by roads, powerlines, reservoirs, land conversion, land treatments, etc.; and habitat degradation caused by land treatments and other uses that have changed grass, forb, and sagebrush composition, reduced organic material in the soil, and increased the loss/movement of soil resulting in changes in water table levels, and basic soil productivity. Sage grouse are specialists of sagebrush ecosystems and have not adapted to changing land uses.

Colorado Natural Heritage Program element occurrence records at Gunnison Basin Potential Conservation Area. Elements in bold are those upon which the PCA's B-rank is based.

Scientific Name	**Common Name**	**Global Rank**	**State Rank**	**Federal and State Status**	**EO* Rank**
Animals					
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	B
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	B
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	B
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	B
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	B
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	B
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	C
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	C
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	C
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	C
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	C
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	C
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	C
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	C
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	D
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	D
Centrocercus minimus	Gunnison Sage Grouse	G1	S1	C, SC	D
Plants					
Astragalus anisus	Gunnison milkvetch	G2	S2		B
Astragalus anisus	Gunnison milkvetch	G2	S2		B
Astragalus anisus	Gunnison milkvetch	G2	S2		C
Astragalus anisus	Gunnison milkvetch	G2	S2		C
Astragalus anisus	Gunnison milkvetch	G2	S2		C
Astragalus anisus	Gunnison milkvetch	G2	S2		C
Astragalus anisus	Gunnison milkvetch	G2	S2		C
Astragalus anisus	Gunnison milkvetch	G2	S2		C
Astragalus anisus	Gunnison milkvetch	G2	S2		C
Astragalus anisus	Gunnison milkvetch	G2	S2		D
Astragalus anisus	Gunnison milkvetch	G2	S2		D
Astragalus anisus	Gunnison milkvetch	G2	S2		D
Astragalus anisus	Gunnison milkvetch	G2	S2		E
Astragalus anisus	Gunnison milkvetch	G2	S2		E
Astragalus anisus	Gunnison milkvetch	G2	S2		E
Astragalus anisus	Gunnison milkvetch	G2	S2		E
Astragalus anisus	Gunnison milkvetch	G2	S2		E
Astragalus anisus	Gunnison milkvetch	G2	S2		E
Astragalus anisus	Gunnison milkvetch	G2	S2		E
Astragalus anisus	Gunnison milkvetch	G2	S2		E

Boundary Justification: This boundary represents all known lek sites within the Gunnison Basin, as well as nesting habitat, critical winter habitat, and the rivers and creeks used for brood rearing. There are areas within this site that have concentrations of lek sites and high quality habitat as well as areas that have been developed and no longer serve as sage grouse habitat. This boundary includes nearly all of what the Colorado Division of Wildlife has identified as the Gunnison Sage Grouse overall habitat in Gunnison Basin. In addition, this boundary represents nearly the entire world's population of Gunnison milkvetch.

Protection Comments: Protection actions are needed to secure long-term survival of the Gunnison Sage Grouse. Although much of the land is federally owned, numerous important brood rearing and lek sites for the grouse are under private ownership with potential for development.

Management Comments: The following is excerpted from the Gunnison Sage Grouse Conservation Plan, 1997:

The major factors that drive sage grouse populations are quality and extent of habitat. No other bird is so habitat specific to one particular plant type (sagebrush) in meeting its annual life requirements. Size of habitat is important because sage grouse move seasonally between suitable habitat types. Sage grouse require several distinct habitat types during different times of the year, which can be divided as following:

1. Winter
2. Nesting and early brood-rearing (uplands)
3. Late summer (riparian)
4. Escape and hiding habitat (needed yearlong)
5. Lek (breeding areas)

The key to sage grouse management is habitat, but in many locations of the Gunnison Basin key components of the sagebrush ecosystem are either insufficient or have been altered. The number and distribution of high quality nesting and early brood-rearing areas appear to be limiting factors for sage grouse in the Gunnison Basin (Gunnison Sage Grouse Plan, 1997). The quality and quantity of residual herbaceous cover have an important role in sage grouse production and survival. Residual herbaceous vegetation (grasses and forbs) in sagebrush areas, which provide adequate cover, both horizontal and vertical, is necessary to hide nests, nesting hens, and broods, as well as to provide habitat for insects upon which birds depend. However, recent studies have shown that grasses and forbs are under-represented in a large portion of the Gunnison Basin sagebrush ecosystem.

In addition to the Gunnison Sage Grouse, the Gunnison milkvetch (*Astragalus anisus*) is of high biodiversity significance. The world's distribution of Gunnison milkvetch is tightly associated with the same sagebrush ecosystem that the Gunnison Sage Grouse use. Nearly all of the world's known populations of Gunnison milkvetch occur within the Gunnison Basin PCA.