Astragalus leptaleus Gray (park milkvetch): A Technical Conservation Assessment

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Rocky Mountain Region,
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Juanita A. R. Ladyman, Ph.D.
JnJ Associates LLC
6760 S. Kit Carson Circle East
Centennial, CO 80122

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AUTHOR'S BIOGRAPHY

Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as Greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 14 years she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in *JnJ Associates* LLC, an environmental consulting company in Colorado.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ASTRAGALUS LEPTALEUS*

Status

Astragalus leptaleus Gray (park milkvetch) is designated a sensitive species by the USDA Forest Service Region 2 and by the Salmon-Challis and Targhee national forests in Region 4. Within Region 2, *A. leptaleus* has been reported from the San Isabel, Medicine Bow, Routt, Roosevelt, Arapaho and probably the White River national forests. The NatureServe global rank for this species is G4 (apparently secure). Both the Montana and Idaho Natural Heritage Programs list *A. leptaleus* as S3 (vulnerable within the state), and the Colorado Natural Heritage Program ranks it S2 (imperiled within the state). The Wyoming Natural Diversity Database ranks it as SH ("historical"). It has not been observed in Wyoming since 1951 and may be extirpated from that state. These state and global ranks have no regulatory status.

Primary Threats

Astragalus leptaleus appears to be most vulnerable to loss of habitat. Over the last century, many of the moist meadows that provide its habitat have been converted to hay production. Its habitat is also valuable for livestock grazing, and it is palatable to livestock and other herbivores. Livestock grazing during the growing season suppresses flower and pod production. Sheep grazing may be particularly harmful. Peat and placer mining have affected some areas in which *A. leptaleus* occurs in Colorado, but the impacts of these activities on the species' abundance and distribution are unknown. *Astragalus leptaleus* grows in environments with relatively open tree canopies, which suggests that fire may be necessary in maintaining its habitat. Fire suppression may be detrimental to the long-term sustainability of occurrences. Significant soil disturbance is likely to be detrimental because the species' root system appears to be important to the long-term survival of an occurrence. For the same reason, factors contributing to accelerated soil erosion are likely to be harmful. The mesic and wet habitats of *A. leptaleus* are vulnerable to invasive weed infestation; however, the competitive ability of this species is unknown. *Astragalus leptaleus* appears to be an obligate wetland species, and because it has a limited geographic range, it is vulnerable to activities that cause its habitat to dry out.

Primary Conservation Elements, Management Implications and Considerations

Although the total range of *Astragalus leptaleus* extends from central Colorado to southeastern Montana and south-central Idaho, occurrences are isolated from one another and it appears to be generally uncommon. The assumption that it has been "overlooked" has not been adequately validated. Support for this assumption would require documented negative surveys in areas where later surveys discover occurrences. Lack of historical information prevents a definitive determination of how this species' abundance and range may have changed over the last century, but with the current understanding of its ecology and biology it is likely that it has suffered a loss of habitat. This mesophytic perennial may prove to be an indicator species of hydrologic changes to its habitat. *Astragalus leptaleus* is able to spread vegetatively, at least to some extent, in areas used by livestock and wildlife. It is also likely to tolerate periodic mowing. However, repeated removal of aerial parts of the plant may limit seed production and be detrimental over the long term. Repeated removal of photosynthetic parts of the plant may ultimately weaken the root system through decreased nutrient input. The level at which aerial parts of the plant can be removed by either mowing or herbivore use without sustaining irreversible damage is unknown.

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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), USDA Forest Service (USFS). *Astragalus leptaleus* (park milkvetch) is the focus of an assessment because it is designated a sensitive species by USFS Region 2 (USDA Forest Service 2003a). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance and/or in habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Astragalus leptaleus* throughout its range but with an emphasis on those occurrences in USFS Region 2. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

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

Scope

This assessment examines the biology, ecology, conservation status, and management of *Astragalus leptaleus* with specific reference to the geographic and ecological characteristics of USFS Region 2. Although some of the literature relevant to this species may originate from field investigations outside the region, this document places that literature in the ecological and social context of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *A. leptaleus* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis, but it is placed in a current context.

In producing this assessment, I reviewed refereed (peer-reviewed) literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on *Astragalus leptaleus* may have been referenced in the assessment, but an effort was made to consider all relevant documents. Refereed literature was emphasized in this assessment because this is the accepted standard in science. Non-refereed literature was used in the assessment when information was otherwise unavailable. While non-refereed reports should be considered carefully, the reader should also realize that many such publications on rare plants are still valid as they are often 'works-in-progress' or isolated observations on phenology or reproductive biology. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or manpower may have prevented work in subsequent years. One year of data is generally considered inadequate for publication in a refereed journal but still may provide a valuable contribution to the knowledge base of a rare plant species. Unpublished data (e.g., Natural Heritage Program and herbarium records) were important in estimating geographic distribution and population sizes. These data required special attention because of the diversity of persons and methods used in collection. Records that were associated with herbarium specimen collection sites were weighted more heavily than observations alone.

Occurrence data were obtained from the Colorado State University Herbarium, the Rocky Mountain Herbarium, the University of Colorado Herbarium, Pomona College Herbarium, The New York Botanical Garden Herbarium, the Wyoming Natural Diversity Database (2003), the Montana Natural Heritage Program (2003a), the Idaho Conservation Data Center (2003), and the literature (Rydberg 1906, Barneby 1964, Barrell 1969).

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. Because our descriptions of the world are 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, in the ecological sciences, it is difficult to conduct experiments that produce clean results, so observations, inference, critical thinking, and models must instead 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.

One element of uncertainty arises from the paucity of information on this species, especially within Region 2. Much of the biology and ecology that is currently known comes from observations outside of Region 2. Collection records from within Region 2 are typically more than 50 years old and do not indicate abundance.

Publication of Assessment on the World Wide Web

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

Peer Review

Assessments developed for the Species Conservation Project are peer reviewed prior to release on the Web. Peer review is designed to improve the quality of communication and to increase the rigor of the assessment. Review of this assessment was administered by the Center for Plant Conservation, who employed two experts on this or related taxa to comment on the draft.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

NatureServe and many state natural resource inventory programs, such as the Idaho Conservation Data Center and the Montana Natural Heritage Program, use a system to rank sensitive taxa at state (S) and global (G) levels on a scale of 1 to 5. A rank of 1 indicates the most vulnerable and 5 the most secure (see Ranks in the Definition section). These ranks carry no regulatory status. The NatureServe (2005a) rank for *Astragalus leptaleus* is G4 (apparently secure globally). Both the Idaho Conservation Data Center (2005) and the Montana Natural Heritage Program (2005) assign this species a rank of S3 (vulnerable in the state). The Colorado Natural Heritage Program (2005) ranks *A. leptaleus* as S2 (imperiled in the state). The Wyoming Natural Diversity Database (2005) considers *A. leptaleus* a sensitive species but one that is "historical, possibly extirpated" (SH). *Astragalus leptaleus* has not been seen in Wyoming since 1951 (Fertig 1999).

Region 2 of the USFS designates *Astragalus leptaleus* a sensitive species (USDA Forest Service 2003a). The Salmon-Challis and Targhee national forests in Region 4 also consider it a sensitive species (USDA Forest Service 2003b, Wyoming Natural Diversity Database 2005). *Astragalus leptaleus* is not considered a sensitive species by USDA Forest Service Region 1 (USDA Forest Service 2005). The Idaho Bureau of Land Management (BLM) has placed it on the Type 5 watch list (USDI Bureau of Land Management 2003).

In Idaho, *Astragalus leptaleus* has Monitor status (M) on the Idaho Rare Plant List. "M" is applied to "taxa that are common within a limited range as well as those taxa that are uncommon but have no identifiable threats" (Idaho Conservation Data Center 2004). The Idaho Rare Plant List is the result of field studies and observations made by professional and amateur botanists throughout the state (Idaho Conservation Data Center 2004). In Montana, *A. leptaleus* was designated a sensitive species in 1991 (Lesica and Shelly 1991). Since that time, *A. leptaleus* has been perceived as being more common. It is currently listed as "of potential concern" by the Montana Natural Heritage Program (2003b, 2004b). Taxa of potential concern are tracked by the Montana Natural Heritage Program (2003b).

The U.S. Fish and Wildlife Service designate *Astragalus leptaleus* as a probable obligate wetland indicator species ("OBL?"). The question mark indicates that there is insufficient information available to determine indicator status (Idaho Conservation Data Center 2005, USDA Natural Resources Conservation Service 2005). Obligate Wetland (OBL) species "occur almost always (probability >99 percent) under natural conditions in wetlands" (USDA Natural Resources Conservation Service 2005).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Astragalus leptaleus is not directly protected by state or federal legislation in any state in which it occurs. The state of Idaho has assigned Monitor (M) status to *A. leptaleus* (Idaho Conservation Data Center 2005). Taxa given this status are believed to be either common within a limited range or uncommon with no identifiable threats (Idaho Conservation Data Center 2005). There are general protections for all wildflowers (native species) along highway right-of-ways in Idaho where the Department of Fish and Game has authority for plant life, biological, and species management issues (House Bill 67, Idaho Statutes 18-3911).

There are no existing management plans that directly address *Astragalus leptaleus*. It has been designated a sensitive species in USFS Region 2 and on the Salmon-Challis and Targhee national forests in Region 4. Unless there are unusual circumstances or human safety or economic issues to be considered, USFS regulations require avoiding disturbance of sensitive species and mandate that a biological evaluation be completed before projects that might affect plants occur on National Forest System lands. A biological evaluation is a "documented Forest Service review of Forest Service actions in sufficient detail to ensure that actions do not contribute to loss of viability of native or desired non-native plant or animal species" (USDA Forest service 2003a). When developing a noxious weed management plan for the Salmon-Challis National Forest, potential impacts on all the known locations of *A. leptaleus* were reviewed (USDA Forest Service 2003b).

Astragalus leptaleus was included in the sensitive plant guide developed for the Medicine Bow National Forest (Region 2), to assist field crews in recognizing it (von Ahlefeldt 1993). Limited surveys for *A. leptaleus* have been done on the Medicine Bow National Forest in Wyoming, but no surveys have been done on National Forest System lands in Colorado.

Astragalus leptaleus is on the Idaho BLM Type 5 watch list (USDI Bureau of Land Management 2003). Type 5 species are not considered to be sensitive species by the BLM although "there are indications that these species may warrant special status species designation and appropriate inventory or research efforts should be a management priority" (USDI Bureau of Land Management 2003). At the present time, there are currently no surveys or monitoring activities planned for *A. leptaleus* in Idaho (Rosentreter personal communication 2004, Mancuso personal communication 2004).

Astragalus leptaleus is typically associated with wetland habitats (Idaho Conservation Data Center 2005, USDA Natural Resources Conservation Service 2005). In many situations, wetland species are protected from development by the Section 404 regulatory program of the Clean Water Act (Comer et al. 2005). This program requires a permit application to the U.S. Army Corps of Engineers before any activity that places even a small amount of fill material into the "waters of the United States" (U.S. Environmental Protection Agency 1977). Before 2001, a broad regulatory definition of "waters of the United States" was used that afforded federal protection for almost all of the nation's wetlands, including isolated wetlands and intermittent waters (Legal Information Institute undated). However in 2001, the Supreme Court decided that Congress had not granted the U.S. Army Corps of Engineers jurisdictional authority over isolated wetlands (Supreme Court of the United States 2001). A narrower definition of what constitutes "waters of the United States" has been proposed. This definition removes isolated wetlands, non-navigable tributaries of navigable waters, intermittent and ephemeral streams, and waters that pass through human-made conveyances from Clean Water Act protection (Legal Information Institute Undated). Therefore, protection of many wetlands, especially in the western United States, will depend on state laws or local ordinances. The number of *A. leptaleus* occurrences that will be affected by the change in the interpretation of these provisions of the Clean Water Act is not known, but it is likely to include most of them.

Those *Astragalus leptaleus* occurrences associated with peat deposits may be protected since peatlands may be placed within "Resource Category 1" of the U.S. Fish and Wildlife Service wetland mitigation

policy (U.S. Fish and Wildlife Service 1981). The criteria for habitat to be designated "Resource Category 1" is that the "habitat to be impacted is of high value for evaluation species and is unique and irreplaceable on a national basis or in the ecoregion section. The mitigation goal for habitat in Resource Category 1 is no loss of existing habitat value" (U.S. Fish and Wildlife Service 1993). Peatland formation is extremely slow in the Rocky Mountains, and it represents an essentially irreplaceable resource (Cooper and MacDonald 2000).

Biology and Ecology

Classification and description

Systematics and synonymy

The genus *Astragalus* belongs to Fabaceae (Leguminosae), commonly known as the pea family. Members of the genus *Astragalus* are known from North and South America, Europe, Asia, India and Africa (Barneby 1964). It is an extremely variable genus both in morphology and in habitat, with approximately 1,500 to 2,000 species worldwide (Isely 1998). North America is particularly rich in *Astragalus* species. Dorn (2001) lists 62 species of *Astragalus* and an additional 21 varieties or subspecies for Wyoming alone.

Astragalus leptaleus belongs to the taxonomically informal Phacoid phalanx of the genus *Astragalus*, and to the taxonomically formal section *Astragalus* (Barneby 1964). It may be closely related to *A. alpinus* (alpine milkvetch), a widely dispersed circumboreal species that has been placed in the same section (Barneby 1964). *Astragalus leptaleus* is related and morphologically similar to *A. molybdenus* var. *molybdenus* (Leadville milkvetch) and *A. molybdenus* var. *shultziorum* (Shultz's milkvetch, Barneby 1949, Barneby 1981, Lavin and Marriott 1997, Welsh 1998, Wojciechowski et al. 1999). Both of these taxa were also placed in the Phacoid phalanx but in a different section (Barneby 1964). In fact, several specimens of *A. molybdenus* var. *shultziorum* (synonym *A. shultziorum*) were tentatively identified as *A. leptaleus* and remained under this name in herbaria for nearly 50 years (Barneby 1981). *Astragalus leptaleus* is an aneuploid with 28 chromosomes, n (haploid number) = 14 (Wojciechowski et al. 1999). This is atypical of the section *Astragalus*, whose members (such as *A. alpinus*) typically have 16 chromosomes, n = 8 (Spellenberg 1976, Wojciechowski et al. 1999).

Synonyms for *Astragalus leptaleus* include *A. pauciflorus* (Gray 1863a) and *Tragacantha leptalea* (Kuntze 1891, Kartesz 1994, International Legume Database and Information Service 2003). Somewhat confusingly, the specific epithet "*pauciflorus*" was given to two other *Astragalus* species in early taxonomic literature. Presumably this was due to the authors being unaware of earlier records. Therefore when reviewing early literature it needs to be noted that *A. leptaleus* is not synonymous with the *A. pauciflorus* described by Hooker (1831) and found "among rocks in the more elevated regions of the Rocky Mountains." This taxon is instead synonymous with *A. vexilliflexus* (Barneby 1964, Harvard University Herbaria 2001). The other taxon originally named *A. pauciflorus* was described by Pallas (1800) and occurs only in Asia (Integrated Taxonomic Information System 2004). *Tragacantha* was first used to describe several *Astragalus* taxa in Europe in 1735 (Kuntze 1891). In 1891, Kuntze apparently considered that this name held precedent in his treatment of *Astragalus* and other Leguminosae (Kuntze 1891). In other early treatments, astragali with one-celled membranous and inflated legumes, unequally pinnate leaves, and ochroleucous (yellowish or creamy white) flowers were placed in the genus *Phaca* (Torrey and Gray 1838, Rydberg 1913, Rydberg 1929). Synonyms for *A. leptaleus* are thus *P. leptalea* and *P. pauciflora*. The authors of the descriptions supporting the botanical names (synonyms) that have been proposed for *A. leptaleus* are: *A. pauciflorus* A. Gray, *T. leptalea* (A. Gray) Kuntze, *P. leptalea* (A. Gray) Rydberg, and *P. pauciflora* Torrey & A. Gray. See **References** section for details of the original publications.

History of knowledge

One of the first collections of *Astragalus leptaleus*, which provided the type for the name *Phaca pauciflora*, was made by T. Nuttall from the "plains of the Rocky Mountains near streams" in 1838 (Gray 1863a). Asa Gray transferred the epithet to *Astragalus*, as *A. pauciflora* in 1863, inadvertently creating a homonym, which he replaced with *A. leptaleus* in 1864 (see nomenclatural history in Barneby 1964 p. 113). The holotype, identified as *P. pauciflora*, is deposited at the Herbarium of The Natural History Museum in London, England (Vickery personal communication 2005). Another of the specimens Nuttall collected in 1838, an isotype identified as *A. leptaleus*, is currently housed at the Gray Herbarium at Harvard University (see **References** section for internet address). In 1862, *A. leptaleus* was collected by Dr. C. Parry, Elihu Hall, and J.P. Harbour (collection no. 141) from "South Park" where it was described as "common" and as "apparently a good forage plant" (Gray 1863a, 1863b). South Park is a grass-dominated, wetland-rich, basin approximately

fifty miles long and thirty-five miles wide, in Park County, Colorado (Spackman et al. 2001).

Non-technical description

Astragalus leptaleus is a rhizomatous, delicate, diffuse, herbaceous perennial (Barneby 1964). It has a taproot and branching subterranean caudices with solitary or, usually, numerous mat-forming stems up to 20 cm long (Isely 1985). It has 15 to 27 elliptic-shaped leaflets per leaf. The upper leaflet surface becomes hairless with age. Two to four, rarely as many as five, downward pointing, predominately white-cream colored flowers are on each flowering stem. There is a characteristic dark-colored purplish spot near the tip of the keel of the flower. The calyx tube is usually densely covered with small, black hairs. The oblong-ellipsoid pods are approximately 1 to 2.5 cm long, hang from their stalks, and are thinly covered with black and white hairs. Each pod is somewhat flattened on the top and bottom sides (at right angles to the seams, or sutures). The suture on the bottom of the pod is slightly raised and keel-like, positioned in a shallow, broad groove. At the base of each pod is a short neck or stipe up to 1.5 mm long. The stipe is between the body of the pod and remnants of the calyx; it is distinct from the stalk of the pod, which is between the calyx and the plant stem. There are six to 10 ovules per fruit (pod), and the brown, smooth, shiny seeds are approximately 1.8 to 2.1 mm long. This description is after that of Barneby (1964), Isely (1985), Moseley (1991), Moseley (1992), and Spellenberg (personal communication 2005). **Figure 1** and **Figure 2** illustrate *A. leptaleus*.

Astragalus alpinus is related to and superficially resembles *A. leptaleus* (Caicco and Henderson 1981). Diagnostic characteristics for both species were described by Barneby (1949) and are outlined in **Table 1**. Within its range, *A. leptaleus* is most recognizable by its mat-forming habit and the typically two- or three-flowered inflorescence (Isely 1985, Isely 1998). Barrell (1969) suggested that *A. miser* might be mistaken for *A. leptaleus* as both have small, white flowers with a purple-tipped keel and grow in similar habitats. *Astragalus miser* has an erect habit and straight narrow pods that are spread out at nearly right angles whereas *A. leptaleus* has a sprawling habit and the pods are short, elliptical, and pendulous. *Astragalus bodinii* (synonym *A. debilis*) occurs in similar habitats above

Figure 1. Close-up photograph of the flowers of *Astragalus leptaleus*. Photograph by Martin F. Wojciechowski, used with permission.

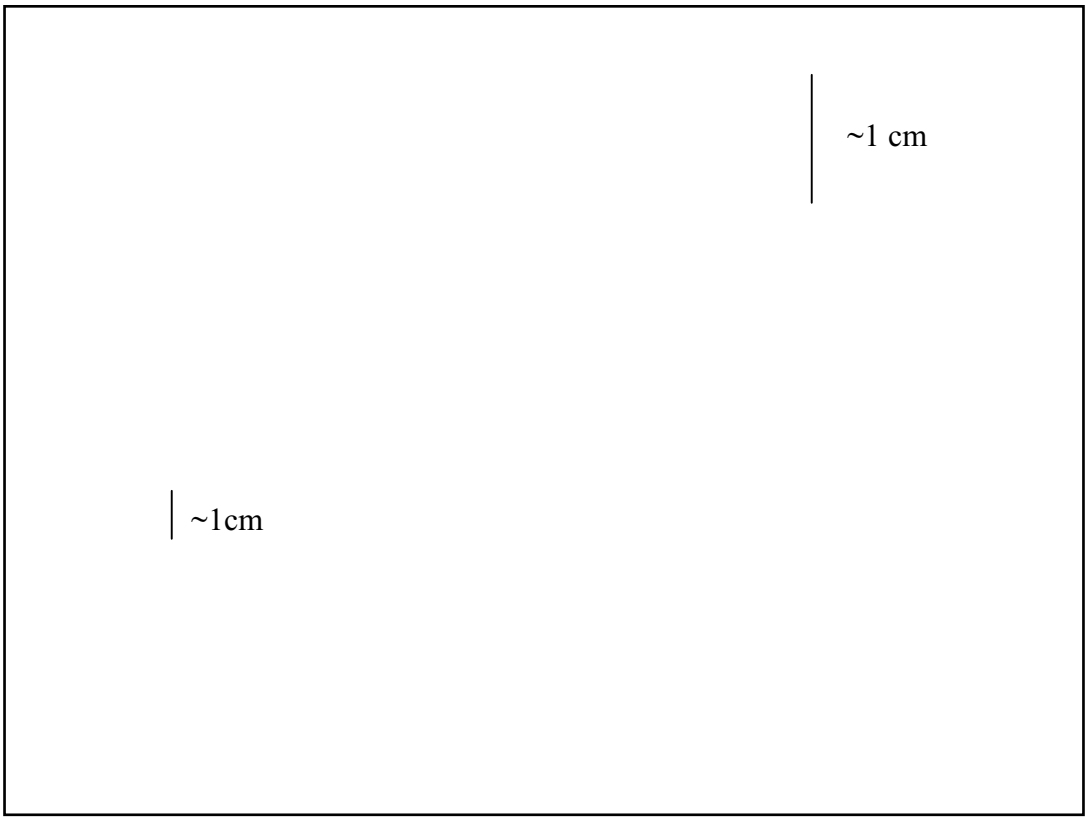

Figure 2. Illustration of *Astragalus leptaleus*, after von Ahlefeldt (1993).

Table 1. A comparison of the diagnostic characteristics of *Astragalus leptaleus* and its relative *A. alpinus* (after Barneby 1949 and Moseley 1991).

Species	Petals	Flower color	Stipe	Pod	Leaflets
Astragalus alpinus	Sub-equal in length, broad, sub-truncate keel equaling both wings and banner	Pale bluish-purple; the petal bases usually whitish	Long as the calyx tube; 1.4 to 3.5mm long	Pod deeply sulcate dorsally, the valves inflexed dorsally as a narrow scarious partition	Emarginate or retuse.
Astragalus leptaleus	More or less graduated, the obtusely rounded keel evidently shorter than both the wings and banner	White except for maculate keel	Very short and occult; <1.5 mm long	Flattened dorsally, wholly unilocular, ventral suture convex	Obtuse or acute, not emarginate

approximately 1,800 m (Barneby 1964). It can be distinguished from *A. leptaleus* by its numerous vivid purple flowers and determinate superficial root crown (Barneby 1964). *Astragalus leptaleus* sometimes occurs with *A. diversifolius* (meadow milkvetch) in east-central Idaho and Montana (Idaho Data Conservation Center 2004, Montana Natural Heritage Program 2004b). *Astragalus leptaleus* is readily distinguished from *A. diversifolius* by having leaves with 15 to 25 leaflets rather than the one to five linear leaflets per leaf of *A. diversifolius*. In addition, the terminal leaflet of *A. diversifolius* is continuous with the leaf stalk.

Astragalus ceramicus (painted milkvetch) and *A. convallarius* (lesser rushy milkvetch) grow in the same range as *A. leptaleus* but occupy drier habitats

and are unlikely to grow with *A. leptaleus*. *Astragalus ceramicus* has inflated, reddish- to purplish-mottled pods and a terminal leaflet that is continuous with the leaf stalk. *Astragalus convallarius* has narrow fruits more than 20 mm long and particularly narrow leaflets.

Technical descriptions, photographs, line drawings, and herbarium specimens

Technical descriptions of *Astragalus leptaleus* appear in Gray (1863a), Jones (1923), Rydberg (1929, as *Phaca leptalea*), Barneby (1964), Dorn (1984), Isely (1985), Isely (1998), Dorn (2001), and Weber and Wittmann (2001a and 2001b). Additional brief technical descriptions appear in Barneby (1949) and Harrington (1964). Details of an isotype of *A. leptaleus*, located at the Harvard University Herbarium, can be accessed through the World Wide Web (see **References** section for internet address).

Distribution and abundance

Astragalus leptaleus is a regional endemic that has been reported from Colorado, Idaho, Montana, and Wyoming (**Figure 3**, **Table 2**, **Table 3**). It has been collected in Jackson, Chaffee, Larimer, Summit, Park, Gunnison, and possibly Eagle counties in Colorado and from Carbon County in Wyoming. In Montana, *A. leptaleus* has been collected from Beaverhead, Park, and Lake counties, but only poorly documented collections made at the turn of the twentieth century are known from Lake County (**Table 3**). *Astragalus leptaleus* has also reportedly been found in Madison County in Montana (Lesica et al. 1984); however, no specimens or other information have been found to confirm this observation for this assessment. *Astragalus leptaleus* also occurs in Custer and Lemhi counties in Idaho.

Jones (1923) reported that the range of *Astragalus leptaleus* extended from Santa Fe in New Mexico to British America (Canada). However, the specimens collected in Canada have all since been identified as *A. bodinii* (Barneby 1964). Jones (1923) described the flower as "sometimes purplish," which is contradictory to Barneby (1964) who noted that except for the spot on the keel-tip, the petals of *A. leptaleus* are always white. *Astragalus bodinii* is a weak-stemmed taxon of moist meadows that also grows in northern New Mexico (Martin and Hutchins 1980). *Astragalus leptaleus* is not included in a well-researched checklist of the flora of New Mexico (Allred 2003). Given the lack of evidence that it occurs in New Mexico and its similarity to *A. bodinii*, the reports from New Mexico may represent misidentified specimens.

Although known for over a century, *Astragalus leptaleus* has been collected infrequently, indicating that it may always have been quite rare. In the early part of the nineteenth century Nuttall was quoted as saying that he had "seen but a single specimen and that not in flower" (Torrey and Gray 1838). Occurrence records are listed in **Table 2** and **Table 3**. Some records (such as CO-9, CO-12, and CO-17 in **Table 2**, MT-3, MT-4, and ID-19 in **Table 3**) consist of two or more collections because the information provided suggests they were made from the same location. In other cases in **Table 2**, the vagueness of the location description does not fully justify combining the records. However, by assigning each record a unique number more occurrences may have been listed than actually exist. Occurrences listed in **Table 2** that may be referring to the same site are: (1) CO-1, CO-2, CO-3, CO-4, and CO-5; (2) CO-6 and CO-7; (3) CO-9 and CO-10. In **Table 2** and **Table 3**, the date of each collection needs to be noted because many are more than a century old.

The term "occurrence" as used in this report includes plants in areas where there are contiguous stretches of apparently suitable habitat. An occurrence may be composed of one to several patches or sub-occurrences (NatureServe 2005a). The definition of occurrence is thus the same as for a population where a population is "a group of individuals of the same species that occurs in a given area" (Guralnik 1982). A more specific definition of population is "a group of individuals of the same species living in the same area at the same time and sharing a common gene pool or a group of potentially interbreeding organisms in a geographic area" (National Oceanic and Atmospheric Administration 2004). Sub-populations in the latter case are genetically related and interact either through pollination or seed dispersal. Ideally it is most useful for conservation planning purposes to understand spatial distribution in terms of the latter population definition. However, this concept of population cannot be applied when a taxon's genetics, seed dispersal characteristics, and reproductive biology are not known with certainty. Since the genetics of *Astragalus leptaleus* and the interactions among patches of individuals are unknown, the term "occurrence" is used to denote spatially contiguous groups of plants, with no genetic implications. The term "population" is only used to refer to genetic concerns of the species or plants in general.

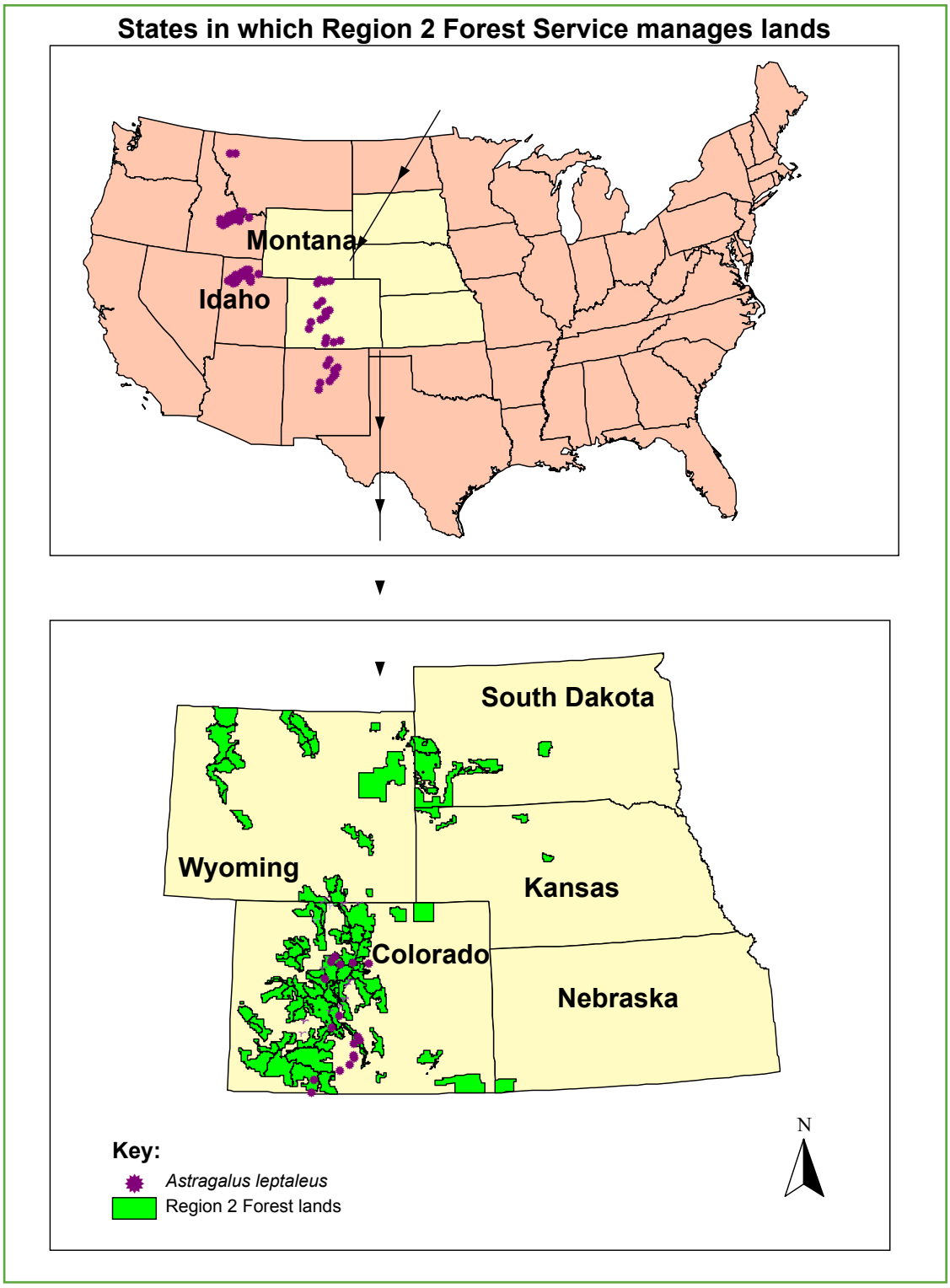

Figure 3. Distribution of *Astragalus leptaleus* in USDA Forest Service Region 2.

Astragalus leptaleus was collected within and near the Medicine Bow National Forest in Wyoming. However, it has not been observed in Wyoming since 1951 (Wyoming Natural Diversity Database 2005). There is very little information on which to base abundance estimates in Colorado. Many of the collections are more than 50 years old. Estimates of abundance were rarely provided for older collections,

Table 2. *Astragalus leptaleus* occurrences in Colorado (CO) and Wyoming (WY). Reports from Region 2 lands are shaded.

State-Arbitrary Number	Date Observed	County	Management/ Ownership	Location	Habitat (and abundance if available)	Source[1]
CO-1	03-Aug-1895	Jackson	Bureau of Land Management (BLM) and/or private land	North Park	No information	*G.E. Osterhout #s.n.* 1895 NY
CO-2	13-Jul-1896	Jackson	BLM and/or private land	North Park, near the North Platte River	No information	*G.E. Osterhout #s.n.* RM, COLO (RM received from G.E. Osterhout 1937)
CO-3	06-Aug-1914	Jackson	BLM and/or private land	North Park, North Fork. RM specimen (*Astragalus leptaleus*) included New Windsor in location details. Two specimens with same collection number at RM: (1) *A. leptaleus* (2) *Phaca pauciflora* (syn), received at different times from the collector	No information	*G.E. Osterhout #5167* COLO, RM
CO-4	24-Jul-1898	Jackson	BLM and/or private land	North Park on edge of Wyoming	No information	*G.E. Osterhout #5* COLO
CO-4	27-Jul-1898	Jackson	BLM and/or private land	North Park (CSU); No information (COLO)	No information	*G.E. Osterhout #1735A* COLO; *G.E. Osterhout #s.n.* CSU
CO-5	13-Jul-1896	Jackson	Unknown	Platte, North Park	No information	*G.E. Osterhout #1069* RM
CO-6	Before 1906	Larimer	Unknown	Laramie River	No information	Rydberg (1906)
CO-7	08-Jul-1975	Larimer	Roosevelt National Forest	Along County Road 59, 0.4 miles south of Wyoming border	Meadow edge with *Pinus*	*D. Wilken #12339* CSU
CO-8	24-Jun-1982	Summit	Arapaho National Forest and/ or private land	Green Mountain Reservoir along road on south side of the dam	Aspen grove	*W.A. Weber #16292* with R. Wittmann COLO
CO-9	1862, Aug-1871, Jul-1873	Park	Unknown	South Park	No information	*J. Wolfe #229-244* Jul 1873 NY; *W.C. Canby #s.n.* Aug 1871 (NY); *E. Hall & J.P. Harbour #141* 1862 NY, GH
CO-10	11-Jul-1990	Park	Probably State of Colorado or private land	South Park; at seeps on west and northwest edge of Antero Reservoir	Wetlands, with *Juncus ater*, at seeps	*D.J. Cooper #1796* COLO
CO-11	05-Aug-1990	Park	Probably State of Colorado or private land	South Park. Along road from US 285 into Salt Creek Ranch near Antero Reservoir	Edge of wet meadows dominated by *Juncus ater*	*D.J. Cooper #1874* COLO
CO-12	23-Jul-1994	Park	State of Colorado or private land	West of Antero Reservoir, along roadside west of US 285 in grassy area just next to wet gully along wire stock fence	Grassy area just next to wet gully; uncommon, with *Juncus* and grasses; total 10 to 20 plants	*M.F. Wojciechowski #471* with M.J. Sanderson COLO. [Wojciechowski personal communication 2004]. Voucher specimen for DNA sample H446353, *M.F. Wojciechowski*, January 1994 ARIZ

Table 2 (cont.).

State-Arbitrary Number	Date Observed	County	Management/ Ownership	Location	Habitat (and abundance if available)	Source[1]
CO-13	20-Jul-1963	Park	Private land	North end of South Park, 0.5 mile west of Jefferson; Michigan Creek Drainage Area	Frequent in the moist roadside areas; 9,000 to 10,500 ft. altitude	*R. Walter #775* COLO
CO-14	11-Jul-1954	Park	Private land	South Park, one mile east of Jefferson	On edge of sedge meadow, intermingled with taller grasses and sedges	*W.A. Weber #8768* COLO
CO-15	03-Aug-1895	Park	Pike National Forest - Region 2, BLM, or private land	(1) Como. (2 & 3) Como, South Park	No information	(1) *Crandall & Cowen #s.n.* CSU. (2) *Crandall and M? #s.n.* RM received from G.E. Osterhout 1938. Marked a topotype but this was disputed in an additional note by B.C. Johnston 2003. (3) *C.S. Crandall #s.n.* NY
CO-16	02-Sep-1978	Gunnison	BLM or private land	Powderhorn Valley. Along Deldorado Creek, 50 m northeast of old cow pens	Plants growing in thick mat with variety of grasses; alluvial terrace along stream	*R. Jennings #78-0003* COLO
CO-17	24-Jul-1901, 25-Jul-1901	Gunnison	Unknown	Gunnison, Region of Gunnison Watershed (#593 collected for "Plants of west central Colorado")	7,680 ft.	*C.F. Baker #593* 25-Jul-1901 RM; *C.F. Baker #572* 24-Jul-1901 NY; *C.F. Baker #573* 25-Jul-1901 NY
CO-18	Unknown (likely 1950s or 1960s)	Gunnison	BLM or private land	3 miles west of Gunnison in the Gunnison Basin	Growing with *Astragalus agrestis*	Barrell (1969)
CO-19	20-Jul-1945	Gunnison	BLM or private land	4 miles west of Gunnison	Moist meadow; 7,700 ft.	*H.D. Ripley & R.C. Barneby #7180* NY
CO-20	27-Jul-1892	Chaffee	San Isabel National Forest-Region 2, or private land	Buena Vista	No information	*C.S. Sheldon #s.n.* NY
CO-21	1886	Chaffee	San Isabel National Forest	Mt. Harvard	No information	*F. Clements #30* NY
CO-22	20-Aug-1873	Eagle	White River National Forest, BLM, and/or private	Eagle River	No information	*J.M. Coulter #s.n.* NY
CO-23	Aug-1873	Unknown	Unknown	Wet Mountain Valley	No information	*T. Brandegee #s.n.* NY
WY-1	05-Jul-1896, 24-Jul-1898	Carbon	Medicine Bow National Forest	Sierra Madre, "North Park at edge of Wyoming/Colorado state line" [vicinity of Big Creek Park]	No information	Wyoming Natural Diversity Database (2003); *G.E. Osterhout #s.n.* RM

Table 2 (concluded).

State-Arbitrary Number	Date Observed	County	Management/ Ownership	Location	Habitat (and abundance if available)	Source[1]
WY-2	11-Jul-1896	Carbon	Medicine Bow National Forest	Big Creek Park	No information	Wyoming Natural Diversity Database (2003); *G.E. Osterhout #s.n.* RM
WY-3	11-Jul-1896	Carbon	Medicine Bow National Forest	Hiltons	No information	*G.E. Osterhout #s.n.* RM
WY-4	05-Sep-1951	Carbon	Private land - within a mile of the Medicine Bow National Forest boundary - Region 2	In Saratoga Valley, along Big Creek west of Hwy 230 on a ranch; near Encampment	No information	Wyoming Natural Diversity Database (2003); *H.F. Eppson #R-457* RM

[1]Herbaria abbreviations:

ARIZ Herbarium University of Arizona, Tucson, Arizona, USA

COLO The University of Colorado Herbarium, Boulder, Colorado, USA

GH Harvard University, Cambridge, Massachusetts, USA

NY William and Lynda Steere Herbarium, New York Botanical Garden, New York, New York, USA

RM Rocky Mountain Herbarium, University of Wyoming, Laramie, Wyoming, USA

CSU Herbarium, Biology Department Colorado State University, Fort Collins, Colorado, USA

Table 3. *Astragalus leptaleus* occurrences in Montana (MT) and Idaho (ID).

State-Arbitrary Number	Date Observed	County	Management/ Ownership	Location	Habitat	Source[1]
MT-1	11-Jul-2003	Beaverhead	Likely Beaverhead National Forest-Region 1	About 5 miles south of Medicine Lodge Peak, in the meadows between Medicine Lodge Creek and Road 302	Level ground; alkaline peat derived in part from limestone and quartzite; hummocky; sub-irrigated meadows dominated by *Carex utriculata*, *Salix brachycarpa*, *Betula occidentalis*, *S. boothii*, and *Thermopsis montana*	Montana Natural Heritage Program (2003a); *C. Bjork #7781* 2003 MONTU
MT-2	1997 (approx.)	Beaverhead	Beaverhead National Forest-Region 1 (may extend into Bureau of Land Management (BLM) and/or private land)	Morrison wetland	Wetlands	Cooper et al. (1999)
MT-3	14-Jul-1908, 27-Jul-1922, 11-Jul-1986	Beaverhead	Beaverhead National Forest-Region 1 and/or BLM and/or private land	1908 & 1922: Monida; 1986: 0.125 miles northeast of Monida	1908:Upper Temperate Life Zone; 1922: Upper temperate life zone, alpine; 7,500 ft.; 1986: With *Haplopappus integrifolius*, *Sphaeralcea* ssp. and *Castilleja* ssp. in "dryish place with few grasses."	*M.E. Jones #8187* POM-24810 POM; *M.E. Jones #s.n.* 27-Jul-1922 NY. *Astragalus leptaleus* remarked associated with herbarium specimen of *Haplopappus integrifolius* collected by *K.H. Lackschewitz #11015* 11-Jul-1986 MONTU
MT-3	26-Jun-1986	Beaverhead	Management status unavailable - likely private land	At Monida near the southbound entrance ramp	Common on hummocks in a moist alkaline meadow; with *Juncus balticus* and *Potentilla fruticosa*; 6,800 ft.	*P. Lesica #3917* NY
MT-4	05-Apr-1905, 10-Jul-1986	Beaverhead	Red Rocks Wildlife Refuge and probably private land	1905: Around the headwaters of Red Rock Creek; 1986: On ledge above main road, south of Upper Red Rock Lake	1905: No information; 1986: "On dryish ledge" with *Haplopappus integrifolius*, *Hedysarum* ssp., and *Bupleurum* ssp.	Specimen in 1905 reported in Barneby (1964). *Astragalus leptaleus* remarked associated with herbarium specimen of *Haplopappus integrifolius* collected by *K.H. Lackschewitz #11005* 10-Jul-1986 MONTU.
MT-5	18-Jul-1908	Lake	Management status unavailable - likely private land	Bigfork, Daphnia Lake [Bigfork is near Flathead Lake]	Middle temperate life zone	*M.E. Jones #8188* POM-24809 POM [Possibly associated with the location "Flathead Lake" given by Barneby 1964]
MT-6	20-Aug-1909	Lake	Management status unavailable - likely private land	Somers [near Flathead Lake]	Middle temperate life zone	*M.E. Jones #s.n* POM-24705 [Possibly associated with the location "Flathead Lake" given by Barneby 1964]
MT-7	25-Aug-1916	Park	Management status unavailable	North of Wilsall	No information	*W.N. Suksdorf #120* WTU

Table 3 (cont.).

State-Arbitrary Number	Date Observed	County	Management/ Ownership	Location	Habitat	Source[1]
ID-1	04-Aug-1993	Custer	BLM Upper Columbia-Salmon Clearwater Districts, Challis Field Office	In riparian bottomland along Corral Creek north of the confluence with Jimmy Smith Lake	*Salix geyeriana/Poa pratensis* community along a small low gradient stream that is largely spring fed (no spring scouring); valley bottom is 20 m wide; plant occurs in drier portions of the riparian zone in dark loamy soil that is not saturated; sagebrush on adjacent slopes	Idaho Conservation Data Center (2003)
ID-2	07-Jul-1991	Custer	Upper Columbia-Salmon Clearwater Districts, Challis Field Office, and State of Idaho land	Bear Creek	Moist site; flat aspect; bottom; 0-20 degree slope; open light; plants on hummocks and in drier sites of small *Poa pratensis* meadows adjacent to *Salix geyeriana-Salix boothii* riparian community; with *Poa pratensis*, *Taraxacum officinale*, and *Ranunculus cymbalaria*	Idaho Conservation Data Center (2003)
ID-3	1988, 17-Jul-1991	Custer	Upper Columbia-Salmon Clearwater Districts, Challis Field Office	Road Creek; population may be extension of ID-2	Moist, open, flat bottom site; with *Glaux maritima*, *Hesperochiron* ssp., *Poa pratensis*, *Eleocharis* ssp., and *Triglochin maritimum*	Idaho Conservation Data Center (2003); *Moseley #2223* ID
ID-4	17-Jul-1991	Custer	BLM Upper Columbia-Salmon Clearwater Districts, Challis Field Office	Along Horse Basin Creek above the confluence with Road Creek, extending for at least 1.5 miles upstream; over 3 sections; population may be extension of ID-2 and ID-3	Saturated (wet-mesic); bottom; 0-3 percent slope; open and partial light; in ecotone between wet *Carex* and *Juncus*-dominated meadow and drier riparian community of *Salix geyeriana* and *S. boothii*	Idaho Conservation Data Center (2003)
ID-5	1988, 17-Jul-1991	Custer	Upper Columbia-Salmon Clearwater Districts, Challis Field Office	Road Creek exclosure	On hummocks and in moist meadow upland ecotone; flat creek bottoms, 0-20 degree slope; open graminoid-dominated area between *Salix geyeriana* stands. Associated with *Trifolium* ssp., *Carex* ssp., *Poa pratensis*, *Sisyrinchium idahoense*, *Erigeron lonchophyllus*, and *Iris missouriensi*	Idaho Conservation Data Center (2003); *Elzinga #4485* Salmon BLM Herbarium
ID-6	18-Jul-1991, 12-Jul-1997	Custer	Upper Columbia-Salmon Clearwater Districts, Challis Field Office, Thousand Springs ACEC and private land	Chilly Slough, Thousand Spring Valley; over 5 contiguous sections	Saturated (wet-mesic); bottom; flat; open light; *Juncus balticus-Phlox kelseyi* community; hummocky, white alluvium; associated with *Senecio debilis*, *Glaux maritima*, *Haplopappus uniflorus*, *Astragalus diversifolius* occurs near some clusters	Idaho Conservation Data Center (2004)

Table 3 (cont.).

State-Arbitrary Number	Date Observed	County	Management/ Ownership	Location	Habitat	Source[1]
ID-7	10-Aug-1991, 06-Aug-1992, 22-Jul-1997	Lemhi	Targhee National Forest, Dubois Ranger District, Idaho Dept. of Fish and Game land, and private land	Throughout Birch Creek Fen, at headwaters of Birch creek in Birch Creek Valley	Bottom; flat aspect; 0-3 percent slope; open light; saturated organic substrates to somewhat drier mineral substrates; *Potentilla-Juncus balticus* community.	Idaho Conservation Data Center (2003); *Moseley #2434* ID; *Mancuso #727* ID
ID-8	05-Aug-1997	Custer	State of Idaho land	Near head of Summit Creek adjacent to large wetlands between Summit Reservoir and campground	Heavily grazed mesic ecotone between *Carex simulata* wetland (standing water) and sagebrush upland; level compacted soils derived from parent material; narrow zone of habitat	Idaho Conservation Data Center (2003)
ID-9	20-Jul-1995	Custer	BLM Upper Columbia-Salmon Clearwater Districts, Challis Field Office and private land	Along Goldburg Creek in the Pahsimeroi Valley	*Carex* ssp. and *Juncus* spp. dominated sod within riparian strip alongside creek characterized by hummock topography, silty texture, probably calcareous alluvial soil	Idaho Conservation Data Center (2003); *M. Mancuso #1408* ID
ID-10	11-Sep-1991, 22-Sep-1997	Lemhi	Salmon - Challis National Forest and BLM Upper Columbia-Salmon Clearwater Districts and private land	Northeast side of Texas Creek, approximately 9 to 13 miles south of Leadore.	Deep hummocky topography, full sun, sub-irrigated and seasonally saturated. *Juncus balticus* and *Deschampsia caespitosa* community types	Idaho Conservation Data Center (2003); *M. Mancuso #607* ID
ID-11	17-Jul-1995, 25-Jul-1997	Lemhi	BLM Upper Columbia-Salmon Clearwater Districts, Salmon Field Office and State of Idaho land	Along 18 Mile Creek, approximately 10 miles southeast of Leadore	"*Deschampsia caespitosa* community type; soils are alkaline, clayey, high in organic matter, hummocky, and moist to saturated at the surface; the population is adjacent to an apparent old channel and may be wet due to natural flow as well as irrigation; meadow vegetation varies from dense with 95-100 percent cover to full sun." "*Astragalus* seems to be especially associated with *Thermopsis montana*."	Idaho Conservation Data Center (2003); *C. Elzinga #448* Salmon BLM herbarium
ID-12	21-Jul-1995	Lemhi	BLM Upper Columbia-Salmon Clearwater Districts, Salmon Field Office	West side of State Route 28, south of Texas Creek	"Moderately dry area adjacent to small wet swale; soils alkaline and clayey; vegetative cover about 50 percent."	Idaho Conservation Data Center (2003)
ID-13	25-Sep-1997	Lemhi	Salmon - Challis National Forest, Leadore Ranger District	Lower Texas Creek, within small enclosure area where 2 goose boxes are located	Occurs in slightly hummocky, drier portions of wet meadow complex; community dominated by *Juncus balticus*, *Agropyron dasystachyum*, and *Carex praegracilis*	Idaho Conservation Data Center (2003); Land ownership map shows area as all private land but Forest Service owns small parcel in which *Astragalus leptaleus* was found

Table 3 (cont.).

State-Arbitrary Number	Date Observed	County	Management/ Ownership	Location	Habitat	Source[1]
ID-14	01-Jul-1997	Lemhi	Salmon National Forest, Leadore Ranger District	Approximately 7 miles north east of Leadore and approximately 8.5 miles south of the Idaho/ Montana border	Hummocky wet meadow	Idaho Conservation Data Center (2003)
ID-15	30-Jul-1997	Lemhi	Private land	Northeast of the Canyon Creek/Cruikshank Creek Confluence approximately eight miles north of Leadore	On margins of *Carex simulata* meadow; flat; seasonally moist; full sun; hummocky topography	Idaho Conservation Data Center (2003)
ID-16	30-Jul-1982	Custer	Challis National Forest	Kane Creek, south of its junction with Summit Creek; could not be relocated in July 1991	No information	Idaho Conservation Data Center (2003); *D. Henderson #6426* ID
ID-17	16-Jun-1991	Custer	Salmon - Challis National Forest, Lost River Ranger District	Edge of riparian zone along Wildhorse Creek, downstream from the confluence with Fall Creek	Most (mesic); bottom; flat aspect; 0-3 percent slope; open light; uniformly loamy with no cobbles or rocks; *Poa pratensis* meadow at edge of *Salix geyeriana* thicket	Idaho Conservation Data Center (2003)
ID-18	1982, 1991	Custer	Challis National Forest	Wild horse Creek	Drier hummocks and in meadow-upland ecotone in *Salix* communities; on moist loamy alluvium without rocks at the surface; all heavily grazed	Idaho Conservation Data Center (2003)
ID-19	31-Jul-1981, 16-Jul-1991	Custer	Salmon - Challis National Forest	Upstream from Jim Canyon among willows along North Fork Big Lost River	1981: Habitat moist in spring. With *Sisyrinchium idahoense* var. *occidentale*, *Agropyron repens*, *Poa pratense*, and *Hordeum brachyantherum*; 1991: Moist *Poa pratensis* meadow on edge of *Salix geyeriana* thicket	Idaho Conservation Data Center (2003); *Caicco #143* NY, ID; *S.L. Caicco and J. Civille #287* 1981 ID, NY (see Caicco and Civille 1983)
ID-20	18-Jul-1991	Custer	BLM Upper Columbia-Salmon Clearwater Districts, Challis Field Office, and possibly private land	Twin Bridges Creek, upstream from the confluence with the Big Lost River	Saturated (wet-mesic); bottom; flat aspect; 0-3 percent slope; open light; on hummocks of loamy alluvium	Idaho Conservation Data Center (2003)
ID-21	19-Jul-1991	Custer	Challis National Forest - Long River Ranger	East Fork Big Lost River below the confluence with Willow Creek	Saturated (wet-mesic); bottom; flat aspect; 0-3 percent slope; open light; on river bank	Idaho Conservation Data Center (2003)

Table 3 (cont.).

State-Arbitrary Number	Date Observed	County	Management/ Ownership	Location	Habitat	Source[1]
ID-22	1947, 1948, 18-Jul-1991	Custer	Private land	Cedar Creek Bar. "Valley of the Big Lost, River 11 miles below Dickey"	Broad meadows, alkaline meadows	Idaho Conservation Data Center (2003). *J.H. and C.B. Christ #17965* WS (reported as WSU); *H.D. Ripley and R.C. Barneby #8815* IDS, UTC. Barneby (1949) remarked that this specimen was its exactly typical form
ID-23	25-Aug-1998	Custer	Sawtooth National Forest, Sawtooth National Recreation Area	Bowery Hot Springs area in the White Cloud Mountain; occurrence extends from hot-springs source to downstream wetland complex	Thermally influenced, graminoid-dominated wetland to *Salix*-dominated vegetation in wet meadow complex; flat to gentle slopes	Idaho Conservation Data Center (2003); *M. Mancuso #1755* ID
ID-24	14-Jul-1982, 26-Jun-1984, 18-Jul-1991	Custer	Private land (?)	Confluence of Thousand Springs Creek, Southeast of junction Highway 75/Alternate 93	1982: Associated species: *Astragalus diversifolius*, *Senecio debilis*, *Haplopappus lanceolatus*, *Dodecatheon conjugens*, *Plantago eriopoda*, *Juncus balticus*, and *Glaux maritima*. 1984: Edge of meadow near sagebrush community in bottomland north of Big Lost River 1991: Moist ecotone between wet meadows along creek and upland; with *Juncus balticus*, *Smilacina stellata* and *Astragalus agrestis*; adjacent to *Salix geyeriana*, *S. boothii* woodland	Idaho Conservation Data Center (2003); *S.L. Caicco #384*, *422* ID, NY. 14-Jul-1982; S.L. *Caicco #384* NY, *S.L. Caicco #422* NY; *D. Atwood #10286* BRY. 1984; *N.D. Atwood #10286* with *D. Henderson*, *B. Ralphs*, *R. Jenkins*, *C. Wellner & W. Ririe* NY
ID-25	17-Jul-1991	Custer	BLM Upper Columbia-Salmon Clearwater Districts, Challis Field Office, Third Creek Watershed ACEC/ RNA, and State of Idaho land	Between Herd Creek Road and Lake Creek	Saturated (wet-mesic); bottom; 0-3 percent slope; open light; hummocks in *Poa pratensis-Juncus* community on edge of *Salix geyeriana-S. boothii* community; loamy alluvium	Idaho Conservation Data Center (2003)
ID-26	20-Jul-2002	Lemhi	Not reported	Beaverhead Mountains; in meadows along Canyon Creek; adjacent to Hwy. 29 and the Cruickshank Creek Road (FR 130)	Growing in moist, alkaline (calcareously derived) soil	*C.R. Bjork #6514* NY
ID-27	18-Jul-1991	Custer	BLM land in Thousand Springs Valley	Meadows around Whiskey Springs approximately 17 miles northwest of Mackey, adjacent to Highway 93	Moist loamy alluvium; hummocky *Juncus balticus-Phlox kelseyi* community with *Ranunculus cymbalaria*, *Erigeron lonchophylla*, and *Hordeum brachyantherum*	*R. Moseley #2225* NY

Table 3 (concluded).

State-Arbitrary Number	Date Observed	County	Management/ Ownership	Location	Habitat	Source[1]
ID-28	08-Jul-1948	Custer	Not reported	10 miles northwest of Mackay, on road to Chilly	In broad meadows	*J.H. Christ & C.B. Christ #17865* NY
ID-29	06-Aug-1986	Custer	Not reported	East Fork of the Salmon River at Little Boulder Creek, trailhead, adjacent to road	Meadow	*N.D. Atwood #12268* NY

[1]Herbaria abbreviations:

BRY	Stanley L. Welsh Herbarium, Brigham Young University, Provo, UT, USA
ID	Stillinger Herbarium, Biological Sciences Department University of Idaho, Moscow, ID, USA
IDS	Herbarium, Biological Sciences Department, Idaho State University, Pocatello, ID, USA
MONTU	University of Montana, Missoula, MT, USA
NY	William and Lynda Steere Herbarium, New York Botanical Garden, Bronx, NY, USA
POM	Herbarium, Pomona College, Claremont, California, USA
UTC	Intermountain Herbarium, Utah State University, Logan, UT, USA
WS	Marion Ownbey Herbarium, Washington State University, Pullman, Washington, USA
WTU	University of Washington Herbarium, The Burke Museum, University of Washington, Seattle, Washington, USA

and no records suggest that the plant was particularly abundant. Only 10 to 20 plants were estimated at the Park County occurrence site in 1994 (CO-12 in **Table 2**; Wojciechowski personal communication 2004). Considering past location information, National Forest System lands in Region 2 where the species is most likely to be found include the San Isabel National Forest, the Roosevelt National Forest, the Arapaho National Forest, and possibly the Routt National Forest. Plants have also been located near, and perhaps in, the Pike National Forest, the White River National Forest, and the Gunnison National Forest (**Table 2**).

Astragalus leptaleus appears to be most abundant in Idaho, where surveys for the taxon were conducted in the 1990s. The center of abundance includes the area of the Targhee and Challis national forests (Region 4). The Idaho surveys were prompted by the rediscovery of the taxon in 1981 after approximately three decades of no reports (**Table 3**; Caicco and Henderson 1981, Caicco and Civille 1983). Estimates of occurrence sizes range in Idaho from "occasional and scattered" individuals to several hundred or thousands. Within any defined area of habitat, individuals are typically clumped. At one population in Idaho (ID-19 in **Table 3**), even though scattered individuals could be found several yards upstream from the main population, the densest concentration of plants was no more than 200 feet square (Caicco and Henderson 1981). There are few records of *A. leptaleus* occurring in Montana, and the populations there appear to be small. The most recent collection in 2003 came from a population of 27 plants counted within less than one acre of habitat (MT-1 in **Table 3**).

The term "individuals" may not be appropriate for this taxon because it spreads vegetatively to form loose mats. Therefore, the number of stems may not represent the number of genetically unique individuals. The term "individual" is useful to describe an occurrence size as long as the reader understands that the numbers do not necessarily reflect independence or the genetic richness of the population. Similarly, using the term "genets" to describe the composition of an occurrence should be applied cautiously. For example, the abundance of plants at occurrence MT-1 (**Table 3**) was described thus: 27 genets (each with multiple ramets) counted in one acre or less, 30 percent (of ramets) fruiting, 70 percent (of ramets) vegetative. A plant that originates from a seed is called a genet (Silvertown 1987). Such a plant may be any size and can be divided into many ramets, all of which will share the same genes. *Astragalus leptaleus* plants that appear to be individuals may actually be linked by rhizomes and may actually be ramets. Without subterranean excavation, it is very difficult to determine whether plants are actually genets or ramets.

Population trend

Astragalus leptaleus has been rarely reported within the states in which it occurs. It was, however, historically described as "common" in South Park, Colorado (Gray 1863a, 1863b). Considering its frequency and abundance across its range, Barneby wrote in 1964 that *A. leptaleus* was "locally plentiful but uncommon." There are insufficient data to be derived from the literature, herbarium specimens, or state natural heritage programs to state with confidence the long-term trends over the entire range or even within Region 2. It is unfortunate that, until relatively recently, the numbers of plants were rarely counted or even estimated when occurrences were found.

Astragalus leptaleus was collected relatively frequently in the Sierra Madre and Park ranges of Colorado and Wyoming in the late 1890s (**Table 2**). A more recent floristic survey of the same areas failed to report any specimens of this taxon (Kastning 1990). This may be significant and an indication that it has declined in abundance over the last century. Historically, *A. leptaleus* was found within and near the Medicine Bow National Forest in Wyoming (**Table 2**). However, it has not been observed in Wyoming since 1951 (Fertig 1999). In Colorado, most of the reported occurrences are several decades to more than a century old. The most recent collection was made in 1994 when fewer than 20 individuals were found (CO-12 in **Table 2**).

Outside of Region 2, *Astragalus leptaleus* occurs in Idaho and Montana. However, there are only two recent records of this species in Montana (MT-1 and MT-2 in **Table 3**; Cooper et al. 1999, Montana Natural Heritage Program 2003a); both are from the southwestern part of the state. The greatest number of records for *A. leptaleus* is from Idaho where it is tracked by the Idaho Conservation Data Center (2005). Fourteen Idaho occurrences were known to be extant in 1991 (Moseley 1991). In that year, eight Idaho occurrences were revisited and eight new sites were found. The surveyors' estimates of abundance at revisited sites are reported in **Table 4**. Two known occurrences could not be relocated (Moseley 1991). One occurrence (ID-16 in **Table 3**), which was first located in 1982, could not be relocated despite a thorough search; it may be extirpated (Moseley 1991). The other occurrence may still be extant because the area vaguely described in the original location report may well be on private land

Table 4. Numbers of plants estimated at Idaho *Astragalus leptaleus* occurrences visited more than once.

Occurrence[1]	1981	1982	1988	1991	1997
ID-19	"Probably 100s"	No data	No data	"Approximately the same number of plants as in 1981"	No data
ID-24	No data	"Hundreds"	No data	"Approximately the same number of plants as in 1982"	No data
ID-6	No data	No data	No data	Two localized populations; no numbers	>1,000
ID-2	No data	No data	1,000 to 10,000	"Approximately the same number of plants as in 1988"	No data
ID-5	No data	No data	Approximately 200 mature plants	"same as in 1988"	No data
ID-18	No data	"Occasional and widely scattered"	No data	>10,000	No data

[1]Arbitrary site designation; see **Table 3**.

(Moseley 1991). *Astragalus leptaleus* has inconspicuous flowers and grows among tall, dense vegetation. It therefore may easily be overlooked, and Isely (1985, 1998) suggested that it is "probably more frequent than the relatively few records indicate." Ideally, support for this hypothesis would include documentation of negative surveys in areas where subsequent surveys discover occurrences.

Habitat

Astragalus leptaleus typically grows in sedge-grass meadows, swales and hummocks, and among streamside willows (Fertig 1999). Reports from both Idaho and Colorado suggest that *A. leptaleus* may often occupy the ecotone between soils saturated with water throughout the growing season and adjacent dry uplands (**Table 2** and **Table 3**; Moseley 1991).

Astragalus leptaleus occurs on loamy, often calcareous soils. Plants typically grow on level to gently sloping ground with no aspect favored. Collections have been made at elevations between 884 m to just over 2,900 m (**Figure 4**). The lowest elevations where plants have been found are in Montana. All known occurrences within Region 2 are above 2,340 m. Descriptions of the habitat encountered at each occurrence, as reported by the collector or observer, are included in **Table 2** and **Table 3**.

The most detailed habitat information is from Idaho, but no critical habitat models have been developed. Habitat information gathered in geographic locations distant from the area of interest should be considered only at a general level when developing a search image for *Astragalus leptaleus* in Region 2. Habitat information from Idaho may not apply to evaluating potential habitat in Wyoming and Colorado.

In Idaho, several habitat descriptions indicate that *Astragalus leptaleus* grows in relatively drier microsites within riparian zones or wet meadows. Often, it grows in the ecotone between wetlands with standing water or wet meadows that are dominated by *Poa pratensis* or *Juncus/Carex*, and adjacent upland communities. The community types that include *A. leptaleus* are willow-Kentucky bluegrass (*Salix geyeriana-Poa pratensis*), riparian willow (*S. geyeriana-S. boothii*), and tufted hairgrass (*Deschampsia caespitosa*). *Astragalus leptaleus* occurs in meadows within the sagebrush/bunchgrass zone and adjacent to the Douglas-fir (*Pseudotsuga menziesii*) zone in Idaho (Henderson and Caicco 1983). Plants have mostly been reported from open sites but also from partially shaded sites. Hummocks are common habitat features in both Idaho and Montana. In Idaho, soils have been described as alkaline, probably calcareous, clay-like, high in organic matter, moist to saturated at the surface, silty textured, and alluvial. The most detailed description of the soil in Montana indicated that *A. leptaleus* plants grew in alkaline peat (MT-1 in **Table 3**).

Astragalus leptaleus occurs in the montane life zone in Colorado and Wyoming, which includes National Forest System lands in Region 2. The montane zone occurs between about 6,000 and 9,000 feet and is generally divided into an upper and lower zone. This zone is characterized by woodlands of *Pinus ponderosa* (ponderosa pine) and *Pseudotsuga menziesii* (Douglas-fir), which frequently alternate; *Pinus ponderosa* dominates on lower, drier, more exposed slopes, and *Pseudotsuga menziesii* is dominant in higher, more

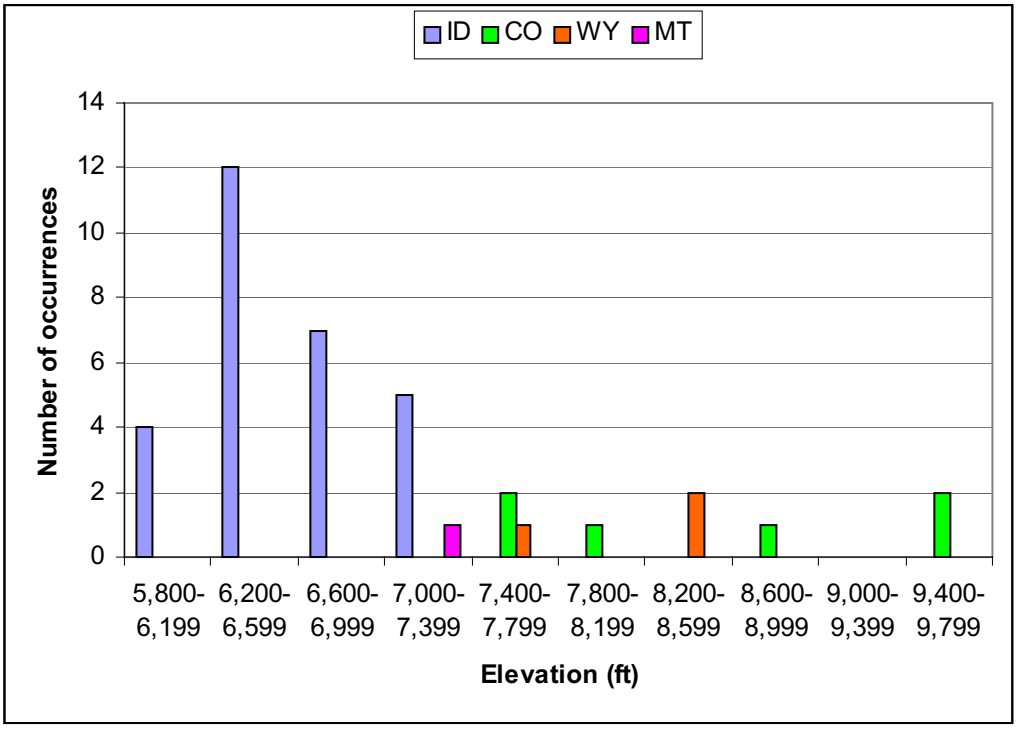

Figure 4. Graphic representation of the elevation distribution of *Astragalus leptaleus* occurrences. The data do not include estimates for occurrences where elevation was not reported.

moist, and more sheltered areas (McNab and Avers 1994). Fire is important to maintaining open canopies and grass understory. The lack of *A. leptaleus* occurrence information in Colorado and Wyoming does not allow a thorough assessment of habitat, but it appears to grow in sites that are comparable to those in Idaho and Montana. In Colorado, *A. leptaleus* has been found in four areas similar to its habitat in Idaho: "edge of wet meadows dominated by *Juncus ater*" (CO-11 in **Table 2**), in a "grassy area just next to wet gully" (CO-11 in **Table 2**), "at a meadow's edge with *Pinus*" (CO-7 in **Table 2**), and it was "frequent in the moist roadside areas" (CO-13 in **Table 2**). It has also been reported in an aspen grove, in wetlands, and at seeps. One record (CO-18 in **Table 2**) describes it growing with *A. agrestis* (purple milkvetch) in "a grassy old field" (Barrell 1969). This description at first appears to be somewhat atypical habitat. However, the site is likely to have substantial amounts of available water because *A. agrestis* is also mesophytic. The only specific soil information available in Colorado is that it was found on an alluvial terrace along a stream, which is similar to some occurrences in Idaho.

Range-wide habitat information suggests that *Astragalus leptaleus* is an obligate wetland species ("OBL?" in USDA Natural Resources Conservation Service 2005). Obligate Wetland species (OBL) are defined as those taxa that "occur almost always (estimated probability >99 percent) under natural conditions in wetlands" (U.S. Fish and Wildlife Service 1996).

Reproductive biology and autecology

Astragalus leptaleus flowers from June to August. The timing is influenced by elevation (Lesica and Shelly 1991) and probably latitude. The taxon has small ("tiny" in Hu et al. undated), inconspicuous flowers that are often hidden by foliage. There are few flowers per stem, and a former name, *A. pauciflorus*, is particularly appropriate because it means "few-flowered *Astragalus*".

The reproductive system of *Astragalus leptaleus* has not been studied. Considering other *Astragalus* species, the flowers may be self- or cross-pollinated, or both. Some authors have proposed that rare species have higher levels of auto-fertility and lower-levels of open pollination than do common species (Geer and Tepedino 1993). In fact, several rare species of *Astragalus* are self-fertile and are less dependent upon pollinator activity for successful fruit set compared to some of their widespread congeners (Karron 1987a, Karron 1991). It should be noted that the converse is

not true and that some widespread *Astragalus* species also exhibit a high degree of self-fertility. Where cross-pollination occurs, *Astragalus* species are generally insect-pollinated (Geer and Tepedino 1993). Bilaterally symmetrical flowers, such as those of *A. leptaleus*, are frequently pollinated by medium to large polylectic bees in the genera *Bombus*, *Osmia*, and *Anthophora* (Karron 1987b). When a bee lands on the keel and inserts its head under the banner, the keel is depressed and pollen is deposited on the anterior ventral surfaces of the bee (Green and Bohart 1975). Although the bees themselves remove much of the pollen, pollen on hairs and crevices in the head are available for cross-pollination.

The ability to self-pollinate is especially important to small populations of a species primarily pollinated by bees because bees, unlike many other flower visitors, are density-dependent foragers and will avoid areas where the reward is potentially low (Heinrich 1976, Thomson 1982, Geer and Tepedino 1993). The size and density of a mat or patch of flowers may influence the frequency with which cross-pollination occurs. Bumblebees appeared to preferentially visit large, rather than small, clumps of *Astragalus canadensis* in an Iowa prairie (Platt et al. 1974). Where there are small populations of *A. leptaleus* separated by relatively large distances, pollinators may be especially limited because *A. leptaleus* tends to have few and inconspicuous flowers.

Astragalus species are recognized for their rapid development of autogamous lineages where pollinators are unreliable (Kalin Arroyo 1981). It appears unlikely that the mesic conditions associated with *A. leptaleus* habitat would contribute to unreliable arthropod populations, but the relative attractiveness of other associated species, such as more showy clovers (*Trifolium*) and golden banner (*Thermopsis*), suggests that *A. leptaleus* may be under-visited. In summary, studies of other rare *Astragalus* species and the flowering habit of *A. leptaleus* suggest that the species is likely to be self-pollinated at least to some extent, but the possibility that it relies on cross-pollination for sexual reproduction cannot be discounted without further study.

The unilocular pods of *Astragalus leptaleus* are persistent or slow to disarticulate at the pedicel (Isely 1985). Therefore, they likely lose at least some of their seeds before dropping from the plant in the fall. Seed dispersal may be localized around the parent plant. This characteristic, and its rhizomatous growth habit, may explain the patchy nature of this species' distribution. Wind, water, arthropods, and small mammals may also play a role in seed dispersion. Wind is likely to only disperse seeds short distances (Silvertown 1987). Dispersal by water may be important in riparian locations. Rodents often cache fruits and can also contribute to short-distance dispersal.

There are no data on the longevity of seed or seed bank dynamics for *Astragalus leptaleus*. Many members of the family Fabaceae have a hard, impermeable seed coat that needs to be scarified or otherwise ruptured before germination can occur (Spellenberg 1976, Bewley and Black 1982). Such an impermeable seed coat imposes a form of dormancy that may confer some tolerance to wildfire (Whelan 1997). The degree of seed predation for this species is unknown.

Astragalus leptaleus typically forms loose mats. The paucity of flowers and fruits and the plant's spreading growth habit suggest that plants allocate most of their resources to vegetative growth and individual survival rather than to sexual reproduction. Species with a similar life form and regenerative strategy are characterized as having a stress tolerant-competitive or competitive strategy by Grime et al. (1988) or as a "K-selected species" with a long life span in relatively stable habitats, by MacArthur and Wilson (1967).

Demography

Astragalus leptaleus occurs either individually or in clusters composed of fewer than ten to several hundred individuals. It forms loose mats, and many stems may represent one individual. However, adjacent stems are also likely to arise from independent seed germination events since when seeds are produced, dispersal is limited. The other parameter that affects population structure and growth is the annual length of rhizome growth. This parameter also significantly influences the rate of recovery after disturbance.

Figure 5 is a simple lifecycle diagram for *Astragalus leptaleus*. The development of underground stems may be essential for establishment and persistence in moist habitats where competing vegetation can be dense. Population growth by clonal propagation reduces the need for frequent successful seed production and seedling recruitment; vegetative expansion is a common strategy of stress-tolerant plants (Grime et al. 1988). However, the relative importance of seed production, seedling recruitment, and vegetative expansion to the life history of *A. leptaleus* is unknown. Seedlings have not been reported at any of the occurrences, but that could be because they were either not seen or not identified.

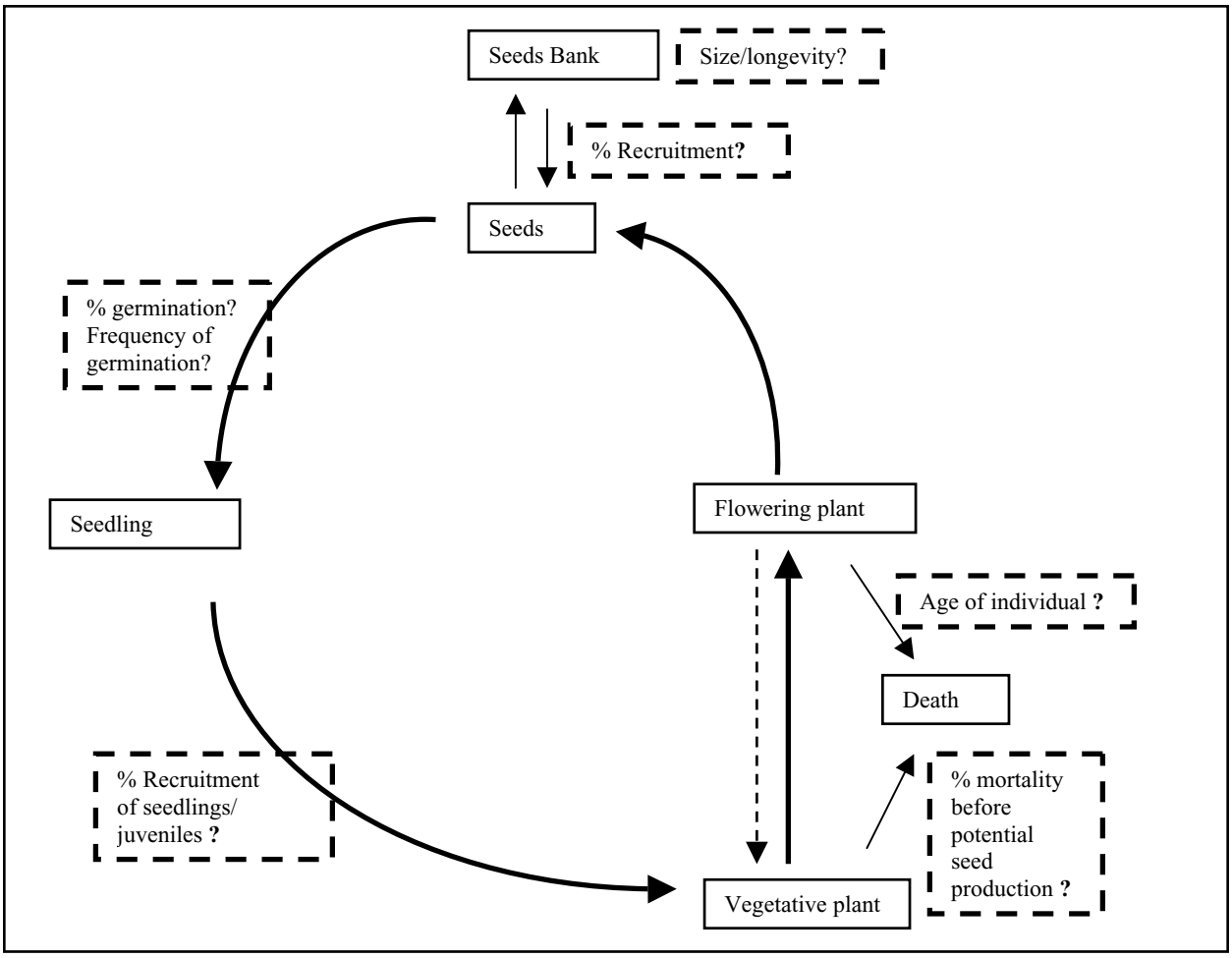

Figure 5. A diagram of the probable life cycle of *Astragalus leptaleus*. The dashed boxes indicate the unknown variables associated with the hypothesized life cycle.

There have been no demographic studies or analyses of population viability for *Astragalus leptaleus*. Barneby (1964) and Isley (1998) observed that this species is rhizomatous. Therefore, multiple stems that appear to be unrelated above ground can actually belong to the same plant. This condition can lead to an overestimation in the potential for genetic diversity within a population and may also confound population viability analysis (Menges 1991). Minimum population viability (MVP) analysis can take two approaches. Genetic analyses may be based on the minimum sustainable numbers of genetic individuals or genets, while a demographic-based approach may consider the minimum viable number of ramets (Menges 1991). It may be appropriate to consider the "minimum" number of physiologically independent ramets in short-term population viability analyses, but understanding the distribution of genetic variation may be most important in assessing long-term evolutionary potential (Menges 1991). Demographic studies that incorporate stage-structured transition models and elasticity analyses are especially useful when comparing the importance of different life stages and strategies, such as recruitment or adult survivorship, which can change depending upon the conditions experienced by different populations (Caswell 1989, Silvertown et al. 1993). Although the results must be interpreted with care, such studies assist in evaluating the vulnerability of the different life stages to management practices or to different environmental conditions (Mills et al. 1999).

Rhizomatous growth forms can also be difficult to work with because destructive sampling may be necessary in order to determine growth habit and population structure. Destructive sampling is inappropriate if the species is rare and the occurrences are small. However, studies can be accomplished on rhizomatous species and valuable information collected (Menges 1991, Silvertown et al. 1996, Berg 2002). Over several growing seasons, the demographics in

three populations of the clonal, cleistogamous herb *Oxalis acetosella* (family Oxalidaceae) were studied to assess the impact of seedling recruitment relative to ramet recruitment on its population dynamics (Berg 2002). In this case seedling recruitment was found have the most impact.

The local abundance of *Astragalus leptaleus* is highly variable, and limits to its population growth are not well defined. In Idaho, several sites occur in a sharply defined ecotone between waterlogged sites and adjacent dry habitats. This suggests that occurrences are primarily restricted by substrate and hydrologic conditions. The role of competition in limiting population expansion is not known.

Community ecology

Astragalus leptaleus typically grows in, or at the edge of, sedge-grass meadows, swales and hummocks, or streamside willows (**Table 2** and **Table 3**). It is generally associated with *Juncus* and mesophytic grasses. Specific plant taxa associated with *A. leptaleus* are listed in **Table 5**. This is not an exhaustive list but includes the species mentioned in the source documentation (**Table 2** and **Table 3**).

Since *Astragalus leptaleus* grows in densely vegetated areas, it is likely to tolerate some degree of inter-specific competition. Additionally, its ability to spread vegetatively suggests that it could be quite competitive. *Astragalus leptaleus* is associated with *Thermopsis montana* in some occurrences in Montana and Idaho. *Thermopsis montana* is generally not, or only lightly, grazed by livestock and becomes more abundant under heavy livestock pressure (USDA Forest Service 1988). In contrast, livestock do make use of *A. leptaleus* (Moseley 1992). It is possible that *T. montana* plants serve as refugia for *A. leptaleus* by providing protection from grazers. Alternatively, the association may be due to mutually favorable microsite characteristics for germination and/or seedling development. A third possibility is that the stands of *T. montana* have developed around existing patches of *A. leptaleus* and the association is merely a consequence of high numbers of *T. montana*.

Not withstanding its adaptation to a densely vegetated community type, *Astragalus leptaleus* may be at risk from inter-specific competition by aggressive invasive plants such as whitetop (*Cardaria draba*) and Canada thistle (*Cirsium arvense*). These weedy species can physically out-compete slow growing, low seed-producing plants. For example, a single individual of whitetop can produce more than 450 shoots and up to 4,800 seeds in one year (Sheley and Stivers 1999). Since *A. leptaleus* stems are rarely abundant and each stem produces only few flowers, it appears to have a low potential for abundant seed production. Therefore, this species is unlikely to be able to compete with this type of weed. Also, the rate of underground stem extension is unknown, but the few stems observed at some occurrences suggest that it is not an aggressive colonizer. Other aggressive weeds such as musk thistle (*Carduus nutans*) and knapweeds (*Centaurea* spp.) are allelopathic and create an unfavorable edaphic environment for native species (Sheley and Petroff 1999, Inderjit 2005). Whitetop and Canada thistle have been observed near *A. leptaleus* occurrences in Idaho (**Table 3**). Both species grow in moist soils (Sheley and Petroff 1999).

Livestock graze *Astragalus leptaleus* (Moseley 1992). Gray (1863a) and Barneby (1964) reported that it affords palatable forage. There are indications that livestock grazing can have detrimental effects; especially on the sexual reproduction of this species since fruit production appeared to be inhibited by livestock grazing (Caicco and Henderson 1981, Moseley 1992). When compared with ungrazed sites, flowers and fruits tended to be fewer at grazed sites (Moseley 1992). Three consecutive visits were made to occurrence ID-19 in Idaho during the growing season of 1981, and those observations exemplify the likely impacts of grazing. On the first visit many plants had flowers, but on the return trip a month later very few fruits had been produced (Caicco and Henderson 1981). In the intervening time the site had been moderately trampled by cattle and also by the passage of a flock of sheep. No fruits were found during a third visit in the last week in August (Caicco and Henderson 1981). By this time, the site had been heavily trampled by livestock, which tend to congregate in moist areas late in the growing season (Caicco and Henderson 1981). Although significantly less flower and fruit production appears to be a result of recurrent livestock grazing, populations can otherwise appear dense and vigorous (Moseley 1992). However, this is not a universal situation. Among several populations within Birch Fen in Idaho, the small occurrence that was the most heavily grazed also had the lowest vigor of any occurrence known in the region (Moseley 1992). This occurrence was reported to be near a spring and thus may have received more trampling than most sites. Sheep may be particularly damaging herbivores, not only because they tend to graze a plant down to ground level but also because they can interact negatively with bee pollinators. Sugden (1985) reported that sheep grazing in the habitat of *A.*

Table 5. Species reported to be associated with *Astragalus leptaleus*.

State	Species	State	Species
ID	*Achillea millefolium*	ID	*Haplopappus uniflorus*
ID	*Agropyron dasystachyum*	ID	*Hesperochiron* spp.
ID	*Agropyron repens*	ID	*Hordeum brachyantherum*
ID	*Agropyron smithii*	ID	*Hordeum jubatum*
ID	*Agrostis stolonifera*	ID	*Iris missouriensis*
ID, MT	*Allium schoenoprasum*	CO	*Juncus ater*
ID	*Alnus incana*	ID	*Juncus balticus*
ID	*Antennaria anaphaloides*	ID	*Juncus tenuis* (tentative identification)
ID	*Antennaria microphylla*	ID	*Muhlenbergia richardsonis*
ID, MT	*Antennaria pulchella*	ID	*Oxytropis deflexa*
ID	*Aquilegia formosa*	ID	*Oxytropis viscida*
ID	*Aster ascendens*	ID	*Pedicularis groenlandica*
ID	*Aster occidentalis*	CO	*Pinus* spp.
ID	*Aster* spp.	ID	*Poa pratensis*
CO, ID	*Astragalus agrestis*	ID	*Polygonum vivipara*
ID	*Astragalus alpinus*	CO	*Populus tremuloides*
ID	*Astragalus eucosmus*	ID	*Potentilla fruticosa*
ID	*Betula glandulosa*	ID	*Potentilla gracilis*
ID, MT	*Betula occidentalis*	ID	*Ribes niveum*
ID	*Cardaria draba*	ID	*Rosa woodsii*
ID, MT	*Carex lanuginose*	ID, MT	*Salix boothii*
ID, MT	*Carex nebrascensis*	ID, MT	*Salix brachycarpa*
ID	*Carex praegracilis*	ID	*Salix geyeriana*
ID	*Carex* ssp.	ID	*Salix planifolia*
ID, MT	*Carex utriculata*	ID	*Salix* spp.
ID	*Chrysothamnus nauseosus*	ID	*Sarcobatus vermiculatus*
ID	*Cirsium arvense*	ID	*Scirpus americanus*
ID	*Cirsium scariosum*	ID	*Senecio debilis*
ID	*Deschampsia caespitosa*	ID	*Sisyrinchium idahoense*
ID	*Distichlis stricta*	ID	*Smilacina stellata*
ID	*Dodecatheon* spp.	ID	*Thalictrum alpinum*
ID	*Eleocharis rostellata*	ID	*Thelypodium sagittatum*
ID	*Eleocharis pauciflora*	ID, MT	*Thermopsis montana*
ID	*Erigeron lonchocarpa*	ID, MT	*Trifolium longipes*
ID	*Erigeron lonchophyllus*	ID	*Trifolium repens*
ID	*Erigeron peregrinus*	ID	*Trifolium* spp.
ID	*Geum macrophyllum*	ID	*Zigadenus elegans*
ID	*Glaux maritima*	ID	*Zizia aperta*
ID	*Haplopappus* spp.		

monoensis, a perennial species endemic to California, endangered the bee pollinators by destroying potential and existing nest sites and removing food resources. There is no information on the palatability of *A. leptaleus* to herbivorous arthropods or rodents.

Aliphatic nitro-compounds are accumulated by many *Astragalus* species (Stermitz et al. 1972, Williams and Barneby 1977, Stermitz and Yost 1978, Niknam et al. 2003). Some forms of these accumulated nitro-compounds are catabolized to extremely toxic

compounds by ruminants while others are less poisonous. Levels of generic aliphatic nitro-compounds are usually determined to make an initial evaluation of potential *Astragalus* toxicity. Later, more detailed analyses can determine the specific chemical structure. When part of a dried *A. leptaleus* herbarium specimen from Gunnison County, Colorado (CO-13 in **Table 2**) was analyzed for aliphatic nitro-compounds, it was found to contain approximately 14 to 19 mg NO_2/g of dry plant tissue (Williams and Barneby 1977). This is not a high level of nitrite to occur in *Astragalus* species, especially if it occurs as the less toxic forms of aliphatic nitro-compounds. Because *A. leptaleus* appears to be readily used by herbivores, the nitro-compounds that it contains are likely of low toxicity. However, when evaluating the potential toxicity of *Astragalus* species, it needs to be noted that there are also seasonal variations in aliphatic nitro-compound levels related to growth stage (Williams and James 1978). In addition, many nitrogenous secondary plant compounds are influenced by environmental conditions (Ladyman et al. 1983). Therefore palatability and toxicity can change according to both the time of year and the environment of the area in which the *Astragalus* grows.

Evidence of rhizobial or mycorrhizal associations with the root system has not been documented. Rhizobial association is likely since *Astragalus alpinus*, a closely related species, was reported to be nodulated (Allen and Allen 1981). This association with nitrogen-fixing bacteria would provide an important source of nitrogen to the soil environment, as well as directly to *A. leptaleus*.

Herbarium label data usually report *Astragalus leptaleus* as being in open or only partially shaded areas. It is not known how populations respond to canopy closure. Even though generally mesic, the environment in which *A. leptaleus* grows suggests that it is adapted to periodic fire. Fire is one of the primary ways that forest openings are maintained (Oliver and Larson 1996). However, there is no information to predict *A. leptaleus*' response to fire (Oliver and Larson 1996). The intensity, frequency, extent, and season of fire are all important parameters. *Astragalus leptaleus* may be a "fire evader", escaping the negative effects of fire by storing rhizomes and seeds in the soil (Lyon and Stickney 1976, Whelan 1997). However, its wet-soil habitat may make rhizomes more susceptible to damage by fire than if it grew in drier sites. Although soil is typically a good insulator, moist soil reaches a higher peak temperature more rapidly than air-dry soil at a given depth (Whelan 1997).

The specific pollinators of *Astragalus leptaleus* are not known, but members of the Hymenoptera (particularly bees) often pollinate *Astragalus* species. The frequency of cross-pollination among patches of *A. leptaleus* plants is not known, and many factors can influence pollination success. There is potential for cross-pollination between plants located relatively far apart since bees will fly long distances from their hives to forage. Osborne et al. (1999) tracked individual bumblebees using harmonic radar and recorded that most bees regularly fly more than 200 m (range 70-631 m) from the nest to forage even when food was ostensibly plentiful nearby. Honeybees regularly forage 2 km away from their hive (Ramsey et al. 1999). Although not documented, there may be other arthropods that interact with *A. leptaleus*. Some *Astragalus* species host the larval stages of certain butterfly species (Scott 1997). The extent of seed predation is also unknown. Although appearing superficially detrimental, seed predation by arthropods is not necessarily bad at levels under which the species has evolved and may be important to the long-term sustainability of the species. In fact, seed predation may have had an important influence on population dynamics and diversity within the genus *Astragalus* (Green and Palmbald 1975, Mancuso and Moseley 1993).

An envirogram is a graphic representation of the components that influence a species and reflects its chance of reproduction and survival. Envirograms have been used extensively to describe the conditions of animals but may also be applied to describe the condition of plant species (Andrewartha and Birch 1984). Those components that directly affect *Astragalus leptaleus* make up the centrum, and the indirect components comprise the web (**Figure 6** and **Figure 7**). Unfortunately, there is very little information on which to build a detailed envirogram for *A. leptaleus*. The envirogram in **Figure 6** summarizes some of the resources that affect the species. The more uncertain factors are presented in dashed boxes.

CONSERVATION

Threats

Range-wide, the major threats to *Astragalus leptaleus* are related to large-scale habitat modification, such as development projects or meadow conversion for hay production (Jacobs et al. 1993, Coles 2002). Without suitable habitat, the species is unlikely to persist. Local threats include livestock grazing, invasive non-native plant species, off-highway vehicle use, road building,

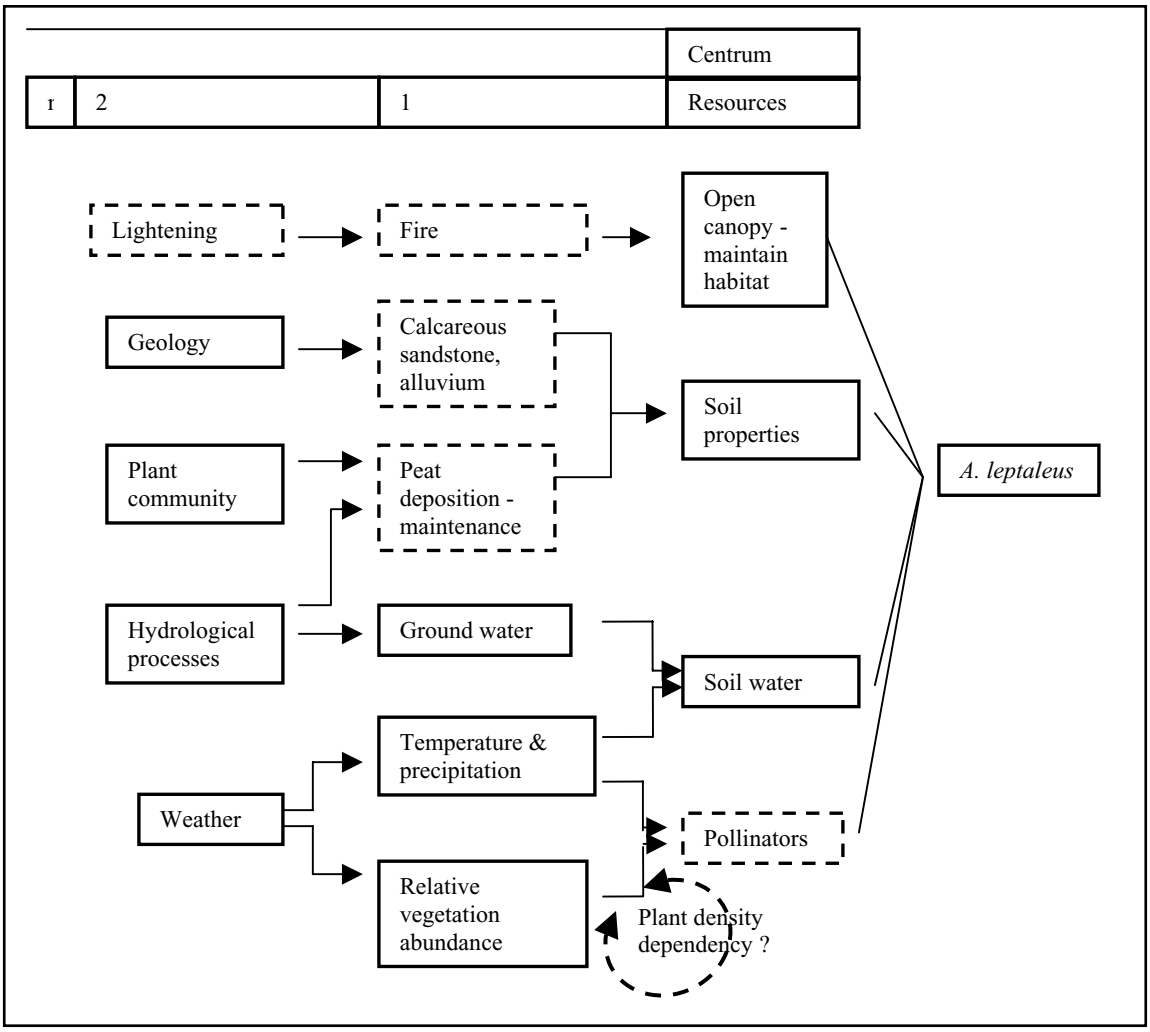

Figure 6. Envirogram of factors that may act as resources to *Astragalus leptaleus*. The dashed boxes indicate that the resource is speculative. For example, *A. leptaleus* appears to require open conditions, but whether the habitat is maintained by fire is uncertain.

and resource development. All of these activities have resulted in habitat degradation, fragmentation, and in some cases total loss. According to NatureServe (2005b), all known occurrences on National Forest System lands are "subject to trampling and grazing, and also fishing and camping vehicle traffic." Environmental stochasticities, including those related to global climate change, may also be a threat.

Each threat, or potential threat, is discussed briefly in the following paragraphs. There is so little information concerning the distribution or abundance of *Astragalus leptaleus* on lands managed by the USFS in Region 2 that the level of threat to specific occurrences cannot be discussed in detail. Also, the lack of information regarding this species' response to management activities makes it difficult to evaluate individual threats to *A. leptaleus*. However, all the threats mentioned in the following paragraphs are potentially applicable to occurrences on National Forest System lands in Region 2.

Meadow conversion and resource development

Wet meadows in the Rocky Mountains have commonly been used for annual hay production (Taylor et al. 1985, Jacobs et al. 1993), and this use has likely contributed to the loss of *Astragalus leptaleus* habitat (Coles 2002). Meadows converted to hay production typically are dominated by non-native pasture grasses such as timothy, Kentucky bluegrass, and smooth brome (Mortvedt et al. 1995, Coles 2002). In order to increase hay production, the meadows are often fertilized with nitrogen (Taylor et al. 1985, Jacobs 35 al. 1993, Mortvedt et al. 1995), and fertilizer generally favors exotic species over native species (Wolf et al.

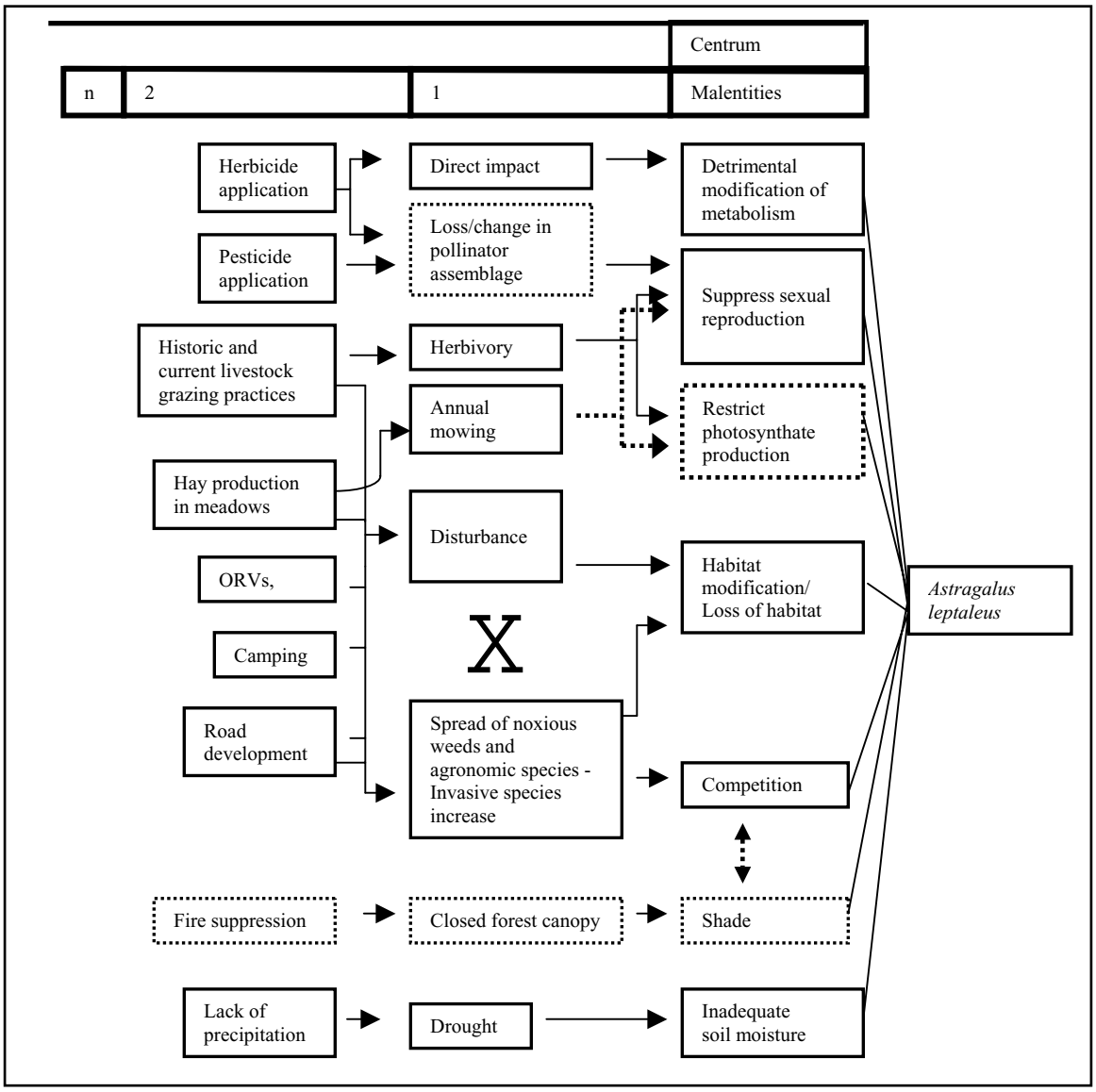

Figure 7. Envirogram of some current and historic threats and malentities to *Astragalus leptaleus*. The dotted lines indicate threats and malentities that are speculative. The potential for interaction between disturbance and increase in invasive species is marked by "X."

2003). Herbicides such as 2,4-D are used to control undesirable or poisonous forbs (Eckert et al. 1973). Such herbicides are relatively non-specific and can also kill *A. leptaleus*.

Astragalus leptaleus was reported to be "quite common" in South Park, Colorado in 1862 (Gray 1963a). This grass-dominated basin includes a network of streams and wetlands that provide habitat for several rare plant species and communities (Spackman et al. 2001). Potential habitat for *A. leptaleus* is likely to have been degraded or lost since the region has been impacted significantly by residential, agricultural, and commercial developments and most of the streams are used to support irrigation (Spackman et al. 2001). Almost 20 percent of the extremely rich fens in the area have been lost to peat mining (Sanderson and March 1996). In addition, placers were mined in the Fairplay district in northwestern South Park, and large dredges were used during the peak activity in the 1930s (Kirkemo 1991). The extent to which such activities affected *A. leptaleus* or will affect it in the future is not documented. Peat mining is now discouraged in Colorado (Hoelter 2002), and there is a currently no active peat mining in Park County (U.S. Fish and Wildlife Service 2005). Placer mining still occurs in the

area, but at a lower level than historically (U.S. Fish and Wildlife Service 2005).

Additional evidence of habitat loss within South Park comes from a recent study of BLM lands (Culver 2004). Thirty-one BLM parcels that included fens, wetlands, and meadows were surveyed during 2003 and 2004 to assess whether the wetlands were in Proper Functioning Condition (Culver 2004). Proper Functioning Condition was evaluated according to the BLM (1994, 1998) Process for Assessing Proper Functioning Condition for Lotic and Lentic Riparian-Wetland Areas (Culver 2004). Twenty-nine percent of the parcels (a total of approximately 498 acres) were determined to be in Proper Functioning Condition whereas 71 percent of the parcels (a total of approximately 283 acres) were either Functioning At Risk with a downward trend or were Nonfunctional (Culver 2004). The potential for spontaneous peatland recovery is very low since many peat-mined areas show little natural re-colonization by fen species even after 40 years (Cooper and MacDonald 2000). Wetland status information is not available for the Pike National Forest, which manages approximately 80 square miles on the east side of South Park (as delineated by Sanderson and March 1996).

Livestock grazing

Astragalus leptaleus habitat is used, often intensively, for livestock grazing (Knight 1994). In Idaho, the majority of occurrences experience some degree of livestock grazing (Moseley 1991, 1992). *Astragalus leptaleus* is palatable to herbivores, and moderate to heavy grazing activity has been correlated with the production of fewer flowers and fruits. On the other hand, at least in the short term, occurrences apparently persist in the presence of livestock grazing (Moseley 1991, 1992). This is likely to be because annual reproduction and recruitment are probably not paramount to the survival of this perennial species. However, source-sink paths can vary over a growing season, and the timing as well as the amount of herbivory may influence growth, not only in the current year but also the extent to which effects are carried over to subsequent reproductive seasons (García and Ehrlén 2002).

No information is available regarding the long-term effects of grazing. There is also no information on how grazing affects plant size. In many species, larger plant size indicates a competitive advantage (Menges 1991), and size rather than age has been reported to be a better predictor of success (Frankel et al. 1995). One may consider that plant species such as *Astragalus leptaleus* that grow within riparian communities evolved with herbivory by large native mammals. However, these plants did not necessarily evolve mechanisms to resist the impacts of trampling and extended periods of mammalian herbivory. Even in historical times, elk and deer may only have briefly browsed areas in which *A. leptaleus* grew. It has been reported that in the presence of top predators such as wolves, herbivorous prey animals forage differently (Fascione 2003). When predators are absent, elk are similar to cows in that they spend more time browsing along riversides, trampling vegetation, and inhibiting new growth. With wolves present, elk spend more time in open areas (Fascione 2003).

Invasive species

There is no specific information on the past or potential impact of invasive species on *A. leptaleus* on National Forest System lands in Region 2. Invasive species, such as sweet yellow clover (*Melilotus* spp.) and white clover (*Trifolium* spp.), used in restoration and hay production projects could pose a competitive threat to *Astragalus leptaleus* occurrences outside, as well as within, modified habitat (Wolf et al. 2003; Community Ecology section). The impact of aggressive, invasive alien plant species on *A. leptaleus* has not been documented. Whitetop and Canada thistle are well established in the riparian zone near at least one *A. leptaleus* occurrence in Idaho (ID-9 in **Table 3**). Determining the impact of these weeds on this occurrence would be helpful in evaluating the potential threat of invasive species range-wide. Livestock, vehicles, and recreation activities contribute to the spread of invasive weed species. Once weed species arrive, they have vigorous colonizing potential and a high reproductive capacity that permits them to dominate and persist (Cousens and Mortimer 1995).

Disturbance

The importance of the root system for the long-term persistence of *Astragalus leptaleus* suggests that activities that disturb or compact the ground surface and/or lead to soil erosion are detrimental to this species. These activities include off-road-vehicle traffic and heavy livestock grazing. Camping is common alongside rivers and streams throughout the species' range. Even though this is a relatively low-impact activity, associated vehicles have led to habitat damage in Idaho (Caicco and Henderson 1981). In Idaho, the size of an *A. leptaleus* occurrence was reduced by as much as one-third by vehicle tracks that appeared to

be primarily used by campers (Caicco and Henderson 1981). There is no information to indicate how such disturbance has affected specific occurrences of *A. leptaleus* on National Forest System lands in Region 2. It has been observed that all known *A. leptaleus* locations on National Forest system lands are subject to trampling and grazing, and also fishing and camping vehicle traffic (NatureServe 2005b).

Road building and road widening activities have probably impacted some occurrences both in Idaho (Moseley 1991) and in Colorado, where one of the occurrence locations (CO-7 in **Table 2**) was described as "roadside." The current status of this occurrence is unknown. Moseley (1991) reported that roads had affected several Idaho occurrences in the past, but the full extent of the impact was unknown because the habitat was already damaged when the occurrences were found. Road maintenance practices, such as herbicide use and mowing, probably affect *Astragalus leptaleus* occurrences that are adjacent to roads. Mowing is unlikely to have any short-term impacts. In contrast, annual mowing during the growing season may eliminate seed production and so may have detrimental long-term consequences. In addition, the repeated removal of photosynthetic parts of the plant may ultimately weaken the root system because of decreased nutrient input. The level at which aerial plant parts can be removed by either mowing or herbivore use without the plant sustaining irreversible damage is unknown.

Road construction, intensive livestock grazing, and placer mining have also led to stream incision and reduced bank and channel stability throughout the range of *Astragalus leptaleus* (May and Rose 1986, Armour et al. 1991, Clary 1999). The extent to which these factors may have led to degradation of *A. leptaleus* habitat is also unknown, since there is so little information on past and current abundance or distribution of this species.

Fire

The potential for interaction between the consequences of fire and herbivory has not been examined for *A. leptaleus*. Considering the species' habitat and life history, fire is not perceived to be a significant threat and may be beneficial. Benefits of fire include removal of competing vegetation and overstory that may shade *A. leptaleus*. An indirect consequence of fire that negatively affects palatable species is that herbivores tend to congregate on patches where vegetation has recently burned (Whelan 1997). Re-growing shoots are typically protein-rich after a fire and attract herbivorous insects and mammals. This is especially pertinent in areas where prescribed burns cover small areas. The subsequent regrowth of herbaceous vegetation in small areas will attract herbivores, increasing the pressure on palatable species.

Tree canopy cover

Astragalus leptaleus appears to be restricted to open meadow and partially shaded communities, and thus canopy closure may be detrimental. The policy of total fire suppression practiced during the last 60 years may have contributed to loss of habitat by allowing increased tree cover (Knight et al. 2000). Livestock grazing also contributes to tree encroachment and canopy closure in wet meadows (Murray 1997, Knight et al. 2000). Livestock can disturb vegetation cover by cutting through the roots and exposing bare soil, which is conducive to tree seedling establishment at the expense of native forbs (Dunwiddie 1977). In addition, grazing can lead to soil loss and to the drying out of wet meadows by altering the hydrology and by increasing erosion. However, cessation of grazing can also result in a rapid recruitment of tree seedlings (Oliver and Larson 1996). Although logging may open up the tree canopy, the associated soil disturbance may be detrimental to herbaceous root systems. Such activities may have the least detrimental impact if carried out in the winter when the ground is frozen. It is unknown what impacts canopy closure has had on specific occurrences in Region 2 since there is so little information on occurrences of *A. leptaleus* on National Forest System lands.

Stochasticity

In addition to threats associated directly or indirectly with human activities, there are uncertainties that can only be addressed by maintaining an adequate number of viable populations. These uncertainties are typically described using population viability analysis (Demography section) and include elements of demographic stochasticity, genetic stochasticity, environmental stochasticity, and natural catastrophes (Shaffer 1981). The influences of the different types of stochasticity on *Astragalus leptaleus* may only be surmised because of the lack of supporting quantitative data.

Demographic stochasticity

Demographic stochasticity refers to chance (random) events independent of the environment that affect the reproductive success and survival of

individuals within a fixed population. For example, individuals vary in the number of progeny that they can produce. Where occurrences of *Astragalus brevistyla* are *sm*all, for example less than 50 individuals, demographic uncertainty is likely to be important (Pollard 1966, Keiding 1975). In very small populations, individuals have a proportionally greater influence on the survival of the whole population. The number of genetic individuals of *A. leptaleus* is difficult to judge because of its spreading growth habit; one cannot be sure that a population of abundant aerial stems is substantially more genetically diverse than a smaller population.

Genetic stochasticity

Genetic stochasticity is associated with random changes in the genetic structure of populations due to phenomena such as inbreeding and founder effects. No studies have been undertaken to determine the genetic diversity of *Astragalus leptaleus*, either in individual occurrences or across the entire range. The growth habit of *A. leptaleus* indicates that the number of aerial stems does not necessarily reflect genetic diversity. Several biological and geographic factors may have led to homogeneous populations. If the species is predominantly self-pollinating and has relied on vegetative growth for sustainability, there may be exceptionally little genetic variation within populations. Local selection pressures acting on individual occurrences may have led to increased fitness to local conditions (Ellstrand and Roose 1987). The extreme case is that each occurrence is dominated by a single genotype. Because occurrences are isolated from one another, there is likely little genetic exchange among most of them.

For the same reasons, there may be a high degree of genetic variability among populations. Significant genetic differences were shown between two occurrences of the closely related taxon *Astragalus molybdenus* var. *molybdenus* (Lavin and Marriott 1997). This situation has special significance if transplanting or reseeding is considered. Locally endemic species of *Astragalus* tend to exhibit reduced levels of polymorphism (Karron 1991) that may also imply a reduced robustness against environmental uncertainty. Loss of heterozygosity is correlated with a substantial decrease in population fitness in many species (Reed and Frankham 2003). Frankham (2003) summarized both theoretical and empirical evidence that indicated that genetic changes in small populations are intimately involved with their fate. Loss of genetic diversity may contribute to plants being unable to respond to changes in biological or environmental conditions (van Noordwijk 1994) and is also often associated with inbreeding depression (Newman and Pilson 1997). However, while rare species can have statistically less genetic variation than their widespread congeners, there is a large range in values (Gitzendanner and Soltis 2000). In fact, some rare species exhibit levels of diversity equal to, or exceeding, that of widespread congeners (Gitzendanner and Soltis 2000). It is important to understand the genetic relationship among isolated occurrences because without genetic evaluation, it is difficult to assess the genetic vulnerability of *A. leptaleus*. Hybridization between *Astragalus* species is very rare in nature (Liston 1992, Spellenberg personal communication 2002). Therefore, it is unlikely that hybridization between sympatric species is a potential threat to genetic integrity.

Environmental stochasticity and natural catastrophe

Environmental stochasticity includes the random, unpredictable changes in weather patterns or in biotic members of the community (Frankel et al. 1995). Variation in precipitation is an example of specific environmental uncertainty that is likely to directly affect the survival and reproductive success of *Astragalus leptaleus*. Variable populations of arthropods (i.e., pollinators, herbivores, granivores), rodents, and other wildlife can also affect populations. The assemblage and abundance of pollinator populations can be especially critical to the seed production in many plant species (Bond 1995). There is no information on the importance of pollinators or other animal species in the life cycle of *A. leptaleus*. Flooding is an example of natural catastrophe. Occurrences along rivers and streams are vulnerable to scouring in years of heavy spring runoff. During the same season, sediment deposition in meadows alongside rivers after flooding may bury *A. leptaleus* plants. The consequences of burial would depend upon the depth and composition of the sediment.

Climate change is another facet of environmental stochasticity that could potentially affect *Astragalus leptaleus*. Global climate change may be a threat to all high elevation species. Warming could affect mountain habitats and cause tree lines to rise by roughly 350 feet for every degree Fahrenheit of warming. Mountain ecosystems would shift upslope, reducing habitat for many subalpine as well as alpine tundra species (U.S. Environmental Protection Agency 1997a). The potential to move into suitable habitat may be severely limited if *A. leptaleus* seed is dispersed over only short distances

(Reproductive biology and autecology section). Wetland species may be particularly vulnerable to the predicted warmer, drier conditions. In the last century, the average temperature in Fort Collins, Colorado, has increased by 4.1 °F, and precipitation has decreased by up to 20 percent in many parts of the state. The Hadley Centre's climate model (HadCM2) and the Intergovernmental Panel on Climate Change have projected that by the year 2100, temperatures in Colorado could increase by 3 to 4 °F in spring and fall, with a range of 1 to 8 °F, and 5 to 6 °F in summer and winter, with a range of 2 to 12 °F (U.S. Environmental Protection Agency 1997a). Similar predictions have been made for Wyoming (U.S. Environmental Protection Agency 1998b), Montana (U.S. Environmental Protection Agency 1997b), and Idaho (U.S. Environmental Protection Agency 1998a).

In one scenario of global climate change, there will be longer droughts punctuated by heavy rains (U.S. Environmental Protection Agency 1997a, 1997b, 1998a, 1998b). It is not clear how *Astragalus leptaleus* would tolerate warmer temperatures, but it is clear that as an obligate wetland species, it is ill-adapted to endure long droughts. The same manifestations of climate change may also have indirect effects. Long droughts punctuated by heavy rains can increase soil erosion (Feddema and Freire 2001, Jenkins 2005) and reduce populations of predators, such as owls and coyotes, so that rodents that may then become more abundant (Epstein 2000).

Atmospheric deposition of nitrogen oxides and ammonium are increasing throughout the world. The western United States has been less affected than the eastern states, but there are hotspots of elevated wet nitrogen (acid rain) deposition in southern California and along the Colorado Front Range when compared with the rest of the West (Barron 2001). Wet nitrogen deposition occurring in the high mountain areas of the Colorado Front Range is high enough to cause chemical and ecological changes (Baron et al. 2000, Baron 2001, Rueth and Baron 2002). There is the potential that an increase in the amount of nitrogen deposition will favor non-native species, which might have a detrimental impact on *Astragalus leptaleus*.

In summary, the impact of threats to *Astragalus leptaleus* is likely to depend on the extent, timing, and intensity of those threats. Even if the intensity of threats remains the same, an increase in their area of impact will have negative consequences. In addition, the potential colonization by invasive and competitive plant species that are typically exacerbated by anthropogenic disturbances and warming temperatures should not be underestimated. Malentities and threats to *A. leptaleus* are incompletely understood. Some of the known or potential threats and malentities are outlined in **Figure 7**.

Conservation Status of Astragalus leptaleus in Region 2

Even though relatively few collections of *Astragalus leptaleus* have been made over the last fifty years and the species grows in habitat that is subject to various and often extreme perturbations, it is perceived by NatureServe (2005a) to be Apparently Secure (G4). However, *A. leptaleus* has not been located in Wyoming since 1951, and there are relatively few occurrences in Colorado (**Table 2**). Only one Colorado collection appears to have been made within the last decade (1994; CO-6 in **Table 2**). Therefore, there is little evidence to suggest that it is secure, at least within that part of its range within Region 2. There are few known occurrences of this species on National Forest System lands. A large proportion of *A. leptaleus* habitat has likely been lost to meadow conversion, gold and peat mining, historic livestock grazing practices, and possibly fire suppression. However, information to perform an accurate analysis of its response to management decisions is unavailable. Habitat requirements are incompletely understood. Currently, potential habitat can only be described as habitat that from casual observation appears to be suitable for the species but which is not occupied by it. Using this uncritical definition, there is a great deal of suitable habitat within Region 2 that remains to be surveyed.

Astragalus leptaleus seed is not currently being banked although native seed collection efforts are currently being undertaken at a national level. Seeds of Success is an interagency program coordinated though the Plant Conservation Alliance that supports and organizes seed collection of native plants. Their goal is to increase the number of species and the amount of native seed that is available for use in stabilizing, rehabilitating, and restoring lands in the United States. The appropriateness of *A. leptaleus* as a species to include as a target in the Seeds for Success Program is debatable, but it does appear to fit two of the collection criteria; namely it is a "native species of known forage or browse value" and it is a "widespread regional endemic plant species whose distribution is limited to small area" (Seeds of Success 2005).

Management of Astragalus leptaleus in Region 2

Implications and potential

Inadequate knowledge of both the abundance and distribution of *Astragalus leptaleus* is a cause for concern. *Astragalus leptaleus* is an inconspicuous plant, and because it is commonly associated with dense grasses and conspicuous flowering forbs, it has been suggested that it is often overlooked. However, there is no real evidence to support this assumption. Ideally, support for this hypothesis would be documentation of negative surveys in particular areas where subsequent surveys discover occurrences.

Degradation of *Astragalus leptaleus* habitat has been substantial over the last century (Knight et al. 2000). Conversion of meadows to hay production results in substantial habitat modification (Jacobs et al. 1993). Other land use practices, such as livestock grazing, have led to drier, less suitable meadow habitats. It is possible that fire suppression has reduced this species' habitat in Region 2 and across its entire range. The impacts from timber sales are difficult to gauge. On the one hand, logging may reduce tree canopy and maintain habitat; alternatively, the associated soil disturbance and soil compaction may be detrimental to plant root systems. Aggressive, non-native species that are used in hay production and for reseeding disturbed sites may outcompete *A. leptaleus* and have had an adverse impact on some occurrences. Being palatable to mammalian herbivores also makes *A. leptaleus* biologically vulnerable; the levels of herbivory and disturbance that permit sustainable populations are unknown. In designated wilderness areas and established Research Natural Areas, livestock grazing and other anthropogenic activities are restricted, and maintaining biodiversity is a primary management goal. However, there are no known occurrences of *A. leptaleus* on any protected National Forest System land in Region 2.

Understanding the reproduction and physiology of *Astragalus leptaleus* is important when evaluating the impacts of habitat modification or loss. It is important to distinguish between whether *A. leptaleus* plants have been able to survive in situ, or re-colonize modified sites through seed dispersal from the surrounding communities. Barrell (1969) indicated that he had observed specimens in an "old field" (CO-18 in **Table 2**). This description could have been applied to an abandoned hay meadow. Sustainability and potential for re-colonization is likely to depend on the extent of the habitat modification and the availability of seeds and/or a pre-existing root system.

When *Astragalus leptaleus* occurrences are located, determining which have the most conservation value may be difficult. Other closely related *Astragalus* species exhibit significant genetic differences between populations. Small populations may be genetically depauperate as a result of changes in gene frequencies due to inbreeding or founder effects (Menges 1991). In addition, the vegetative spread of *A. leptaleus* may lead to one individual dominating an occurrence. However, these facts should not lead to underestimating the value of small populations. For example, alleles that were absent in larger populations were only found in a small population of *A. osterhoutii* (Karron et al. 1988). Therefore, in order to conserve genetic variability, in the absence of genetic (DNA) data, it is likely most important to conserve as many populations as possible in as large a geographic area as possible and to consider that a larger population is not necessarily a higher priority for conservation.

Although there is little on a local level that can be done to avoid the threat of global warming *per se*, management to lessen pressures that contribute to stress may to some extent mitigate the impacts.

Tools and practices

Inventory and monitoring populations and habitat

Astragalus leptaleus is known to occur in South Park, the Sierra Madre Range, and the Gunnison Basin within Region 2. There has been no monitoring activity in Region 2. Limited inventories for *A. leptaleus* appear to have been undertaken on the Medicine Bow National Forest.

While evaluating the data for this assessment, it was clear that most of the occurrence information that exists outside of Idaho couldn't be critically assessed because of the lack of detail and formal documentation. Collections have been sporadic, and data collection methods have been inconsistent.

In the 1990s, a number of surveys for this species were conducted in Idaho. This was due in part to its status as a sensitive species in that state. Habitat descriptions were completed at the sites located during these surveys (Moseley 1991, 1992). The status of the plants after ten years could now be assessed if these sites were revisited.

Species inventory: Inventories would be valuable in clarifying the distribution and abundance of *Astragalus leptaleus* within Region 2. This species can be difficult to locate during casual surveys because of its patchy distribution and inconspicuous characteristics. However, attempts need to be made to describe the spatial structure of an occurrence as well as to estimate or count the number of aerial stems. Because of its irregular distribution and the frequent observation that potential habitat is not always occupied, attempts to extrapolate the total population from a small sampled area or transect are subject to error. Before attempting extrapolation from transect or plot data, a much larger area should be surveyed and described to determine what is an appropriate and representative conversion factor for the area. It is likely that a reasonable estimate cannot be made beyond the surveyed area unless the concept of potential habitat has been accurately defined. Because *A. leptaleus* is so inconspicuous, surveys should always be conducted when it has flowers and preferably also fruits. It should be noted that the plants were difficult to see in September when the plant was in fruit and not in flower. Flowers are most useful because their color helps one to detect plants as well as to aid in identification.

The current "Field survey form for endangered, threatened or sensitive plant species" used by the Gunnison National Forest (Austin 2001), the Colorado Natural Heritage Program (2005), and the Wyoming Natural Diversity Database (2005) allows surveyors to record all the necessary data to document an occurrence. An additional formal "space" on the form to show a diagrammatic representation of the occurrence may be useful if an aggregated spatial pattern, or "patch structure," needs further explanation. The number of individuals, the area they occupy, associates, habitat characteristics, and the apparent proportion of potential habitat are important data for occurrence comparison purposes. It is important that the observer defines whether stem counts or patch counts are made and the distances between patches and stems should be reported. These parameters will help to elucidate population dynamics over time.

Habitat inventory: Habitat inventories have not been reported. Descriptions of occupied habitat suggest that mesic or wet meadows and the ecotone areas between saturated riparian communities and drier upland communities at 6,600 to 10,000 ft. (possibly 10,500 ft.) are "potential habitat". However, since it is not certain what portion of this area actually can support *Astragalus leptaleus*, making an inventory of potential habitat in its absence is probably not an effective use of resources unless the information is collected incidentally to another project.

Population monitoring: There have been no monitoring studies of *Astragalus leptaleus* populations in Region 2, and only limited studies have been conducted in Idaho. It is unknown how *A. leptaleus* responds to most management practices. Although the flowers and fruits appear to decrease in abundance due to livestock grazing, the effects have not been critically examined (Moseley 1991). A monitoring program designed to understand the impacts of grazing has been proposed for populations in Idaho (Caicco and Henderson 1981, Henderson and Caicco 1983, Moseley 1991, Moseley 1992).

When setting up a monitoring study, it is critical to define the goals. Permanent monitoring plots for *Astragalus leptaleus* may be appropriate if the aim is to learn more about overall population trends and the transition probabilities associated with the life cycle. Permanent plots are an excellent way to make demographic studies of such a species and to monitor individuals over the years to determine their fate. It is likely that many years of useful data can be collected using such a strategy. Because *A. leptaleus* spreads vegetatively, the monitoring plot must be large enough to observe annual changes in stem frequency.

A monitoring program that includes a demographic study to assess if *Astragalus leptaleus* is truly rhizomatous and has the ability to reproduce asexually would be very useful in defining best management practices for this taxon. Barneby (1964) described *A. leptaleus* as rhizomatous, but it is unclear exactly what he meant. Technically, rhizomes are underground stems that bear buds that can develop into adventitious roots and leaves (Abercrombie et al.1973, Allaby 1992). Therefore, rhizomes can serve as a means of vegetative propagation since individuals will become established away from the parent plant. This piece of information is vital to understanding the biology and potential population structure of *A. leptaleus*.

If the goal is to monitor samples to detect changes in a larger population over a long time period, the use of permanent monitoring plots may induce errors associated with autocorrelation (Goldsmith 1991). If the size of the plot is too small and the establishment of new plots is not part of the original scheme, when plants die and no replacement occurs within the plot it is impossible to know the significance of the change without studying a very large number of similar plots. Given the likely short distance of seed dispersal and

the network of underground stems, the patches of *Astragalus leptaleus* plants may be persistent, and the populations may not be very spatially dynamic. However, this has not been confirmed. Therefore, it is important to monitor the areas between sub-populations because the population dynamics are not known, and shifts in stands within a population need to be recognized. There may be a series of colonizations and local extirpations of patches. This circumstance also needs to be differentiated from temporal variations in the number of stems. The change in the number of stems from year to year may reflect a change in above-ground productivity of the population rather than a change in the number of individuals. Variation in the number of stems is an interesting parameter, but many years of observations must be made to determine the stability of a population. To minimize the problems associated with auto-correlation, monitoring protocols for species with a spatially aggregated or patchy distribution have been described by Goldsmith (1991), Elzinga et al. (1998), and Elzinga et al. (2001). In addition, Lesica and Steele (1994) discussed the special challenges of monitoring vascular plants exhibiting prolonged dormancy. *Astragalus scaphoides*, which also does not exhibit extensive vegetative reproduction, demonstrated prolonged dormancy (Lesica 1995). Although there is no evidence that *A. leptaleus* might exhibit such a phenomenon, it may be prudent to consider the possibility when designing a monitoring plan for the taxon.

Macroplots may be used to monitor *Astragalus leptaleus* occurrences. Macroplots are relatively large areas containing sampling units such as quadrats, transects, or points located within them. Macroplots are usually permanently defined to ensure that the same area is measured. Since some *A. leptaleus* occurrences appear to be small, a macroplot containing all potential habitat and a sufficient number of randomized sample units to meet the targeted levels of statistical precision and power may be used to monitor *A. leptaleus*. If the occurrence is distributed over a very large area, macroplots may still be used in the monitoring design (Elzinga et al. 2001). One or more macroplots may be established over a portion of the occurrence in key areas. A drawback to the use of macroplots to monitor a very large occurrence is that changes observed in a subjectively placed macroplot may not represent those occurring throughout the occurrence as a whole. Elzinga et al. (2001) recommends supplementing the quantitative results within the macroplot with qualitative studies dispersed throughout the larger population. In this way, the statistical study along with the supporting evidence may be sufficient for management decisions (Elzinga et al. 2001).

Habitat monitoring: There have been no formal habitat monitoring studies specifically for *Astragalus leptaleus*. Habitat conditions at known sites are customarily recorded if plants are being monitored. Habitat monitoring for this species in the absence of plants is premature because the exact conditions for colonization and survival are not well defined. Its rarity may be due to elements of its habitat requirements that are not known. However, it is known that *A. leptaleus* requires mesic conditions, and therefore gross changes in hydrology in an area may profoundly affect the spread and survival of the species. Similarly, weed management surveys for invasive species are valuable "habitat monitoring" strategies since the habitat of *A. leptaleus* is prone to invasions by aggressive, unpalatable, or noxious species.

Information Needs

Details of the current distribution and abundance of *Astragalus leptaleus* are the most important facts that need to be gathered. The information gathered for this assessment suggests that *A. leptaleus* is a very rare species that has experienced a loss of habitat over the last century. The hypothesis that it has been "overlooked" has not been adequately validated.

Assessing the long-term impacts of grazing on *Astragalus leptaleus* would be valuable for guiding management decisions (Henderson and Caicco 1983, Moseley 1991, 1992). Assessing impacts from other potential threats, such as vehicular disturbance and fire suppression, would aid in designing sound management plans. Clarification of whether *A. leptaleus* is truly rhizomatous and has the ability to reproduce asexually would be useful in defining best management practices for this taxon. It appears premature to consider studies to evaluate genetic variability among and within occurrences until more occurrences are documented. The small number of known occurrences suggests that all are equally important at the present time. When more occurrences are located, genetic studies may aid in determining which populations have the highest conservation priority.

If *Astragalus leptaleus* is more abundant than it currently appears, then its resilience to the effects of land use practices would be a good reason to monitor and study this species. Although it cannot be definitively determined how the abundance and range

of *A. leptaleus* have been affected over the last century, its habitat has been substantially modified.

The most critical information needs for *Astragalus leptaleus* are to determine:

- its distribution and abundance range-wide and within Region 2
- the long-term effects of livestock grazing, which is a common land use practice its range. This could be accomplished using long term monitoring procedures
- the impacts from land use practices and human activities in order to promote steps towards threat mitigation
- its habitat requirements
- the degree to which this species is rhizomatous and thus has the ability to reproduce asexually.

DEFINITIONS

Aneuploid – an organism whose nuclei "possess a chromosome number that is greater by a small number than the normal chromosome number for that species. An aneuploid typically results from non-disjunction of one or more pairs of homologous chromosomes" (Allaby 1992).

Congeners – individuals of the same genus (in other contexts it may be an person, animal, or thing of the same kind or race).

Emarginate – "With a shallow notch at the apex" (Harrington and Durrell 1979).

Homonym – In botanical literature and in the context of this report a homonym is: An identical scientific name that has been given to two or more taxa that are quite distinct from each other.

Hymenoptera – arthropod order that includes bees, wasps, sawflies, Ichneumons, chalcids, and ants.

Inflexed – "Turned abruptly or bent inwards; incurved" (Harrington and Durrell 1979).

Mesic – moist or wet.

Ovule – in plants, the structure that, after fertilization, develops into a seed.

Phalanx – Barneby (1964) divided North American species of the genus *Astragalus* into informal groups he called "phalanxes." He then placed taxonomically formal sections and sometimes sub-sections within the phalanxes (Barneby 1964).

Ranks – NatureServe and the Heritage Programs Ranking system (Internet site: http://www.natureserve.org/explorer/granks.htm).

> G4 indicates the taxon is "Apparently Secure – Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals."
>
> S3 indicates the taxon is "Vulnerable – Vulnerable in the nation or subnation [state] either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals."
>
> SH indicates the taxon is "Possibly Extirpated (Historical) – Element occurred historically in the nation or subnation [state], and there is some expectation that it may be rediscovered. Its presence may not have been verified in the past 20 years. An element would become NH or SH without such a 20-year delay if the only known occurrences in a nation or subnation were destroyed or if it had been extensively and unsuccessfully looked for. Upon verification of an extant occurrence, NH or SH-ranked elements would typically receive an N1 or S1 rank. The NH or SH rank should be reserved for elements for which some effort has been made to relocate occurrences, rather than simply using this rank for all elements not known from verified extant occurrences."

Retuse – "A rounded apex with a shallow notch" (Harrington and Durrell 1979).

Rhizomatous – "Having the characters of a rhizome. A rhizome is any prostrate more or less elongated stem growing partly or completely beneath the surface of the ground; usually rooting at the nodes and becoming upturned at the apex." (Harrington and Durrell 1979).

Ruminant – any hoofed animal that digests its food in two steps; first by eating the raw material and regurgitating a semi-digested form known as cud, then eating the cud by a process called ruminating. Ruminants include cows, goats, sheep, bison, and deer.

Scarious – "Thin, dry, membranous and more or less translucent, not green" (Harrington and Durrell 1979).

Section – Barneby (1964) divided North American species of the genus *Astragalus* into informal groups he called "phalanxes." He then placed taxonomically formal sections and sometimes sub-sections within the phalanxes (Barneby 1964).

Stipe – the stalk between the pod body and the calyx.

Sulcate – "Grooved or furrowed, especially if the groove is deep and longitudinal" (Harrington and Durrell 1979).

Synonym – In taxonomy, a plant name that differs from the official name; usually an older name that does not conform to the rules governing priority in the application of names (Allaby 1992).

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