Astragalus gilviflorus Sheldon var. *purpureus* Dorn (plains milkvetch): A Technical Conservation Assessment

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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 11 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.

COVER PHOTO CREDIT

Astragalus gilviflorus var. *purpureus* (plains milkvetch). Photograph by Hollis Marriott, used with permission.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ASTRAGALUS GILVIFLORUS* VAR. *PURPUREUS*

Status

The NatureServe global rank for *Astragalus gilviflorus* var. *purpureus* (plains milkvetch.) is G5T2, indicating that the species is demonstrably secure but the variety *purpureus* is imperiled. It is ranked imperiled (S2) by the Wyoming Natural Diversity Database. Currently, the U.S. Fish and Wildlife Service does not confer any protective status on the taxon. It is designated a sensitive species by the Bureau of Land Management in Wyoming. It is not currently designated a sensitive species by the USDA Forest Service in Region 2.

Primary Threats

Recreational off-road vehicle use of habitat poses a significant threat to some occurrences of this species. As the human population grows in areas within easy access to *Astragalus gilviflorus* var. *purpureus* habitat and as recreational use increases, the impacts may become substantially more significant. Mountain bike riding is common throughout this species' range and may also become a threat as that sport grows in popularity. Urbanization is likely to impact some known occurrences. At current levels, grazing and trampling by native and non-native ungulates may have an impact on some of the smaller colonies but do not appear to threaten any of the known populations. Activities associated with resource extraction are not currently perceived to be a threat although individual occurrences may have been impacted in the past. The potential impact from coalbed methane gas development or a renewed interest in uranium mining is unknown. Invasive weeds, which are growing in numbers throughout the range of this species, are likely to threaten the long-term sustainability of some occurrences.

Primary Conservation Elements, Management Implications and Considerations

Astragalus gilviflorus var. *purpureus* is a rare species endemic to the badlands within an approximately 30-mile radius of Dubois, Wyoming. It is restricted to areas with low vegetation cover, suggesting that it is unable to compete with invasive plant species. Apparently it can persist in, and/or re-colonize, areas after some vehicle or animal disturbance although the sustainability of occurrences at high disturbance sites is unknown. At present one population contains approximately 90 percent of the total number of plants, suggesting that the variety may be vulnerable to certain stochastic events. The current information available suggests that some occurrences are relatively secure because they occur in areas that are afforded some protection from anthropogenic disturbance by land use designation, for example wilderness study areas on land managed by the Bureau of Land Management. However, some of those areas have not been recommended for permanent wilderness designation, and so the protections may be withdrawn in the future. There are no management plans directly concerning *A. gilviflorus* var. *purpureus*. Most of the area in which plants occur in the Shoshone National Forest is managed to maintain healthy bighorn sheep herds.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Astragalus gilviflorus* Sheldon var. *purpureus* Dorn (plains milkvetch or Dubois milkvetch) is the focus of an assessment because it is a rare species endemic to the area around the Dubois badlands in central Wyoming. It is designated a sensitive species by the Wyoming Bureau of Land Management (Wyoming Bureau of Land Management 2000), but it is not formally listed as a sensitive species by the USFS Region 2. This assessment addresses the biology of *A. gilviflorus* var. *purpureus* throughout its range.

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 of 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, it cites management recommendations proposed elsewhere, and when these have been implemented, the assessment examines their success.

Scope

This assessment examines the biology, ecology, conservation status, and management of *Astragalus gilviflorus* var. *purpureus* with specific reference to the geographic and ecological characteristics of Region 2 of the USFS. Although some of the literature relevant to the species may originate from field investigations of other species outside the region, this document places that literature in the ecological and social context of the central Rockies. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *A. gilviflorus* var. *purpureus* 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 placed in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. Refereed literature is preferred because it is the accepted standard in science. In some cases, non-refereed publications and reports were used because information was unavailable elsewhere, but these sources were regarded with greater skepticism. Many reports or non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology and are reliable sources of information. 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 provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (for example, state natural heritage program and herbarium records) were important in estimating the geographic distribution and population sizes. These data required special attention because of the diversity of persons and methods used in collection. Records that are associated with occurrences where herbarium specimens have been collected are often more reliable than observations only.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct critical experiments in the ecological relations. Therefore, while well-executed experiments represent the strongest approach to developing knowledge, alternative methods, such as observations, inference, good thinking, and models must be relied on to guide the understanding of features of biology. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Publication of the Assessment on the World Wide Web

To facilitate their use, species assessments are being published on the Region 2 World Wide Web

site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates their revision, which will be accomplished based on guidelines established by Region 2.

Peer Review

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

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Astragalus gilviflorus var. *purpureus* is endemic to the badlands around Dubois in central Wyoming. Due to its limited geographic range and small population size, this taxon was listed as a Category 2 (C2) candidate for listing under the Endangered Species Act (U.S.C. 1531-1536, 1538-1540) by the U.S. Fish and Wildlife Service (USFWS) in 1993. The C2 list included species that might have warranted listing as threatened or endangered, but for which the USFWS lacked sufficient biological data to support a listing proposal. In February 1996, the USFWS revised its candidate policy and eliminated the C2 designation (U.S. Fish and Wildlife Service 1996). *Astragalus gilviflorus* var. *purpureus* has no federal legal status at the present time. It is designated a sensitive species by U.S. Bureau of Land Management (BLM) in Wyoming (2001).

The NatureServe (2004) global[1] rank for *Astragalus gilviflorus* var. *purpureus* is G5T2. This rank indicates that the species, *A. gilviflorus*, is demonstrably secure over its whole range. However, the variety *purpureus* is ranked T2, indicating that this taxon is imperiled because of rarity or because of other factors demonstrably making it vulnerable to extinction (see Ranks in the Definitions section). It is designated S2 by the Wyoming Natural Diversity Database (Fertig et al. 1994), indicating that it is imperiled because of rarity in the state of Wyoming.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Astragalus gilviflorus var. *purpureus* occurs on land managed by the USFS, the BLM, the USFWS, the Wyoming Fish and Game Department, and the Northern Arapaho and Shoshone nations on the Wind River Indian Reservation. It also occurs on private land. Jackson Hole Land Trust has secured conservation easements on some tracts of private land with occupied and potential *A. gilviflorus* var. *purpureus* habitat in the Dubois area (Fertig 1998). The Nature Conservancy owns tracts of land on which there is occupied and potential habitat (Craft personal communication 2003). It is anticipated that this land will eventually be sold under the provision of a conservation easement (Copeland personal communication 2003). A conservation easement is a voluntary permanent agreement to limit development and use the property in ways that are compatible with mutually agreed upon conservation objectives.

Astragalus gilviflorus var. *purpureus* is designated a sensitive species by the Wyoming BLM (2000). Such sensitive species designation is made in order to "maintain vulnerable species and habitat components in functional BLM ecosystems, ensure sensitive species are considered in land management decision, prevent a need for species listing under the Endangered Species Act, and prioritize needed conservation work with an emphasis on habitat" (Wyoming Bureau of Land Management 2000). In general, due to constraints associated with manpower, field surveys and species status updates are made on BLM sensitive species approximately every ten years (Carroll personal communication 2003). Models to predict the distribution of each BLM-designated sensitive species, including *A. gilviflorus* var. *purpureus*, have been developed (Fertig and Thurston 2003). Such models are believed to significantly aid in predicting potential habit when evaluating development permit requests (Carroll personal communication 2003).

The Shoshone National Forest staff is aware of the occurrences of *Astragalus gilviflorus* var. *purpureus* on USFS land (Houston personal communication 2003). There are no specific management guidelines because *A. gilviflorus* var. *purpureus* has not been designated a sensitive species by Region 2 of the USFS (Houston personal communication 2003). Relatively few formal

[1]For definitions of G and S ranking see Ranks in the Definitions section at the end of this document.

surveys have been conducted for this species. The largest and most recent survey was made in 1996 (Fertig 1998). During that survey several sub-occurrences were found in the Wind River Ranger District of the Shoshone National Forest. The known occurrences are located within the Whiskey Mountain unit, which lies almost entirely within the Fitzpatrick Wilderness. The only area of this unit that is not wilderness is a small piece of land located where Torrey Creek exits the Shoshone National Forest. This area was excluded from wilderness in order to accommodate the location of a trailhead. Due to non-specific location information, it is not certain if plants are found in these excluded areas. The Whiskey Mountain unit represents important habitat for a large bighorn sheep herd, which has national significance, and this area is managed for bighorn sheep (USDA Forest Service 1986). In general, the Wilderness Act prohibits habitat modification activities within wilderness areas. However, some of the management guidelines for part of the Fitzpatrick Wilderness are modified, and pursuing water development, seeding, fertilizing, snow fencing, and managing vegetation by prescribed burning are permitted within the Whiskey Mountain area because it is prime winter range for bighorn sheep (USDA Forest Service 1986). The consequences of such actions to *A. gilviflorus* var. *purpureus* occurrences are not formally evaluated because the taxon is not a sensitive species. Part of the area in which the plants occur is closed to motorized vehicles, including snow vehicles, which prevents at least one anthropogenic source of disturbance (Aus 1999).

Biology and Ecology

Classification and description

Systematics and synonymy

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

Astragalus gilviflorus belongs to the *Orophaca* section of the Orophaca Phalanx of the genus *Astragalus* (Barneby 1964). Typical of many species, the taxon *A. gilviflorus* has been examined several times over the last 150 years. *Astragalus triphyllus* is a synonym for *Oxytropis triphylla* and was originally described in 1800 referring to a native of Siberia (Pallas 1800 in Sheldon 1894-1898a). Fourteen years later in the United States, Pursh (1814) described *A. triphyllus* referring to specimens of *A. gilviflorus*. In Eaton's extensive review in 1840, Eaton and Wright described the taxon in their concept of *Phaca triphylla*. In 1894, Sheldon (1894-1898a) published the taxon that he designated *A. gilviflorus* and clarified those names with which it was placed in synonymy. Three years later in 1897, Britton and Brown went on to describe the taxon in their notion of *O. caespitosa* (see the 1970 republication of Britton and Brown 1913). In 1983, Isely suggested that it was most appropriate to segregate the *Orophaca* from the genus *Astragalus* in accordance with what Rydberg had advocated in 1929. Isely argued that the *Orophaca* represents a compact group of eight species that are clearly distinguishable by their palmately trifoliate leaves. In addition, they are clearly separable from all old world *Astragali* by having a base chromosome number of 12, unlike the old world *Astragali* base number of 8 (Spellenberg 1976). Isely (1998) also pointed out that the binomial *P. triphylla* that Eaton and Wright proposed in 1840 is a legitimate name according to Greuter (1994). Therefore, following this reasoning, Isley (1998) considered the appropriate name for this taxon as being *O. triphylla*. It appears that the position of *Orophaca* has still to be resolved. Considering the conventions of phylogenetic classification and based on the nucleotide sequence variation in the internal transcribed spacer regions of nuclear ribosomal DNA from *A. aretioides* (Phalanx *Orophaca*, section *Sericoleuci*), Sanderson and Liston (1995) suggested that one conservative option is to keep the genus *Astragalus* with *Orophaca* as a subgenus. At the present time in widely used floras in Region 2, the taxon is described as *O. triphylla* in Weber and Wittmann (2001) and *A. gilviflorus* in Dorn (2001) and McGregor et al. (1986).

Barneby (1964) reported that *Astragalus gilviflorus* is most closely related to *A. proimanthus* and *A. hyalinus*. *Astragalus proimanthus* is restricted to barren shales in Sweetwater County in southern Wyoming, but *A. hyalinus* is a more widespread species, found east of the continental divide in Wyoming, Nebraska, Colorado, western Nebraska, and western South Dakota. Roberts (1977) also noted a superficial resemblance to *A. barrii*, an endemic of the northern Great Plains, which is also in the *Orophaca* Phalanx but in the section *Sericoleuci* Barneby (Barneby 1964,

Hu et al. 1999). *Astragalus gilviflorus* var. *purpureus* is most closely related to, and most likely derived from, *A. gilviflorus* var. *gilviflorus* (Roberts 1977).

History of species

Astragalus gilviflorus var. *purpureus* was first collected in the Bonneville National Forest, Fremont County, Wyoming, in 1912 by an unknown collector (Rocky Mountain Herbarium specimen accession number 407511). Its species epithet is from the Latin and reflects the fact that the species, *gilviflorus* (meaning yellow flower) has creamy yellow flowers, but the variety *purpureus* (the name the Greeks gave to a purple dye) has purplish flowers. Roberts (1977) first recognized *A. gilviflorus* var. *purpureus* as a unique taxon and described it in an unpublished thesis under the name *A. shoshonensis*. However, it was not officially described until Dorn published a brief account in the first edition of *Vascular Plants of Wyoming* (Dorn 1988). Dorn used the historical precedent of Sheldon (1894-1898a) when he described *A. gilviflorus* var. *purpureus* in 1988. As outlined in the previous Systematic and synonymy section, Isely (1998) considered the binomial *Phaca triphylla* that Eaton and Wright proposed in 1840 had precedence and considered the appropriate name for this taxon as being *Orophaca triphylla* var. *purpurea*.

In summary, *Astragalus gilviflorus* var. *purpureus* is synonymous with *A. shoshonensis*, and *Orophaca triphylla* var. *purpurea*. For further information see Sheldon (1894-1898b) and Britton and Brown (1970). The relevant publications for the authorship of the binomials are listed under 'binomial' in the Definition section.

Non-technical description

Astragalus gilviflorus var. *purpureus* is a low-growing, loosely-matted perennial that becomes cushion-like in eroding habitats. A thatch of persistent leaf stalks covers the much-branched caudex. The leaves have long stalks and are divided into three oval to elongated-oval shaped leaflets. Copious, short hairs cover the foliage and make it look silvery. The hairs are dolabriform, or pick-shaped, looking like they are attached at their mid-point rather than at their end. The pea-like flowers are paired, and the bases are hidden amidst the foliage. The petals are blue, purple, or occasionally pinkish. The wing petals are paler-colored towards the tip. The banner petal is 12 to 28 mm long and has a spoon-shaped blade that tapers to a narrow base. The elliptical to oval shaped pods are erect, with essentially no stalks, and are usually hidden among the leaf bases. There are two to five mature seeds per pod. The seeds are brown, dull, smooth, and 2 to 2.5 mm long (Roberts 1977, Dorn 1988, Barneby 1989, Fertig 1994, Iseley 1998). A line drawing of *A. gilviflorus* var. *purpureus* is shown in **Figure 1**, and a photograph is shown in **Figure 2**.

Flower color (purple blue to pinkish) and banner shape (spoon-shaped) are distinguishing features of this species. The plant needs to be flowering in order to distinguish it positively from *Astragalus gilviflorus* var. *gilviflorus*, which has white- or cream-colored flowers (Roberts 1977, Dorn 1988). *Astragalus proimanthus*, *A. hyalinus*, and an undescribed species from Park County, Wyoming have yellowish or white fiddle-shaped banners (Fertig 1998). Other *Astragalus* species with three leaflets typically have smaller flowers and shorter calyx tubes (Dorn 1992, Fertig et al. 1994, Fertig 1998). Another difference, but at the chemical level, between var. *purpureus* and var. *gilviflorus* is that the aglycone of the flavone, apigen, was found in var. *purpureus* whereas its glycoside is in var. *gilviflorus* (Roberts 1977).

References to technical descriptions, photographs, line drawings, and herbarium specimens

Detailed technical descriptions are given in Dorn (2001), Isley (1998, under *Orophaca triphylla*), and Roberts (1977, under *Astragalus shoshonensis*). Another comprehensive technical description and a line drawing are published in Fertig (1998). A description along with location map, photographs, and a line drawing is published in Fertig et al. (1994) and on the USGS Northern Prairie Wildlife Research internet site (http://www.npwrc.usgs.gov/resource/distr/others/wyplant/spec/astrgilv.htm [accessed March 2003]).

Distribution and abundance

Astragalus gilviflorus var. *purpureus* is endemic to the Dubois badlands of the northwestern Wind River Basin and the adjacent foothills of the northeastern Wind River and southern Absaroka ranges in Fremont County, Wyoming (Biota of North America Program 1998, Fertig 1998). The entire known range is approximately 450 square miles (**Figure 3**). It extends from approximately 9 air miles northwest of Dubois to White Pass and approximately 10 miles south of Dubois to Torrey Rim and the Wind River on the Shoshone National Forest. The range extends approximately 24 miles east of Dubois to Johnson Draw on the Wind River Indian Reservation. Roberts (1977) reported that

Figure 1. A line drawing of *Astragalus gilviflorus* var. *purpureus*. Illustration by Walter Fertig, used with permission. The fruit is shown in the inset.

Figure 2. Photograph of *Astragalus gilviflorus* var. *purpureus*. The photographer is Hollis Marriott, used with permission.

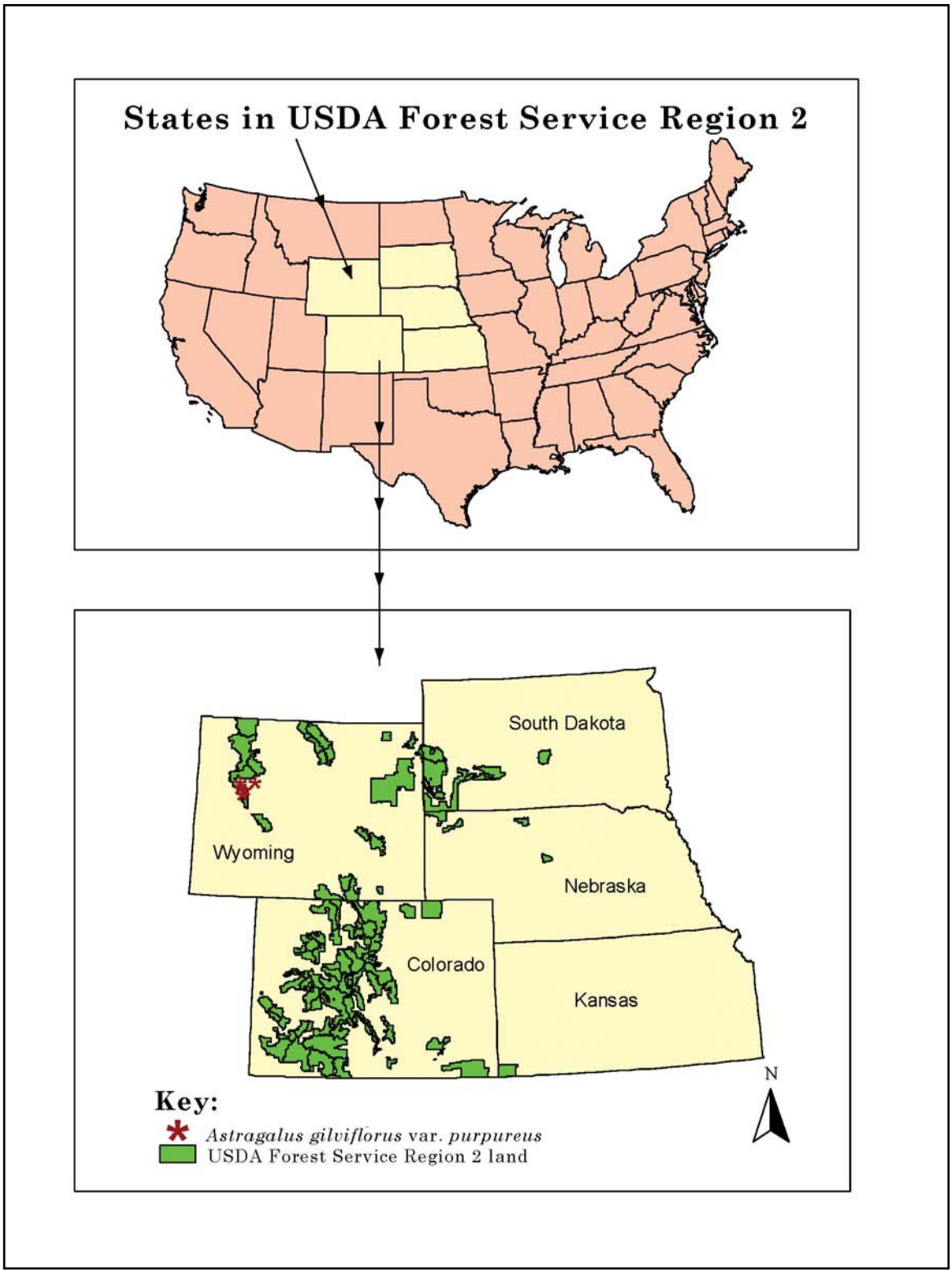

Figure 3. Range of *Astragalus gilviflorus* var. *purpureus*.

the range extended about 40 miles southeast of Dubois, but no specimens have been found to confirm this (Fertig 1998).

Astragalus gilviflorus var. *purpureus* is known from 12 occurrences, nine of which have been discovered or relocated since 1990 (**Table 1**). The total area of occupied habitat is approximately 400 acres (Fertig 1998). Except for one extensive occurrence that occupies approximately 250 acres and another that occupies 70 acres, most occurrences range from less than one to approximately 16 acres. Within an occurrence there are usually several sub-occurrences that consist of 30 to 100 plants distributed within an area of less than 2 acres (Fertig 1998, Wyoming Natural Diversity database element occurrence records 2002). The total area in which the plants are distributed, rather than the actual occupied habitat, is generally extensive. For example the occurrence that was estimated to occupy 70 acres is distributed through five sections (3,200 acres). The population on the Shoshone National Forest was distributed over a total of five sections within the Whiskey Mountain unit although the actual occupied habitat was estimated to be only approximately 5 acres. Fertig (1998) reported that the 11 occurrences found since 1981 consisted of approximately 38 sub-occurrences. In 1996 he estimated that rangewide there was a total of at least 100,000 extant individuals, approximately 90 percent of which were localized in a single extensive occurrence in Dubois badlands in the Table Mountain area. Roberts (1977) cites nine of his own Fremont County collections of *A. shoshonensis*, but he only provides location information on one, that from which his type specimen was taken. None of these specimens have been deposited at the Rocky Mountain or New York Botanical Gardens Herbaria, despite reporting to the contrary (Roberts 1977, Fertig 1998, Zanoni personal communication 2003). Occurrence data have been compiled from the Wyoming Natural Diversity Database, the Rocky Mountain Herbarium, and from the literature (Roberts 1977).

Harper (1977) suggested several reasons why colonies may be small. The available sites may be few and separated by distances beyond the species' normal dispersal ability, the carrying capacity of the site may be low, the habitability of the site may be of short duration because of successional displacement, or colonization is in its early stages and full exploitation of the site has not occurred. In the case of *Astragalus gilviflorus* var. *purpureus*, it is likely that the carrying capacity of the site and the relative paucity of available sites contribute to the small sub-occurrences and fragmented populations. An occurrence is generally ascribed to a population, and sub-occurrences can be equated with sub-populations. Sub-populations interact either through pollination or seed dispersal. In some cases a reported occurrence may be more accurately described as a sub-occurrence, but there may be insufficient information or an absence of field survey data associated with the report to make an accurate delineation (**Table 1**). This is the case with several of the occurrences found in 1996 (**Table 1**; Wyoming Natural Diversity Database element occurrence records 2002). It should be noted that plants are not always found in areas defined as potential habitat. Considerable areas of potential habitat have been surveyed without finding plants (Fertig 1998). Element occurrence delineation in **Table 1** has followed that proposed by the Wyoming Natural Diversity Database (element occurrence records 2002). Delineation may change when the extent of the interaction between sub-occurrences is known.

Classification tree analysis is an analytic process designed to explore large amounts of data and search for consistent patterns and/or systematic relationships between variables. The findings are validated after applying the detected patterns to new subsets of data. Classification tree analysis is a non-parametric method in contrast to many other statistical methods, such as logistic regression and analysis of variance, which are parametric and entail assumptions about distributions. Classification tree analysis does not use a mathematical formula to explain the relationship between predictors and binary response but uses a partitioning algorithm to subdivide predictor variables into ever-smaller groups that are approximately homogeneous relative to the response variable (Breiman et al. 1984). Beginning with the entire set of predictors, the classification tree model continually subdivides the dataset into pairs of smaller subunits based on the single variable that best differentiates between known presence and absence points (Fertig and Thurston 2003). The end result is a dichotomously divided classification tree that can be used to classify independent cases and to describe the environmental space occupied by a species (Fertig and Thurston 2003).

Using classification tree analysis, a predictive model for *Astragalus gilviflorus* var. *purpureus* distribution was developed (Fertig and Thurston 2003). The basic assumption to model development is that correlations exist between the presence/absence of the taxon and selected climate, topographic, substrate, and land cover variables. The presence/absence of each taxon was the response variable in the models and was derived from location records of the Wyoming Natural Diversity Database and Rocky Mountain Herbarium

Table 1. Occurrences of *Astragalus gilviflorus* var. *purpureus*. After more surveys are completed, the occurrences designated 1, 2, 6, 7 and 9 may be found to be essentially confluent. Similarly, occurrences designated 3, 6 and 10 may also be contiguous (The Wyoming Natural Diversity Database provided the majority of the data in 2002).

Arbitrary number	General location	Management	Dates observed	Size of occurrence	Brief account of habitat	Source
1	Northwest Wind River Basin - east and west of Tappan Creek and Horse Creek. Includes area from which holotype collected by *R.D. Dorn 3476* 1980, RM.	Private, BLM	6/5/1996; 6/20/1980	1996 - Five small to medium-sized (<100 individuals) subpopulations all within a 2.5 sq. mi. area. Approximately 8 to 40 acres occupied. Total occurrence covers portions of five sections.	Sparsely vegetated fine red and pale brown sandy clay soils of the Wind River Formation on north, south, or east-facing badlands slopes and draws. Absent from adjacent sandy areas on upper slopes. Elevation: 7,000 to 7,440 ft.	Wyoming Natural Diversity Database element occurrence records.
2	Table Mountain area. Northwest Wind River Basin - Little Alkali Creek and near the head of Mason Draw.	Inberg Roy Wildlife Habitat Management Area under multiple agencies: National Wildlife Refuge and Management Area, BLM, Wyoming State land (Game and Fish Dept. East Fork winter range). Also extends on to private land.	1996; 6/25/1997; 6/8/1981	1996 - Population relatively small and consists of ~ three subpopulations; one of which estimated at 500 to 800 plants. Approximately 10 acres occupied. Total occurrence covers portions of 4 sections.	Cushion plant-bunchgrass community with occasional *Artemisia tridentata* and *Chrysothamnus nauseosus* on south-facing steep slopes of pinkish-white sandy clay of hogback ridges below the main slope. 1981- growing in loam with grasses on 5 percent north facing slope. Elevation: 7,400 to 7,800 ft.	*Jones, D. and D. Rizor 68.* 1981. RM, *Fertig, W. 16516.* 1996. RM, *Rosenthal, D. 1389.* 1997. RM.
3	Northwest Wind River Range	Shoshone National Forest, Whiskey Mountain unit, primarily in Fitzgerald Wilderness (may extend onto BLM and Private land).	6/14/1996	Two main colonies with a total population of 2,800 to 5,000 plants. Approximately 5 acres occupied habitat in over 5 sections.	*Artemisia tridentata* var. *vaseyana* - *Elymus spicata* community with high cover of *Leucopoa kingii* and *Poa secunda*. Elevation: 7,480 to 7,900 ft.	Wyoming Natural Diversity Database element occurrence records. *Fertig, W. 16624, 16630.* 1996. RM.
4	Wind River Basin - Johnson Draw	Wind River Tribal Lands	7/10/1981	No information.	Limestone ridge with *Cryptantha* spp. and *Thelesperma* spp. Elevation: 8,800 ft.	Wyoming Natural Diversity Database element occurrence records. *Lichvar, R. W. 4589.* 1981. RM.
5	Northwest Wind River Basin, southeast of Dubois on southwest side of Highway 26.	Wind River Tribal Lands	6/2/1987; 1990; 7/25/ 1994	Population small. Two main subpopulations; at one of which approximately 30 individuals observed in an area 30 x 200 yards in 1990. Approximately 4 acres occupied.	Sparsely vegetated soil on road cut and below cliffs And on sandy clay outcrops in sagebrush community. Formation on roadcut and below cliffs. 1987 - Red sandy clay outcrops in sagebrush community. Elevation: 6,400 ft.	Wyoming Natural Diversity Database element occurrence records. *Atwood, N.D. 12768.* 1987. RM, *Marriott, H.J. 11134.* 1990. RM.
6	Northwest Wind River Basin, badlands - Lime Kiln Gulch region (near residential area and "type locality" for *A. shoshonensis* described by Roberts 1977; see Synonymy section).	Private, State, BLM - Whiskey Basin Wildlife Habitat Management Area (Bighorn sheep winter range), Whiskey Basin Wilderness Study Area.	6/3/1976; 7/18/1990	Several thousand individuals in 1990. Approximately 250 acres occupied habitat. Total occurrence covers portions of 4 sections.	Forb-rich badlands vegetation (15 to 50 percent cover) with many cushion plant species. On fine red soil capped with scattered gravel and cobbles derived from the Wind River or Indian Meadows formations. Elevation: 6,950 to 7,200 ft.	Wyoming Natural Diversity Database element occurrence records. *Marriott, H.J. 11287.* 1990. RM, *Roberts, M.L. 4599.* 1976. NY.

Table 1 (Concluded).

Arbitrary number	General location	Management	Dates observed	Size of occurrence	Brief account of habitat	Source
7	Table Mountain area. Dubois badlands, Pease Ridge, Byrd Draw.	Wyoming Game and Fish Department - Spence Moriarity Wildlife Habitat Management Area, State land, private land, BLM	6/23/1983; 1984; 1990; 6/5/1996	Fourteen sub-populations known in area approximately 4 x 3 miles. Total population estimated at least 40,000 to 50,000 in 1996 (Wyoming Natural Diversity Database element occurrence records 1996). Approximately 70 acres occupied habitat. Total occurrence covers portions of 12 sections.	In four community types: sagebrush, cushion plant/ bunchgrass, or cushion plant communities or "sparsely vegetated" sandy clay soils and badland slopes. Abundant surface gravel common. Elevation: 6,800 to 7,600 ft.	Wyoming Natural Diversity Database element occurrence records. *Fertig, W. 16496, 16520, 16521.* 1996. RM, *Marriott, H. 11288.* 1990. RM, *Hartman, R.L. 15584.* 1983. RM.
8	Northwest Wind River Basin; Wiggins Fork, Bear Creek and East Fork of the Wind River.	Wyoming Game and Fish - Spence Moriarity Wildlife Habitat Management Area	7/18/1990; 6/4/1996	Size of population unknown. Estimated ~16 acres occupied habitat. Total occurrence covers portions of 4 sections.	Cushion plant and *Artemisia nova/ Carex filifolia/Elymus spicatus* grassland community. Elevation: 6,820 to 7,400 ft.	Wyoming Natural Diversity Database element occurrence records. *Fertig, W. 16507.* 1996. RM, *Marriott, H. 11289.* 1990. RM.
9	Table Mountain Northwestern Wind River Basin, Dubois badlands, Mason Draw Road.	State, BLM - Whiskey Basin Wildlife Habitat Management Area, BLM- Whiskey Basin Wilderness Study Area.	5/29/1980; 6/4/1996	Three subpopulations of which: Colony A = Population ~ 500-1,000 plants in 1996. Colony B = Population ~/> 200 flowering mats in 1994. No size reported for Colony C. Approximately 10 to 15 acres occupied habitat.	Sparsely vegetated cushion plant-bunchgrass communities with scattered *Artemisia tridentata* and *Chrysothamnus nauseosus.* Elevation: 7,160 to 7,280 ft.	Wyoming Natural Diversity Database element occurrence records. *Fertig, W. 16515.* 1996. RM, *Dorn, R.D. 3428.* 1980. RM.
10	Northwestern Wind River: Torrey Lake/Trail Lake Road, and east of Torrey Lake.	BLM - Dubois Badlands Wildlife Habitat Management Area, BLM- Dubois Badlands Wilderness Study Area.	5/1994; 6/1994	Population relatively small. Composed of ~ four colonies: three small (sub) populations with a total of 200+ plants in one section and 1 colony with approx 50 plants. All observed in 1994. Approximately 5 acres occupied habitat. Total occurrence covers portions of 2 sections.	Sagebrush grasslands. Elevation: 6,640 to 7,090 ft.	Wyoming Natural Diversity Database element occurrence records.
11	Southwest foothills of the Absaroka Mountains, White Pass and vicinity Southwest foothills of the Absaroka Mountains, White Pass and vicinity.	Private	6/28/1984	No information.	Elevation: 8,100 ft.	Wyoming Natural Diversity Database element occurrence records.
12	Bonneville National Forest	Bonneville National Forest - currently part of the Shoshone National Forest, Region 2 (see text)	1912	No information.	No information.	*Unknown collector*, RM.

(Fertig and Thurston 2003). Environmental variables, including total monthly precipitation, average monthly air temperature, monthly shortwave radiation, number of wet days, growing degree-days, local topographic relief, bedrock and surface geology, soils, elevation, and land cover, were used as predictors. Location data were randomly subdivided into model-building and validation data sets to test the classification success of the final models. There were 16 known present points and 960 known absent points (Fertig and Thurston 2003). Classification trees readily lend themselves to being displayed graphically, helping to make them easier to interpret than they would be if only a strict numerical interpretation were possible. The model developed by Fertig and Thurston (2003) for *A. gilviflorus* var. *purpureus* is illustrated in **Figure 4**. Surface geology, soil, air temperature, and precipitation at specific times of year were determined to influence its distribution. After validation procedures, it was determined that the model was correct in 97.1 percent of locations and incorrect in 2.9 percent of cases (Fertig and Thurston 2003).

Population trend

There are insufficient data in the literature, associated with herbarium specimens, or at the Wyoming Natural Diversity Database to determine the long-term trends for *Astragalus gilviflorus* var. *purpureus*. It has only relatively recently been recognized as a unique taxon (Roberts 1977, Dorn 1988), and information on its historical abundance is scant. It was first collected in 1912 in the Bonneville National Forest, parts of which have since been absorbed into the Shoshone National Forest (Taft 1911). No comments were made on its abundance at the time it was first collected, and the details on its location were not given. It was (re)discovered in the Shoshone National Forest in 1996.

Few specific sites appear to have been revisited (**Table 1**). In 1990, the total number of individuals at each of two unidentified sites was estimated at about 30 plants (Fertig 1998). These sites were revisited by Fertig in 1996 and found to contain approximately the same number of individuals (Fertig 1998). Specifics as to the locations of the sites were not given. In another case, plants were first reported in the Lime Gulch area (see site 6, **Table 1**) in 1976, and plants were again located within the same area in 1990. Similarly, the Table Mountain area was visited in 1981 and again in 1997 (see site 2, **Table 1**). Therefore it can be concluded that plants have been persistent within the same general area for at least 16 years. In general, revisits to several areas appear to have found additional colonies, rather than relocating the original colony. These colonies are then subsequently included in the original occurrence. Therefore, it is unknown whether there is a greater number of plants within an occurrence or if colonies merely shift and the abundance remains the same. Some habitat may have been lost to residential or agricultural development in the past century, but it is unknown whether this has significantly impacted the abundance of *Astragalus gilviflorus* var. *purpureus*. Based on the present condition of the habitat in the Dubois area, including that on land managed by the USFS, Fertig (1998) considers that the taxon is unlikely to experience significant declines in the near future. Accelerated urbanization or more intensive use of its habitat may change that situation.

Habitat

Astragalus gilviflorus var. *purpureus* is found in the vicinity of Dubois, Wyoming where the average annual precipitation is 207.5 mm, with peak levels in April to June. The mean annual temperature is 4.1 °C, with mean maximum and minimum temperatures in January of 0.7 °C and -12.2 °C and mean maximum and minimum temperatures in July of 26.2° and 5.3 °C, respectively (Martner 1986, Fertig 1998). *Astragalus gilviflorus* var. *purpureus* grows at elevations between approximately 1,950 m and 2,690 m, with the majority of occurrences located between 2,100 m and 2,400 m (**Figure 5**). Where a range was given for an occurrence, the lowest and highest elevations reported were included in the graph in **Figure 5**. Plants have been reported to grow on slopes facing all aspects but most commonly on south- and east- facing slopes.

Astragalus gilviflorus var. *purpureus* grows on shale, limestone, and redbed substrates (see Distribution and abundance section). Redbed formations are sedimentary strata composed largely of sandstone, siltstone, and shale that are red colored because hematite (ferric oxide) coats the individual grains (Bates and Jackson 1984). Specific substrates on which plants have been found include those derived from the Chugwater and Dinwoody formations (TRcd), that are of mesozoic and paleozoic sedimentary rock origin, and from the Wind River (Twr, Twdr) and Indian Meadows (Tim, Twim) formations, that are of cretaceous sedimentary rock origin (Love and Christiansen 1985).

Figure 4. Classification tree used in building the distribution model of *Astragalus gilviflorus* var. *purpureus*. Data is taken from Fertig and Thurston (2003). **Figure 4a** illustrates the tree. **Figure 4b** indicates the path compositions and likelihood of their occurrence. Paths are distinguished by colors in **Figures 4a** and **4b** for ease of use only. Decisions at certain nodes are explained in the footnote.

4a. Classification Tree (after Fertig and Thurston 2003).

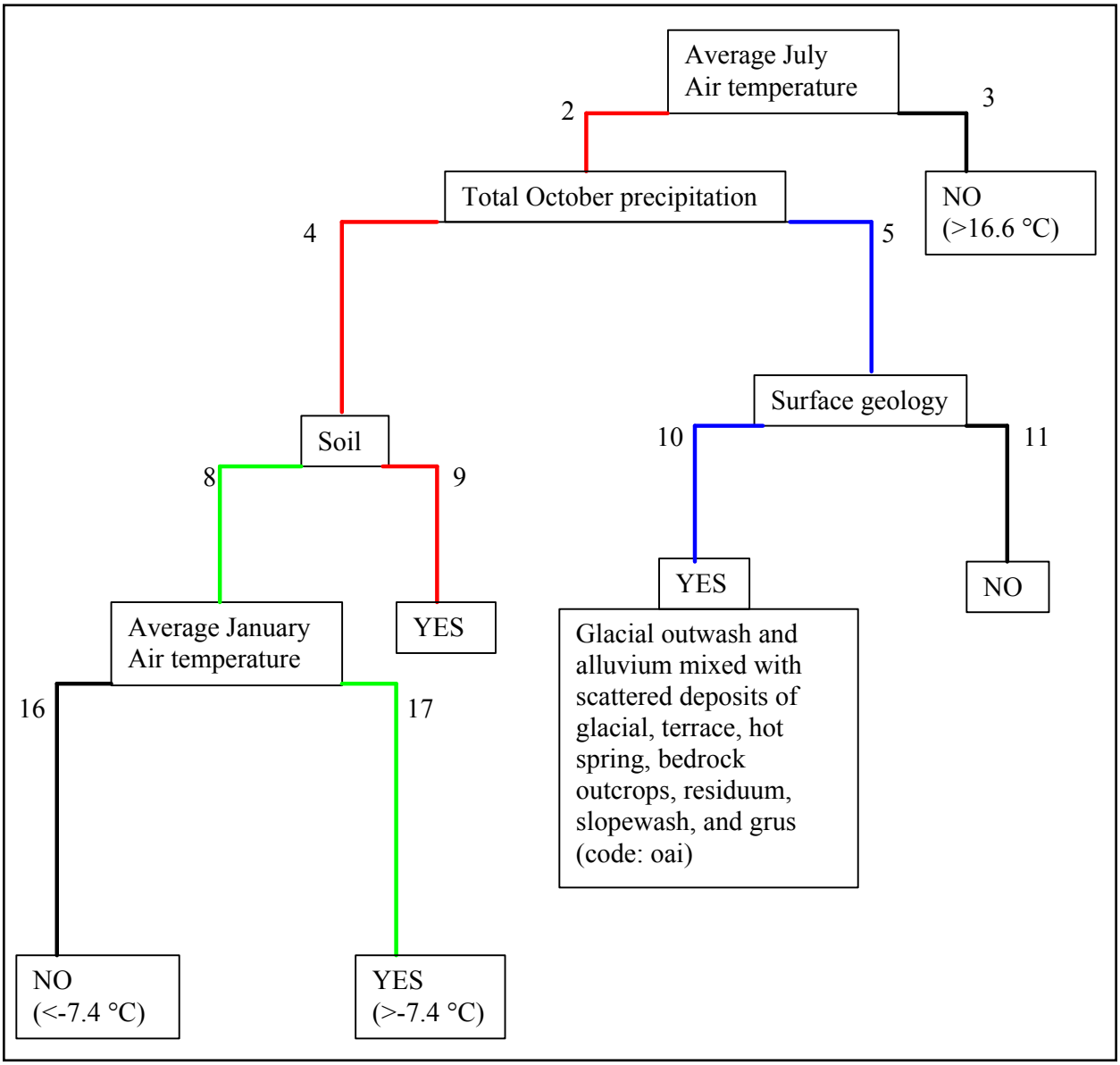

Figure 4b. Path composition and likelihood (after Fertig and Thurston 2003).

Yes path	Path[A] list	% present points	Likelihood class
A	17, 8, 4, 2	6.3	Low
B	9, 4, 2	87.5	High
C	10, 5, 2	6.3	Low

Footnote (see Fertig and Thurston 2003):

[A] Path 2, 3: Average July air temperature: Yes path: <16.6 °C

Path 4, 5: Total October precipitation: Yes path: <2.87 inches

Path 9: YES Soil path

Code	Description of Soil
WY06C	Typic Haplocryalfs, Typic Dystrocryepts and Typic Haplocryolls, loamy-skeletal and Histic Cryaquepts, fine-loamy over sandy or sandy-skeletal Typic Haplocryalfs, Typic Dystrocryepts and Typic Haplocryolls, loamy-skeletal, mixed and Histic Cryaquepts, fine-loamy over sandy or sandy-skeletal, mixed.
WY14	Typic Haplargids and Typic Natrargids, fine-loamy or coarse-loamy, mesic
WY17C	Combination: Typic Torriorthents, loamy, mesic and Rock Outcrop Typic Torriorthents, fine, mesic and Rock Outcrop Typic Torriorthents, loamy-skeletal, mesic and Rock Outcrop Rock Outcrop and Typic Torriorthents, loamy-skeletal, mixed, frigid Lithic Torriorthents, loamy-skeletal, frigid and Rock Outcrop
WY27	Typic Torrifluvents and Typic Haplaquolls, fine-loamy over sandy or sandy-skeletal, mixed, frigid
WY36	Ustic Torriorthents and Ustic Haplocalcids, coarse-loamy, frigid
WY38C	Combination: Ustic Haplocambids and Ustic Haplargids, coarse-loamy, frigid Ustic Haplargids, Ustic Haplocambids and Ustic Natrargids, fine-loamy, mixed, frigid Ustic Haplargids and Ustic Haplocambids fine and fine-loamy, mesic
WY40C	Combination: Ustic Haplocambids and Ustic Torriorthents, fine, frigid and Rock Outcrop Ustic Haplocambids and Ustic Torriorthents, fine, frigid Ustic Torriorthents and Ustic Haplocambids, fine, frigid Ustic Haplocambids and Ustic Torriorthents, coarse-loamy, mixed and Typic Torrifluvents, loamy-skeletal, mixed, frigid

Path 11: NO path from Surface geology

Code	Description of Surface geology
Ai	Old alluvial plain with scattered deposits of eolian, residuum, and slopewash
Ri	Bedrock and glacial bedrock including hot spring deposits and volcanic necks; mixed with scattered deposits of eolian, grus, slopewash, colluvium, residuum, glacial, and alluvium
fi	Alluvial fan and gradational fan deposits mixed with scattered deposits of slopewash, residuum, and eolian
gi	Glacial deposits mixed with scattered deposits of slopewash, residuum, grus, alluvium, colluvium, landslide, and/or bedrock outcrops
li	Landslide mixed with scattered deposits of slopewash, residuum, Tertiary landslides, and bedrock outcrops; landslides too small and numerous to show separately
ri	Residuum mixed with alluvium, eolian, slopewash, grus, and/or bedrock outcrops
sci	Slopewash and colluvium mixed with scattered deposits of slopewash, residuum, grus, glacial, periglacial, alluvium, eolian, and/or bedrock outcrops
tdi	Dissected terrace deposits mixing with alluvium, residuum, eolian, and slopewash
ti	Terrace deposits mixed with scattered deposits of alluvium, residuum, eolian, slopewash, and outwash
ui	Grus mixed with alluvium, eolian, slopewash, grus, and/or bedrock outcrops

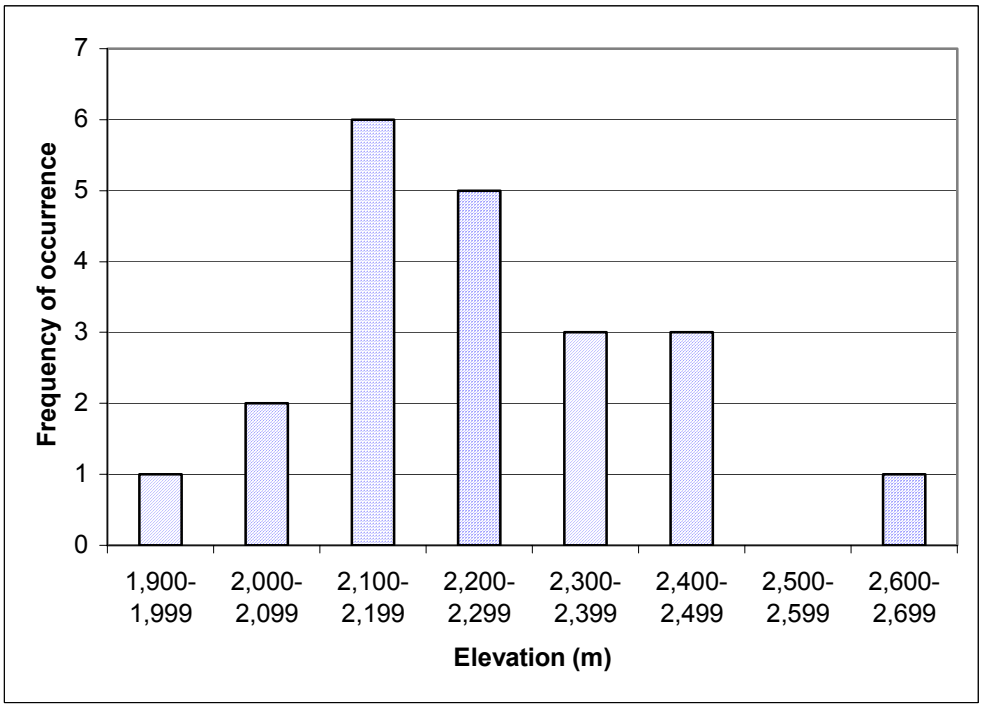

Figure 5. Range in elevation reported for the occurrences of *Astragalus gilviflorus* var. *purpureus*.

Astragalus gilviflorus var. *purpureus* grows on semi-barren slopes with a vegetation cover between 15 to 50 percent. It is most frequently described as a member of cushion plant communities or sagebrush grasslands (**Table 1**). Cushion plants are low-growing species that generally have their highest woody perennial parts flat on the soil surface and are described as hemicryptophytes according to Raunkiaer's life form system (Raunkiaer 1934). Three vegetation communities have been described in some detail (**Table 2**). Plants have also been found on sparsely vegetated reddish sandy-clay soils with surface gravel along roadsides. The light-colored, semi-barren substrates at the rims of steep slopes on which it typically grows are exposed to high levels of solar radiation and wind. Fertig (1998) remarked that these areas are likely to be drier and have higher daytime surface temperatures than adjacent, more highly vegetated sites. Because of the harsh environmental conditions, the unproductive edaphic properties, and occasional natural disturbance, the cushion plant-sagebrush community to which it belongs may represent a "climax" condition (Fertig 1998). Climax vegetation classically refers to a self-perpetuating community that changes very slowly, over a very long time-scale, and is not usually applied to such a cushion plant-sagebrush community. However, a climax community represents the final stage of plant succession, in which the vegetation has reached a state of equilibrium with its environment. Therefore, in this context climax condition was used to refer to fact that the cushion plant-sagebrush community appears have reached an equilibrium with its environment.

The occurrence in the Shoshone National Forest is apparently on the border of two vegetation cover types (ArcView vegetation cover types 2003 provided by USFS Region 2, Denver, CO). The occurrence appears to lie primarily within a vegetation cover type designated "Other sagebrush" (Class Other sagebrush), but it may extend into the Fescue Grassland cover type (Class Foothills/montane grassland). See **Table 1** for additional details of occupied habitat. It also grows with at least four other species of *Astragalus*, which include *A. chamaeleuce* and *A. aretioides* at lower elevations and *A. miser* and *A. simplicifolius* at higher elevations (Roberts 1977). At two occurrences plants appeared to be sympatric with *A. gilviflorus* var. *gilviflorus* (Wyoming Natural Diversity Database occurrence records 1990). This observation needs to be confirmed because it was made past flowering time, and it was noted that the flower color might have faded (Fertig 1998). Additional associated plant species are listed in **Table 3**. This is not an exhaustive list and represents only the observations that were made on herbarium sheets, in the Wyoming Natural Diversity Database element occurrence records, and in the literature (Roberts 1977, Fertig 1998).

Table 2. Three distinctive community types in which *Astragalus gilviflorus* var. *purpureus* occurs (data from Wyoming Natural Diversity Database element occurrence records, Rocky Mountain Herbarium records, and Fertig 1998).

Community	Notable non-biological features	Notable biological features
Type I Cushion plant/bunch grass	East to south-facing convex-shaped slopes of brownish sandy-clay soil with abundant surface gravel derived from the Wind River and Indian Meadows formations	Sagebrush is conspicuously absent
Type II Cushion plant/bunch grass	Gravelly outwash fans below tan sandy-clay gravel knolls derived from the Cody Shale formation	*Artemisia tridentata* var. *wyomingensis* (Wyoming big sagebrush) is scattered throughout the community
Cushion plant	South-facing whitish-sandy slopes above siltstone caprock of red and white-banded shale hoodoos	*Psoralidum lanceolatum* (lemon scurfpea) and *Leptodactylon pungens* (prickly-phlox) are dominant species

Table 3. Plant species reported to be associated with *Astragalus gilviflorus* var. *purpureus*. Names are in accordance with those published in Dorn (2001). Where appropriate the name of the species as it was originally reported is given in square brackets.

Associated Species (common name)	Associated Species (common name)
Achnatherum hymenoides [*Oryzopsis hymenoides*] (Indian ricegrass)	*Leptodactylon pungens* (prickly-phlox)
Antenaria rosea	*Lesquerella alpina* (alpine bladderpod)
Arenaria hookeri	*Leucopoa kingii* (spike fescue)
Artemisia frigida (silver sage)	*Linum lewisii* (blue flax)
Artemisia nova (black sagebrush)	*Machaeranthera grindelioides* [*Haplopappus nuttallii*] (gumweed aster)
Artemisia tridentata (big sage)	*Melilotis* spp. (sweetvetch)
Artemisia tridentata var. *vaseyana* (mountain big sagebrush)	*Oxytropis lagopus* var. *lagopus* (hare's-foot locoweed)
Artemisia tridentata var. *wyomingensis* (Wyoming big sagebrush)	*Oxytropis nana* (Wyoming locoweed)
Astragalus chamaeleuce (cicada milkvetch)	*Oxytropis sericea* var. *sericea* (silvery locoweed)
Astragalus miser (weedy milkvetch)	*Oxytropis* spp.
Astragalus miser var. *decumbens* (weedy milkvetch)	*Penstemon eriantherus*
Astragalus simplicifolius	*Penstemon laricifolius*
Carex filifolia (threadleaf sedge)	*Phlox hoodii*
Chrysothamnus naseosus (rabbitbrush)	*Phlox muscoides* (moss phlox)
Comandra umbellata	*Physaria* spp.
Cryptantha celosioides	*Poa secunda*
Cryptantha spp.	*Potentilla ovina* (sheep cinquefoil)
Elymus spicatus (bluebunch wheatgrass)	*Psoralidium lanceolatum* (lemon scurfpea)
Erigeron compositus	*Senecio canus* (woolly groundsel)
Erigeron tweedyi	*Sisymbrium* spp.
Eriogonum brevicaule (shortstem buckwheat)	*Stipa comata* (Needle-and-thread)
Eriogonum spp. (buckwheat)	*Tetraneuris acaulis* [*Hymenoxys acaulis*] (stemless hymenoxys)
Hymenopappus spp.	*Thelesperma* spp. (Navajo tea)
Koeleria macrantha (prairie junegrass)	*Townsendia* spp.

In order to evaluate habitat for its potential to support a rare plant species, having data on where the species is typically absent as well as where it is found can be very useful. In general *Astragalus gilviflorus* var. *purpureus* is absent from areas with tall, shady vegetative cover but with otherwise suitable substrate conditions (see **Table 4** for further details).

Reproductive biology and autecology

Astragalus gilviflorus var. *purpureus* is a perennial species. Similar to many other hemicryptophytes, the perennating buds of *A. gilviflorus* var. *purpureus* appear to be protected by the old dead leaf bases of the plant. Flowering has been documented from May 28 to July 10, and fruits are present from June 20 to July 18 (Fertig 1998, Specimens from the Rocky Mountain Herbarium).

Astragalus gilviflorus var. *purpureus* reproduces by seed. The plant may spread to a limited extent by vegetative growth from its branching caudex. Mats have been reported to be up to 20 cm wide (Wyoming Natural Diversity Database element occurrence records 2002). The reproductive system has not been studied in detail. The flowers may be either or both, self- and cross-pollinated. Some authors have proposed that rare species have higher levels of auto-fertility and lower-levels of open pollination than those of common species (Geer and Tepedino 1993). In fact, several rare *Astragalus* taxa 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 some widespread *Astragalus* species also exhibit a high degree of self-fertility.

Where cross-pollination occurs, *Astragalus* species are generally insect-pollinated (Geer and Tepidino 1993). Bilaterally symmetrical flowers, such as those of var. *purpureus*, are frequently pollinated by medium to large polylectic bees in the genera *Bombus*, *Osmia* and *Anthophora* (Karron 1987b). The flower structure of *Astragalus* is such that quite a sizeable insect is needed to collect substantial amounts of pollen. Ants were common floral visitors to both *A. cibarius* and *A. utahensis* but did not carry pollen (Green and Bohart 1975). The flowers of both *A. cibarius* and *A. utahensis* are comparable to those of *A. gilviflorus* var. *purpureus* (Barneby 1989). 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 is available for cross-pollination. Black ants and large bumblebees were observed on the flowers of *A. gilviflorus* var. *purpureus* in 1996 (Fertig 1998). *Bombus* species, commonly called bumblebees, are thus very likely pollinators. Considering the observations of Green and Bohart (1975), ants are unlikely to be significant pollinators although they may steal nectar from the flowers. Self-pollination is especially important to small populations of a species primarily pollinated by bees because bees, unlike many other flower visitors, are density-dependent foragers (Heinrich 1976). In addition, the size of a mat may influence the frequency with which cross-pollination occurs. Bumblebees appeared to preferentially visit large, rather than small, clumps of *A. canadensis* in an Iowa prairie (Platt et al. 1974). *Astragalus* species are recognized for their rapid development of autogamous lineages where pollinators are unreliable (Kalin Arroyo 1981). It is not clear whether the harsh conditions associated with *A. gilviflorus* var. *purpureus* habitat would contribute to unreliable arthropod populations. Thus, studies on other rare *Astragalus* species suggest that *A. gilviflorus* var. *purpureus* is likely, at least to some extent, to be self-pollinated although the possibility that it relies on cross-pollination cannot be discounted without further study.

Table 4. *Astragalus gilviflorus* var. *purpureus* appears to be excluded from certain habitat types even though they are contiguous with occupied habitat (from the Wyoming Natural Diversity Database element occurrence records 2002, Roberts 1977, and Fertig 1998).

Arbitrary number	Type of habitat from which *Astragalus gilviflorus* var. *purpureus* appears to be excluded
Type 1	Semi-barren shale sites dominated by *Atriplex gardneri*.
Type 2	Slopes dominated by dense grass or *Artemisia* spp. cover.
Type 3	Upper slopes of bare reddish clay dominated by *Platyschkuhria integrifolia*.
Type 4	Calcareous ridgelines.
Type 5	Ridges with tall, dense grass cover.
Type 6	Upper slopes where the soil is very sandy.

No information on the size of the seed bank, the rate of seed recruitment to the seed bank, and the longevity of seed in the soil is available for this species. The extent of seed predation is also unknown. Seed predation by arthropods can be very high among *Astragalus* species, and some species of beetles readily feed on *Astragalus* species that are selenium accumulators or are otherwise toxic to livestock (Platt et al. 1974, Clement and Miller 1982, Lesica 1995). Roberts (1977) observed that predatory seed beetles, *Acanthoscelides* species (Coleoptera: Bruchidae), were commonly observed on all species of *Orophaca*, especially on *A. gilviflorus*, but other reports (Fertig 1998) suggest that little predation occurs. Dense pubescence on the pod of *A. utahensis* prohibits some arthropod species from penetrating the pod wall and depositing eggs in the pod (Green and Palmbald 1975). It is not known whether the hairs on the pod of *A. gilviflorus* afford it some similar protection.

Seed dispersal mechanisms are also not known with certainty. Roberts (1977) concluded that seed dispersal of *Astragalus gilviflorus* appeared to be largely fortuitous. He pointed out that the papery marcescent calyx associated with the pod might be suited to short distance dispersal by rolling. Dispersal by zoochory, specifically ants and rodents, is also likely. Given the very windy environment in which this species grows, wind may also be effective in dispersing seed although wind-dispersed seeds frequently move only short distances (Silvertown 1987). Roberts (1977) and Fertig (1998) both observed that the clumped distribution pattern of many colonies suggested that dispersal distances are short.

Population density is also likely influenced by the availability of resources. The low nutrient environment of its habitat may be alleviated to some extent by association with nodulating bacteria. Specific associations with nitrogen-fixing bacteria have not been reported. However, since some populations of *Astragalus gilviflorus* (reported as *A. triphyllus* Pursh) in North Dakota are nodulated, it is possible that *A. gilviflorus* var. *purpureus* is also associated with nitrogen-fixing bacteria (Allen and Allen 1981).

Hybridization between *Astragalus* species is a rare phenomenon (Liston 1992, Spellenberg personal communication 2003). In accordance with this observation there is little evidence of hybridization between *A. gilviflorus* and other species of *Astragalus* (Fertig 1998). If the two varieties of *A. gilviflorus* are sympatric (see Habitat section), cross-pollination may be avoided between them because of differences in flowering period. Typically var. *gilviflorus* blooms in late April to early May whereas var. *purpureus* generally blooms in late May and into early July (Roberts 1977, McGregor et al. 1986, Barneby 1989). In addition, cross-pollination may be avoided because some pollinators are species-specific and may not visit multiple species of *Astragalus* (Green and Bohart 1975). Alternatively, genic or chromosomal factors may confer reproductive isolation to the taxon (Grant 1981, Liston 1992).

Demography

Astragalus gilviflorus var. *purpureus* is a perennial that reproduces by seed. Only limited expansion by vegetative growth is possible. It is not known whether individuals that flower one year can revert to a vegetative state in succeeding years or whether they can avoid adverse environmental conditions by remaining dormant over one or more growing seasons. There appear to be both vegetative and flowering individuals of approximately the same size within a population, which suggests that plants do not flower every year (Wyoming Natural Diversity Database occurrence records 2002). This observation implies that resources are directed to maintain the adult individual in favor of producing progeny. In many species of long-lived perennials where assets are allocated to favor the survival of the adult, seed production may be low and the most important life cycle components are growth and survival of the adult plants (Silvertown et al. 1993). Individuals appear to be long-lived, as mats may be on pedicels up to 12 cm above ground level due to erosion of the soft, surrounding soil (Wyoming Natural Diversity Database occurrence records 2002).

A simple life cycle model of *Astragalus gilviflorus* var. *purpureus* can be described in diagrammatic terms (**Figure 6**). Heavy arrows indicate phases in the life cycle that appear unambiguous, and lighter weight dashed arrows indicate the phases that are either apparently less significant or unknown. The steps that particularly need to be clarified are noted by "?" at the appropriate arrow. More information is needed to define which of the life history stages have the greatest effect on population growth and survival. It is not known whether size reflects the age of the plant. It is likely that environmental conditions, for example moisture, have a primary effect on plant size.

Individual mats may be sparsely patchy to densely clustered within populations. A combination of environmental variables and aspects of the species' biology may influence the spatial distribution of

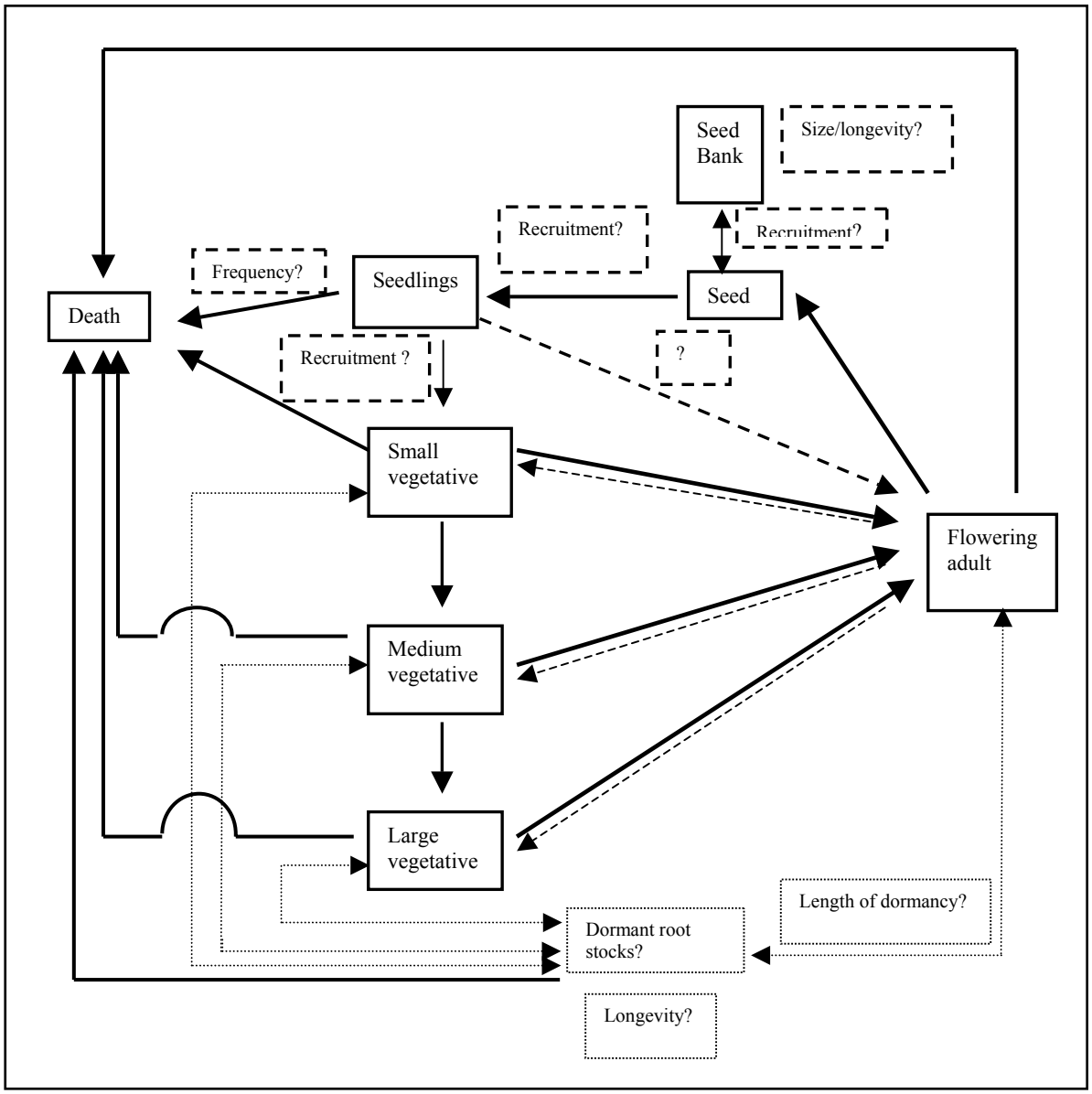

Figure 6. Life cycle diagram for *Astragalus gilviflorus* var. *purpureus*. Heavy arrows indicate phases in the life cycle that appear unambiguous and lighter weight dashed arrows indicate the phases that are either apparently less significant or unknown. The steps that particularly need to be clarified are noted by "?" at the appropriate arrow.

individuals within a population. The spacing of *Astragalus gilviflorus* var. *purpureus* may be influenced by the topography of the site, the presence of suitable substrates, and the availability of suitable microsites for seed germination and seedling establishment. In addition, the amount of seed production by individual plants and the ways the seeds are dispersed will also affect spatial patterns (Platt et al. 1974). Population growth may be related to plant size and density. For example, if *A. gilviflorus* var. *purpureus* is primarily cross-pollinated, large mats may be expected to produce disproportionately more seed than small clumps due to greater pollination success (see Reproductive biology and autecology section, Platt et al. 1974). In this case, smaller individuals will be denser around large mats. This hypothesis can be tested in the field. There is no information to determine the frequency with which independent individuals grow together to form one mat or whether seeds germinate within the mat of established plants. One mat appears to be equated with

one individual in *A. gilviflorus* var. *purpureus* survey reports. Both Roberts (1977) and Fertig (1998) have reported that most occurrences consist of medium to large plants with few or no seedlings present.

The preponderance of adults in *Astragalus gilviflorus* var. *purpureus* occurrences may be ascribed to low seed production, high seed predation, low seedling survival and establishment, or a combination of all three. A fourth alternative explanation for the paucity of seedlings is that seed may be stored in the seed bank and only germinate periodically when conditions are, in some way, most favorable. *Astragalus gilviflorus* var. *purpureus* appears to produce several fruits, each containing two to five mature seeds per individual (Roberts 1977). Therefore seed availability does not appear to be a critical limitation in large populations although it may be a significant factor in small colonies. Fertig (1998) remarked that there did not appear to be significant seed predation, at least in 1996, although *Astragalus* species are often targets of seed predators (see Community ecology section). High seedling mortality may be expected under the harsh environmental conditions in which it grows (see Habitat section).

No demographic studies have been undertaken, and transition probabilities between the different stages, from seed production to the flowering adult are unknown. Lesica (1995) used stage-based transition matrix models and elasticity analysis to elucidate the demography and the effect of herbivory on *Astragalus scaphoides*, a long-lived, tap-rooted perennial. *Astragalus scaphoides* exists as dormant rootstocks, small non-reproductive plants, large non-reproductive plants, and reproductive plants. It suffers from inflorescence predation by insects and livestock and also from insect seed predation. It experiences losses of pre-dispersal fecundity (total number of immature fruits) averaging 50 percent. Elasticity analysis revealed that population growth continues in spite of the relatively small contributions of recruitment as compared to growth and survival of non-reproductive plants and that the survival of the species in total depends little on reproduction and recruitment (Lesica 1995). Even though predation may be low, the paucity of seedlings and small plants and the likely old-age of some individuals suggest that some of *A. scaphoides*'s life history traits may apply to *A. gilviflorus* var. *purpureus*.

The population size of this species is quite variable, with reports between approximately 30 to greater than 2,000 individuals in an occurrence (see Distribution and abundance section). At the present time, evidence suggests that population growth is restricted by extrinsic factors, such as substrate and vegetative cover. Population viability analyses for this species have not been undertaken. *Astragalus gilviflorus* var. *purpureus* usually exists in patches in a subdivided occurrence. It is unknown if there is a balance of frequent local extirpations and colonizations within a colonized area or whether, once established, microsites are occupied for long periods of time. The age and population structure of the plants suggest that once established, occurrences are quite long-lived, but this should not be assumed without monitoring records.

The limited current evidence suggests that *Astragalus gilviflorus* var. *purpureus* is a perennial species that is maintained in established, relatively long-lived populations. These characteristics are thus consistent with those of a k-selected species having a stress-tolerant life strategy (MacArthur and Wilson 1967, Grime et al. 1988).

Community ecology

Astragalus gilviflorus var. *purpureus* does not colonize and/or flourish in highly competitive communities. It is clear that it only grows in areas with relatively sparse vegetation cover and few exotic weedy species. This is true of many *Astragali*. Barneby (1964) noted that the majority of *Astragalus* species occur in xeric conditions that have little competitive vegetation. Not withstanding the sparse vegetation, a relationship between dwarf sagebrush (*Artemisia* spp.) and some *Astragalus* species has been reported in the Intermountain West (Barneby 1964). The dwarf sagebrush provides shelter for seedlings and later protects the tender foliage from grazing animals.

Except for the observations of association with bumblebees and ants (see Reproductive biology and autecology section), interactions with native fauna have not been documented for *Astragalus gilviflorus* var. *purpureus*. An interesting correlation between the specific phenology of certain plant species, such as *A. gilviflorus*, and the life history of the grasshopper was made to determine appropriate times to apply grasshopper chemical control compounds (Hewitt 1980). Grasshopper hatching and development are regulated to a large extent by the same environmental cues that govern flowering; cool rainy weather tends to prolong both flowering and grasshopper development, and hot weather causes a reduction in the duration of nymphal stage and flower longevity. *Astragalus gilviflorus* (var. *gilviflorus*) was dubbed an indicator plant for grasshopper control management (Hewitt 1980).

The *Orophacas* do not accumulate selenium so they do not have the distasteful aroma typical of many *Astragalus* species, which tend to deter livestock from browsing (Roberts 1977). Roberts (1977) also reported that typically the *Orophacas* do not contain the aliphatic nitro compounds that are particularly toxic to livestock. However, this should be confirmed on a species-specific basis because *A. sericoleucus*, another species in the *Orophaca* Phalanx, does give a positive test for nitro compounds (Stermitz et al. 1972). *Astragalus* species that are morphologically related have also been found to have chemotaxonomic relationships with regard to nitro-compounds (Williams and James 1978). Since the specific structure or concentrations of these compounds were not identified, it is unknown to what extent *A. sericoleucus* is poisonous.

Although Fertig (1998) remarked that herbivory is unlikely because of the *Orophaca*'s low matted morphology, experiences in Montana suggest that domestic sheep are potentially damaging herbivores (Vogel and Van Dyne 1966). Vogel and Van Dyne (1966) observed that domestic sheep preferred a list of forbs that specifically included *Astragalus gilviflorus*. Species that are selected by sheep are documented to be more abundant on non-grazed land, implying that grazing negatively affects abundance (Strasia et al. 1970, Bonham 1972). Domestic sheep can also have indirect effects on bee-pollinated plant species. Sugden (1985) reported that sheep grazing in the habitat of *A. monoensis*, another perennial endemic species, endangered bee pollinators by destroying potential and existing nest sites and removing food resources. *Astragalus gilviflorus* var. *purpureus* occurs in areas that are used as bighorn sheep winter range (Breckenridge personal communication 2003). It is unknown what the direct impacts of bighorn sheep are on the *Astragalus* populations, but observations suggest that they are low.

Some arthropod foragers such as Meloid beetles have been reported to have a significant impact on some occurrences of *Astragalus gilviflorus* (see Reproductive biology and autecology section, Roberts 1977). However, seed predation by arthropods is not necessarily bad at levels under which the taxon has evolved. In some cases it may have had an important influence on population dynamics and diversity within the genus *Astragalus* (Green and Palmbald 1975, Mancuso and Moseley 1993).

When suitable substrates were available, occurrences have been reported along road cuts and in semi-disturbed roadside areas, suggesting that the species is tolerant of some disturbance and/or capable of re-colonizing disturbed sites (Fertig 1998). Although plants are unable to become established or to persist on regularly bladed roads or off-road vehicle (ORV) trails that receive continual use, they appear to be capable of colonizing or persisting on semi-disturbed road banks that have received occasional ORV use (Fertig 1998). For example, colonies near the East Fork Road were found after disturbance due to road construction and recreation (Fertig 1998). Even though *Astragalus gilviflorus* var. *purpureus* may persist at disturbed sites or even behave as a pioneer species, it does not have the life strategy characteristics or the competitive ability of a typical ruderal species (see Demography section). The role of fire, another form of disturbance, in maintaining populations is undocumented. The low levels of litter accumulation in its native habitat suggest that it is naturally only infrequently exposed to fire, and those are likely of only cool temperature. In fact, the low vegetation cover suggests that the areas in which it occurs may act as refugia from hot fires at the landscape level.

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used especially to describe the conditions of animals (Andrewartha and Birch 1984) but may also be applied to describe the condition of plant species. Those components that directly impact *Astragalus gilviflorus* var. *purpureus* make up the centrum, and the indirectly acting components comprise the web. Factors in the web are causally related to the factor in the centrum. Unfortunately, much of the information to make a comprehensive envirogram for *A. gilviflorus* var. *purpureus* is unavailable. The envirogram in **Figure 7** is constructed to outline some of the known major components to impact the species directly and also includes some more speculative factors that can be tested in the field by observation or by management manipulation. A dotted box indicates resources that are likely but not proven. Among the resources that have been listed are soils derived from specific geological formations although the specific attributes that are responsible for colonization are not clear. Non-specific pollinators have been included, but they are speculative because the degree to which selfing, or the reliance on cross-pollination, occurs in *A. gilviflorus* var. *purpureus* is also unknown. Disturbance has not been included in the envirogram because the types that may be beneficial are undocumented. Natural disturbances, such as that caused by rodents and rainstorms, and human-induced disturbances, such as that caused by all terrain vehicles, have vastly different consequences. Similarly, the association with foraging arthropods and arthropod seed predators has been omitted because insufficient

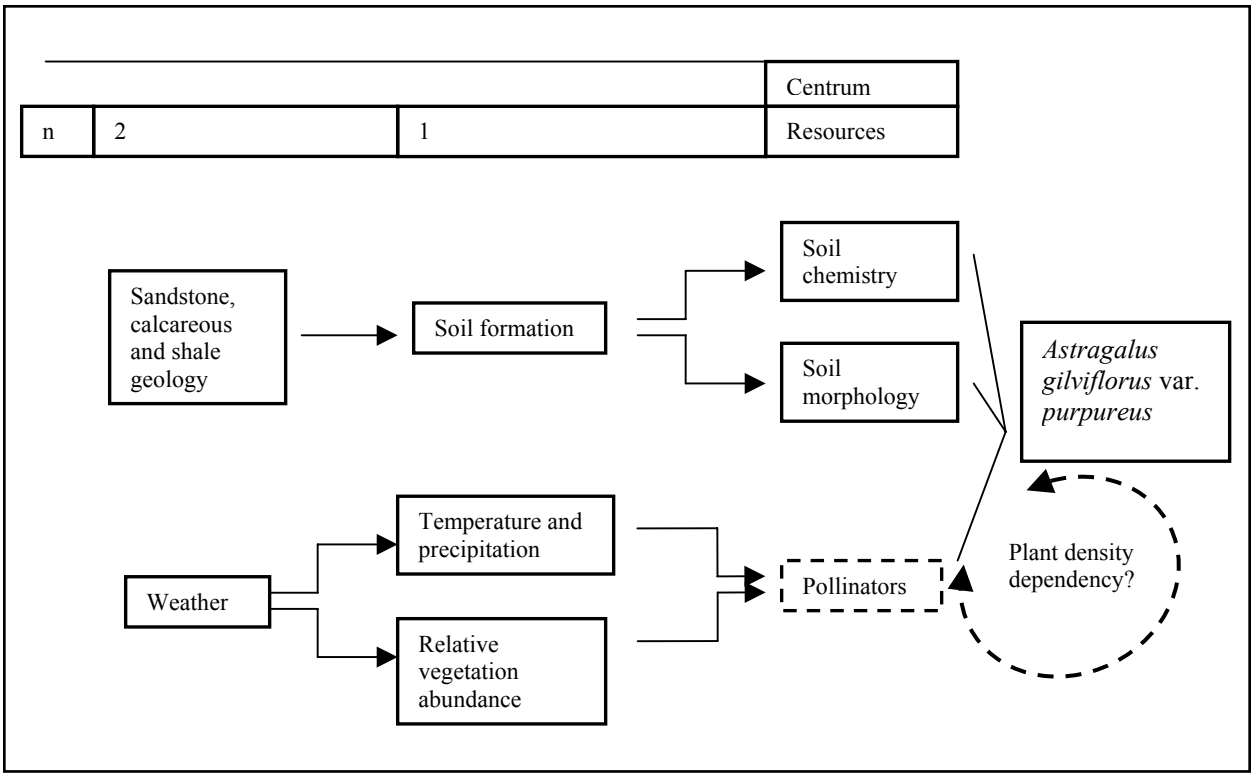

Figure 7. Envirogram outlining the resources of *Astragalus gilviflorus* var. *purpureus*. The dotted box indicates a resource that is speculative.

information exists to suggest which species and levels could be classed as significant resources.

CONSERVATION

Threats

The small geographic range of *Astragalus gilviflorus* var. *purpureus* makes it vulnerable to large-scale natural and human-induced disturbances. An additional aspect to its vulnerability is that it is not evenly distributed within its narrow range. Approximately 90 percent of the known individuals are localized within a single extensive occurrence in the area of Table Mountain in the Dubois badlands (**Table 1**).

Threats and potential threats include certain recreation activities, urbanization, grazing, an increase in the abundance of invasive weeds, and activities associated with resource extraction. Potential threats might also include global climate change and demographic and genetic stochasticity. Each subject is discussed in more detail in the following paragraphs. Many threats are not currently a concern on USFS land, but they should be considered as management practices and land use policies change. The extent to which each threat is currently believed to be a concern on Forest Service land has been noted in the appropriate paragraphs. It should be noted that the Shoshone National Forest began revising its Forest Plan in fiscal year 2004 (USDA Forest Service 2003).

Off-road vehicle use for recreation is probably the most significant current threat to populations of *Astragalus gilviflorus* var. *purpureus* on private and public lands in the immediate vicinity of Dubois (Fertig 1998). Off-road vehicles can impact plants directly by tearing the mats and dislodging the roots, and indirectly by compacting the soil and accelerating soil erosion. The amount of plant mortality in an area is probably related to the intensity of ORV use. The areas where plants occur in the Shoshone National Forest are closed to ORVs, and only occasional trespass is currently experienced (Houston personal communication 2003). Except in the areas designated Areas of Critical Environmental Concern, where there are no known occurrences of *A. gilviflorus* var. *purpureus*, the BLM currently allows ORVs on all existing roads and trails in the Dubois area (U.S. Bureau of Land Management 1987). However, often vehicles leave pre-existing roads, and the observed disregard of these regulations

may impact the survival of *A. gilviflorus* var. *purpureus* at some technically protected sites (Fertig 1998, Carroll personal communication 2003). Mountain bike riding has become very commonplace and may become a threat as it grows in popularity. Mountain bike tours in the region around Dubois are nationally and internationally advertised (Teton Mountain Bike Tours 2003). Other recreational uses, such as hiking, trapping, and big-game hunting, do not appear to adversely impact occurrences of this species (Fertig 1998).

Areas in which *Astragalus gilviflorus* var. *purpureus* grows on the Shoshone National Forest and adjacent land are managed for bighorn sheep (USDA Forest Service 2001, Breckenridge personal communication 2003). It is not clear how much impact on habitat results from visitors who are involved with bighorn sheep viewing (non-consumptive use) on Whiskey Mountain. It appears that, in general, visitors would be concentrated at a roadside interpretive center where there is a telescope, but this is speculation (Wyoming Fish and Game Department 2003). In 1981, Whiskey Mountain received 60,000 recreation visitor days of use for this purpose (USDA Forest Service 2001).

Urbanization may also affect some occurrences. A portion of the private land on which *Astragalus gilviflorus* var. *purpureus* occurs near Dubois is likely to be developed for residential use (Fertig 1998). Between 1990 and 2000, the percent change in population in Fremont County was 6.4 percent (U.S. Census Bureau 2003). This positive change was primarily due to the expansion in the Dubois area. This expansion may also impact both the amount of recreational use USFS land receives and the proportion of the total available *A. gilviflorus* var. *purpureus* habitat that occurs on National Forest System land.

Livestock grazing is one of the major land uses on public and private lands throughout the range of this species (Fertig 1998). However, since most occurrences of this species are located on marginal rangeland with sparse forage and no water, they tend to receive relatively little use by grazing animals. Trampling could be a problem if animals are herded through occupied habitat or induced to use these habitats through salt blocks or water tanks. Although direct impacts from trampling by native and domestic ungulates have not been documented, it may significantly contribute to erosion of the highly erodible soils. Light use by bighorn sheep in the summer is unlikely to have a significant impact on the population, but heavy use during the winter may be more of a concern for small colonies of this taxon. At some sites, cattle and horses are permitted to graze in summer, but their impacts are understood to be low (Fertig 1998, Breckenridge personal communication 2003). Although there is a grazing allotment at Whiskey Mountain on the Shoshone National Forest (USDA Forest Service 2001), domestic sheep are typically prevented from using the areas in which var. *purpureus* grows. This is principally in order to avoid disease transmission to the bighorn sheep (Houston personal communication 2003).

The competitive ability of *Astragalus gilviflorus* var. *purpureus* is likely low considering the habitat to which it is adapted. Therefore, invasive weeds pose a threat. Invasive noxious weed species as defined by the Wyoming Weed and Pest Council (undated) have not been specifically reported at any of the recorded occurrences (Wyoming Natural Diversity Database element occurrence records). However, sweetvetch (*Melilotus* spp.), a persistent species used in agriculture and re-vegetation projects, was recorded at one of the 1996 occurrences not on land managed by the USFS. This is an invasive and highly competitive non-native species, and its impacts on opportunities for *A. gilviflorus* var. *purpureus* colonization and the sustainability of existing occurrences are unknown. Livestock and recreation activities, such as hiking and ORVs, also contribute to the spread of invasive weed species. Once weed species are dispersed, they have vigorous colonizing potential and a high reproductive capacity that permits them to dominate and persist after the initial introduction (Cousens and Mortimer 1995).

Most of the BLM lands in the range of *Astragalus gilviflorus* var. *purpureus* are open to oil and gas leasing and mineral development. The East Fork, Dubois Badlands, and Whiskey Mountain management units have been closed to leasing, or no-surface occupancy stipulations have been put in place, to protect habitat for wildlife (U.S. Bureau of Land Management 1987). Some occurrences are within the BLM Dubois Badlands and Whiskey Mountain Wilderness Study Areas (WSAs). These WSAs are managed to preserve their wilderness values until Congress makes a decision either to designate the areas as wilderness or to release the areas for non-wilderness management (U.S. Bureau of Land Management Lander Field Office 2003). Neither area was recommended for wilderness status in the 1992 report to Congress (U.S. Bureau of Land Management Lander Field Office 2003). Therefore, without wilderness status these provisions are not binding. Coalbed methane development is currently being aggressively pursued in the Powder River, Bighorn, Green River, Hams Fork, and the Hanna coalfields of Wyoming (Carroll personal communication

2003, Wyoming State Geological Survey 2003). The range of *A. gilviflorus* var. *purpureus* is on the border of the Wind River coalfield that has deposits of coalbed methane at less than 5,000 feet at its outer-most edges (Wyoming State Geological Survey undated). These deposits appear to be a desirable target in the future. Other mineral exploration appears to be low at the present time, but renewed interest in uranium mining in deposits of the Wind River Formation could impact populations of this species in the future (Fertig 1998).

It is unclear how global climate change may affect this species. In the last one hundred years, the average temperature in Laramie, Wyoming has increased 1.5 °F, and precipitation has decreased by approximately 20 percent in the Dubois region (U.S. Environmental Protection Agency 1998). Over the next century, the climate in Wyoming may continue to change (U.S. Environmental Protection Agency 1998). Based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), a model that accounts for both greenhouse gases and aerosols, by 2100 temperatures in Wyoming could increase by 4 °F in spring and fall (with a range of 2 to 7 °F), 5 °F in summer (with a range of 2 to 8 °F), and 6 °F in winter (with a range of 3 to 11 °F). Precipitation is predicted to decrease slightly in summer (with a range of 0 to 10 percent), increase by 10 percent in spring and fall (with a range of 5 to 20 percent), and increase by 30 percent (with a range of 10 to 50 percent) in winter (U.S. Environmental Protection Agency 1998). The consensus appears to be that weather will become more extreme. That is, the amount of precipitation on extreme wet or snowy days in winter is likely to increase and the frequency of extreme hot days in summer will increase because of the general warming trend. These changes may not have a profound affect on *Astragalus gilviflorus* var. *purpureus* because it is apparently adapted to harsh and xeric conditions. An optimistic scenario is that even if its current sites become too inhospitable it will be able to colonize sites that have become too xeric for other plant species. Alternatively, one can conjecture that invasive non-native weed species will have become more established and, if the current sites become too inhospitable even for *A. gilviflorus* var. *purpureus*, the species will suffer site-by-site extirpation.

Few comments can be made on the influence of demographic stochasticity on individual populations because there is no information on the survival probability of individuals at any given life-stage, age, or size (see Demography section). Since there are relatively few seedlings, any event that causes mass extermination of mature plants would likely be injurious to the species. However, a robust seed bank may mitigate such adverse consequences. The size of the seed bank and seed longevity, both as yet unknown, directly relate to the species' ability to tolerate mass disturbance of adult individuals (see Reproductive biology and autecology and Demography sections). There appears to be one very large population and several small populations. Because there is no information on the minimum size of a sustainable population it is impossible to speculate on the viability of those small populations. From a genetic perspective, natural populations often behave as if they were smaller than a direct count of individuals would suggest (Barrett and Kohn 1991). Without genetic evaluation it is also essentially impossible to specifically comment on its genetic vulnerability. Locally endemic species, including some *Astragalus* species, tend to exhibit reduced levels of polymorphism (Karron 1991, Gitzendanner and Soltis 2000). If there is an absence of appreciable cross-pollination, the short dispersal distances suggest that widely spaced populations may be genetically isolated (see Reproductive Biology and Autecology section). However, Gitzendanner and Soltis (2000) emphasized that considering that rare species lack genetic variation is an overgeneralization and that each species must be treated as a unique entity. If the species is predominately self-pollinated and there is little genetic exchange among the occurrences, then although there may be considerable genetic variation between populations, there may be little variation within populations. There are several instances where rare species of *Astragalus* show significant genetic differences between populations (Karron et al. 1988, Lavin and Marriott 1997).

The envirogram of **Figure 8** is constructed to outline some of the factors that directly impact *Astragalus gilviflorus* var. *purpureus*. The lack of direct studies on this species leads to stretching the significance of observations and forming opinions from inference rather than fact. Inferences must be tested and are inappropriate to use in predicting responses to management decisions. At the current time malentities and threats tend to be site specific. Disturbance is included in the envirogram, but the type and levels that are actually deleterious to long-term sustainability need to be defined. Disturbance can be of two types: direct impacts and indirect impacts that are the consequences directly attributable to the initial disturbance. Direct trampling by hikers, large mammals, and off-road vehicle traffic can physically disturb plants. Disturbance also contributes to soil erosion and opens areas to invasion by weed species that may eventually result in loss of habitat. Invasive plant species (weeds)

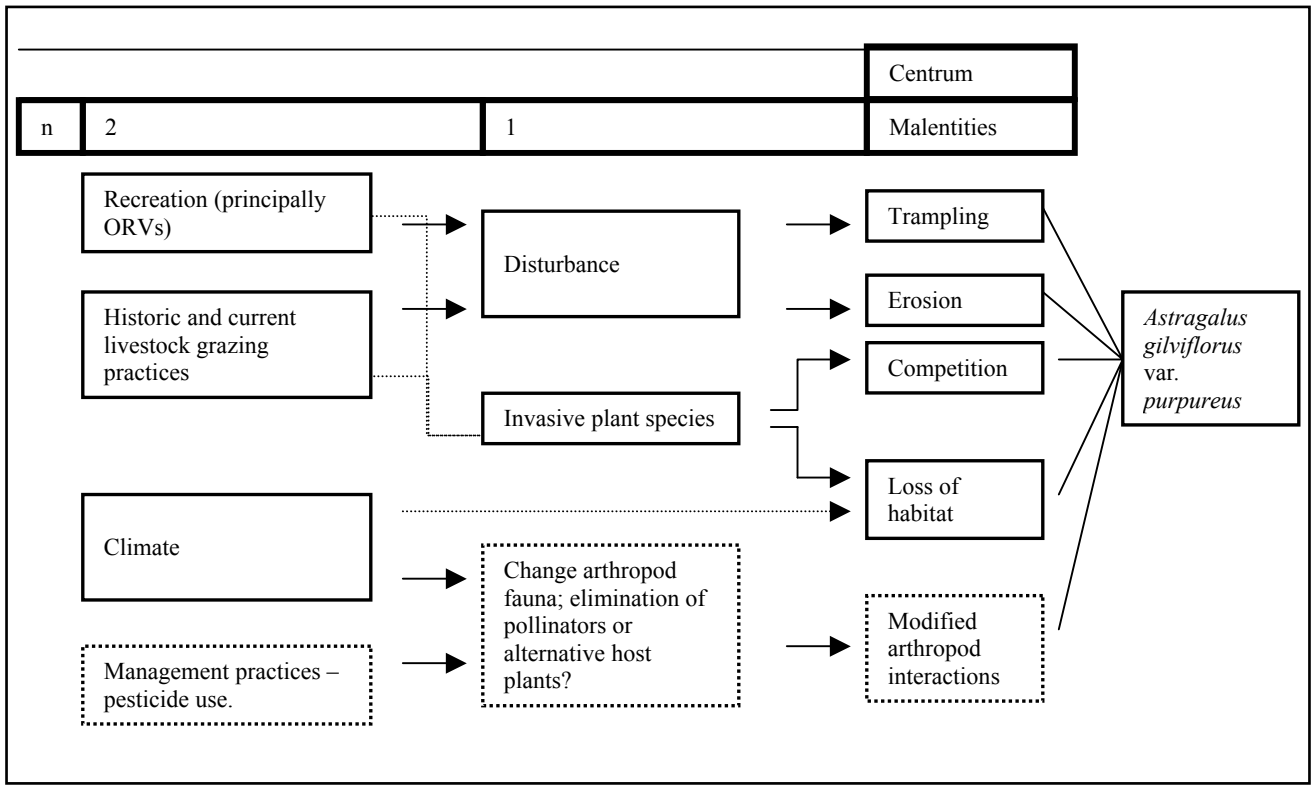

Figure 8. Envirogram outlining the malentities and threats to *Astragalus gilviflorus* var. *purpureus* (also see Community ecology section). The dotted boxes indicate speculative malentities.

directly compete for resources as well as often secreting allelopathic substances into the soil. An important consideration, indicated by a faint dotted line in the envirogram, is the significant contributions that ORVs and large mammals make to the spread of weed species. The impacts of potential colonization by invasive plant species that will be exacerbated by anthropogenic disturbances and possible climate change also should not be underestimated in any area. Threats associated with herbivory by livestock and native ungulates have been included although at current levels the visible impacts are few (Fertig 1998). It is not clear that pollinators are important to this species. However, if the species is cross-pollinated, then their loss or change in abundance is a potential threat. The suite of arthropod species may alter in response to climate change but also as a consequence of some management practices. For example, some pesticides are very detrimental to bees (Larmer 1997). In addition, sheep grazing can destroy wild bee nests (see Community Ecology section). The threats to *A. gilviflorus* var. *purpureus*, including those concerned with global climate change, are likely largely dependent upon the extent and intensity of the activity and the rarity of the species at the time the threat is incurred. These factors require further study.

In summary, the threats that are currently evident on the Shoshone National Forest include habitat modification and competition from invasive non-native plant species. These threats appear to be at relatively low levels.

Conservation Status of the Species in Region 2

Fertig (1998) concluded that *Astragalus gilviflorus* var. *purpureus* is apparently secure in the short term. There is no evidence that the distribution or abundance of *A. gilviflorus* var. *purpureus* is significantly changing. Loss of habitat does not appear to be of significant concern, at least in the short term (Fertig 1998). The majority of occurrences appear to be on BLM, private, and Tribal land (**Table 1**). Currently some of the areas in which it occurs on BLM land have wilderness status although the continuance of wilderness status for some of these areas is not assured (see Threats section). One occurrence has been described on the Shoshone National Forest where there is considerably more potential habitat that has yet to be surveyed (Fertig 1998).

Astragalus gilviflorus var. *purpureus* occurs in the Whiskey Mountain area in the Shoshone National Forest, which has wilderness status (see section entitled Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies). Wilderness is defined in the law as "an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions..." (Environmental Media Services 2001). In general, the Wilderness Act prohibits commercial activities, motorized access, roads, bicycles, structures and facilities and sometimes limits the size of groups in wilderness areas (Environmental Media Services 2001). However, some of the management guidelines for wilderness are modified. For example, pursuing water development, seeding, fertilizing, snow fencing, and managing vegetation by prescribed burning is permitted within the Whiskey Mountain area because it is prime winter range for bighorn sheep (USDA Forest Service 1986). The consequences of such actions to *A. gilviflorus* var. *purpureus* populations are not formally evaluated because the taxon is not a sensitive species by Region 2 of the USFS. On the Shoshone National Forest, the known occurrences are adjacent to, or extend into, populations on land managed by Wyoming Fish and Game Department and the BLM. All three agencies cooperate in area management (Breckenridge personal communication 2003). This cooperation is very important because bighorn sheep migrate throughout the region.

Potential Management of the Species in Region 2

Implications and potential conservation elements

Existing management plans have not specifically addressed this species, and there are no experimental data on the response of this taxon to any management actions. Sustainability of *Astragalus gilviflorus* var. *purpureus* may rely on relatively long-lived mature individuals, and thus management practices that increase either the frequency or intensity of natural perturbations or that provide additional stresses may significantly negatively impact population viability. Observations made in 1996 suggest that *A. gilviflorus* var. *purpureus* is not adversely impacted by current levels of grazing by either domestic or native ungulates, but it may be vulnerable to disturbance by off-road vehicles (Fertig 1998). Its colonization of road cuts and apparent persistence in lightly disturbed sites suggest that it tolerates periodic disturbance. The problem is that there is little information on which to base predictions as to its response to specific disturbance types or levels. A fundamental gap in knowledge is that it is not known how disturbed areas are recolonized or whether plants are able to persist at disturbed sites. It does not grow in areas with high vegetation cover, and invasive weeds will thus likely contribute to loss of habitat. Weed control may be of significant importance in maintaining suitable habitat.

The majority of *Astragalus gilviflorus* var. *purpureus* individuals are found in one extensive population, which ranges across private land and land managed by the BLM and the Wyoming Fish and Game Department. This concentration in one area may increase the vulnerability of the species to environmental, anthropogenic, and genetic stochasticity (see Threats section). The proportion of plants on USFS land is small. However, there is considerably more habitat that has not yet been surveyed, and so there is the potential for a larger population. In addition, the value of small populations should not be underestimated. When considering which populations to protect it is important to remember that rare species often exhibit genetic differences between populations (see Threats section). Even though small populations are often considered genetically depauperate as a result of changes in gene frequencies due to inbreeding or founder effects (Menges 1991), Karron et al. (1988) demonstrated that alleles that were absent in larger populations were only found in a small population of *A. osterhouti*. Therefore, in order to conserve genetic variability, in the absence of genetic data, it is likely most important to conserve as many populations as possible in as large a geographic area as possible and to remember that a large population is not automatically better.

The current occurrences on the Shoshone National Forest are a relatively small fraction of the total number of plants and the total number of known occurrences. However, although only a small percentage of the known populations grow on land managed by the USFS, this proportion may become larger as other populations are impacted by recreation and development activities.

Tools and practices

Documented inventory and monitoring activities are needed for this species because there is little information on population structure and the persistence or colonization rate of individuals.

Species inventory

More surveys would facilitate determining the abundance of *Astragalus gilviflorus* var. *purpureus*. The current field survey forms for endangered, threatened, or sensitive plant species used by the Gunnison National Forest, the Colorado Natural Heritage Program, and the Wyoming Natural Diversity Database all request the collection of data that is appropriate for inventory purposes (see Reference section for internet addresses). The number of individuals and the area they occupy are important data for occurrence comparison. The easiest way to describe populations over a large area may be to count patches, making note of their extent, and to estimate or count the numbers of individuals within patches. A statement like "many individuals" tends to be subjective, and on the field survey form an estimation of the number observed is helpful. Collecting information on reproductive status and phenology, for example the dates flowering is observed, is also valuable in assessing the vigor and fecundity of a population. Observations on habitat should always also be recorded.

In the case of new occurrences it is useful to collect a specimen and to deposit it in a curated herbarium, for example at a university. However, it is not desirable to take specimens from small populations. The advisability of collecting a specimen needs to be considered on a species-specific and site-specific basis. A general guideline may be that a specimen can be collected if there are at least 50 individuals or greater than 20 flowering plants observed. If there are fewer than 20 flowering individuals, a close-up colored photograph and an additional photograph of the plant to show its habitat should be taken in order to document the occurrence. It is best if the collected specimens have both flowers and fruit. Each site should be mapped and, if possible a global positioning system instrument should be used to determine its coordinates (UTM or latitude/longitude), so that it can be easily relocated. Information on plant taxa deposited with local programs within the NatureServe (formerly Natural Heritage) Network contributes to its conservation database (NatureServe 2004).

Habitat inventory

The available information on habitat suggests that it is possible to make a general inventory of areas that have the potential for colonization (Carroll personal communication 2003). There are no studies that relate the abundance or vigor of populations to specific habitat conditions, and so defining the quality of the habitat or the likelihood of colonization is less straightforward and an unrealistic expectation with the currently available information. The patchy and sparse distribution pattern of *Astragalus gilviflorus* var. *purpureus* suggests that certain microclimate conditions need to be met in order to support plants and that interspecific competition, or rather the lack of it, is important to its ecology.

Population monitoring

No monitoring or demographic studies have been reported. Lesica (1987) has discussed a technique for monitoring non-rhizomatous, perennial plant species using permanent belt transects. He also described life stage or size classes and reproductive classes that would be appropriate to consider for *Astragalus gilviflorus* var. *purpureus* (Lesica 1987). He applied the technique to *A. scaphoides*, which grows at moderate to low densities. Following Lesica's guidelines, Rittenhouse and Rosentreter (1994) established similar permanent transects for making demographic studies and monitoring *A. amblytropis*, an endemic of east-central Idaho. They also described a modified transect method that they used in the second year of study that increased the sample size. The latter method marked each plant individually within 1 m of the transect line. Permanent transects appear to be the most accurate way to study long-term trends. Elzinga et al. (1998) and Goldsmith (1991) have discussed using a rectangular quadrant frame along transect lines to monitor effectively the clumped-gradient nature of populations.

Establishing photo points and taking appropriate photographs are very helpful in describing site conditions. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides or even hardcopies, as in 50 years time the technology to read memory sticks and CDs may no longer be available.

Habitat monitoring

Habitat monitoring in the presence of plant occurrences should be associated with population monitoring protocols. Descriptions of habitat should always be recorded during population monitoring activities in order to link environmental conditions with abundance over the long-term. Conditions several years prior to the onset of a decrease or increase in population size may be more important than conditions existing during the year the change is observed. Current land use designation and evidence of land use activities are important to include with monitoring data. For example, where possible it should be noted if an occurrence is on an active grazing allotment even though no use by

livestock is observed. Because there is an understanding of what areas represent potential habitat, it may be possible to monitor total habitat conditions. For example, one could observe changes in vegetative cover and erosion patterns in apparently appropriate, but uncolonized, habitat that is near to known populations.

Population or habitat management approaches

There have been no systematic monitoring programs for the occurrences in protected areas, and therefore the benefits of protection cannot be evaluated. Potential beneficial management practices that have been implemented within the Shoshone National Forest include restricting recreational vehicle traffic, as per wilderness guidelines, but the consequences have not been documented. Because *Astragalus gilviflorus* var. *purpureus* is not designated sensitive by the USFS Region 2, the impacts of management practices have not been evaluated.

Information Needs

At the present time, *Astragalus gilviflorus* var. *purpureus* appears to be a naturally uncommon species restricted to specific soil and community types within a limited geographic range. It does not appear to have significantly declined in abundance over the past few decades, although one cannot say with certainty that it has not experienced a decline in the last century. Additional potential habitat, for example on the Shoshone National Forest, BLM land, and the Wind River Indian Reservation needs to be surveyed. Monitoring pre-existing sites is essential in order to understand the implications of existing and new management practices. Where management practices are likely to change, inventory taken to collect baseline data can be compared to data collected during periodic monitoring conducted after the new policy is initiated. In particular, colonies in high disturbance areas, for example areas that receive ORV, mountain bike, and hiker use need to be monitored because, currently, trend data are not available to determine the long-term survival of plants at disturbed sites. The impacts from accelerated erosion and increased soil compaction may take several decades to become apparent. Therefore, inventory and periodic monitoring of existing sites appear to be the most important needs.

In addition to monitoring and inventorying this species, there are unanswered questions about its biology and ecology that would influence its management. Differentiating between whether plants colonize or persist at sites that have experienced disturbance is an important aspect of this species' ecology and may be central to its management. The observation that most individuals appear long-lived suggests that persistence in adult form is critically important to this species' life history. In this case, some protections may need to be afforded the adult plants. Alternatively, observations that the plant grows in disturbed areas such as roadcuts suggest that it can colonize such areas relatively rapidly and act as a pioneer species. In this case, additional studies need to be carried out to determine if the size of the seed bank or the fecundity of nearby occurrences is of greater importance. The rate at which it colonizes potential habitat is unknown, and there may be a substantial difference between recolonizing an area from a pre-existing seed bank rather than colonizing an area through seed dispersal. The spatial dynamics within populations are also unknown. It is currently understood that substrate and vegetative cover are primary factors that limit population size and abundance and that contribute to the variable occurrence sizes. This should be confirmed experimentally. The rate and mode of colonization and microhabitat preferences influence how populations can recover after significant disturbance (see Threats section).

Astragalus gilviflorus var. *purpureus*' ability to tolerate interspecific competition is speculated as being very low, and non-native invasive species are likely to pose a significant threat. This theory should also be confirmed. For example, it would be interesting to monitor the occurrence presently associated with *Melilotus* spp. to determine the long-term patch dynamics of the two species. This occurrence is not on USFS land, but there may be occurrences in similar circumstances within the Whiskey Mountain unit. The area in the vicinity of the trailhead located where Torrey Creek exits the Shoshone National Forest is especially potentially vulnerable to weed encroachment.

Understanding the reproductive system and the genetic variability of this species would permit making biologically informed management decisions. The extent of genetic variability between populations is important when considering the potential genetic losses associated with loss of individual populations. If genetic variability exists between populations, establishing colonies using seeds or plants from the impacted populations may conserve genetic resources. In conjunction with such studies, research would have to be carried out to determine if transplantation or establishment from seed is even feasible. This species may be recalcitrant to germination and/or establishment. Barneby (1964) noted that it is not long-lived under garden conditions, which suggests

that the plants require specific conditions that are either difficult to meet or non-obvious. The degree to which colonies interact also influences the delineation of discrete occurrences, if occurrences are equated with populations (see Distribution and abundance section). The reproductive method of this species also needs to be clarified to appreciate the importance of pollinators. Although, by comparison with other rare *Astragali*, *Astragalus gilviflorus* var. *purpureus* is likely self-pollinated, it may also be cross-pollinated. Management practices, for example grazing policies, may need to be modified if specific pollinators are found to be essential for cross-pollination (see Community ecology section). In addition, prescriptive pesticide applications may need to be reviewed to ensure that the specific pollinators of *A. gilviflorus* var. *purpureus* are not targets of chemicals used to control other species.

In summary, information needs for *Astragalus gilviflorus* var. *purpureus* include:

- Conducting additional surveys within its range, for example on the Shoshone National Forest, BLM land, and the Wind River Indian Reservation
- Monitoring pre-existing sites
- Determining whether plants colonize and/or persist at disturbed sites
- Ascertaining the extent to which the taxon tolerates interspecific (weed) competition
- Understanding the reproductive system
- Identifying the genetic variability of the taxon

DEFINITIONS

Aglycone — The non-sugar component of a glycoside molecule that results from hydrolysis of the molecule (The American Heritage® Dictionary of the English Language. 2000. Fourth Edition. Houghton Mifflin Company, Boston, MA).

Autogamous — Self-fertilizing.

Binomial — Derived from the binary nomenclature system in which the name of a species consists of a generic name (genus) and a specific epithet (species). Trinomial refers to infraspecific taxa, that is, varieties or subspecies. The authorship of the botanical names proposed for *Astragalus gilviflorus* and the variety *purpureus* are as follows:

Astragalus triphyllus Pursh, Fl. Amer. Sept. 2:740. 1814

Phaca triphylla Eaton & Wright, N. Am. . 351. 1840

Phaca caespitosa Nutt. Gen. 2:98. 1818

P*haca argophylla* Nutt in T. & G. Fl. 1:343 1838 [note: this is not *Astragalus argophylla*]

Astragalus gilviflorus Sheldon var. *purpureus* Dorn [see Dorn 1988]

Orophaca triphylla (Eaton & Wright) Britton var. *purpurea* (Dorn) Isely [see Isely 1998]

See Systematics and synonymy section for additional information.

Caudex — The perennial, often woody, region between the base of the stem and the top of the roots that slowly elongates and is commonly branched.

Flavone — A compound, $C_{15}H_{10}O_2$, and the parent substance of a number of important yellow pigments, occurring on the leaves or in the stems and seed capsules of many primroses (The American Heritage® Dictionary of the English Language. 2000. Fourth Edition. Houghton Mifflin Company, Boston, MA).

Glycoside — Sugar derivative of a chemical. Any of a group of organic compounds, occurring abundantly in plants, that yields a sugar and one or more non-sugar substances on hydrolysis (The American Heritage® Dictionary of the English Language. 2000. Fourth Edition. Houghton Mifflin Company, Boston, MA).

Marcescent — Dry and persistent. Withering, but not falling off, as a blossom that persists on a twig after flowering (The American Heritage® Dictionary of the English Language. 2000. Fourth Edition. Houghton Mifflin Company, Boston, MA).

Phalanx — In North America the species in the genus Astragalus are divided into "phalanxes" (which can be thought of as "sub-genera") that in turn are divided into sections and sometimes further into sub-sections (Barneby 1964).

Polylectic — Applied to bees that visit different species of plants for pollen (and nectar) compared to oligolectic that refers to a bee which visits only one, or a few related, plant species for pollen.

Ranks — NatureServe and the Heritage Programs Ranking system. The status of infraspecific taxa (trinomials) are indicated by a "T-rank" following the species' global rank. Rules for assigning T-ranks follow the same principles as those for binomials. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1. G5T2 indicates *Astragalus gilviflorus* (G5) is a widespread and common species but var. *purpureus* (T2) is "imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50)." S2 indicates it is "imperiled in the nation or subnation because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000)". For further information see NatureServe at internet site: http://www.natureserve.org/explorer/granks.htm.

Section — In North America the species in the genus *Astragalus* are divided into "phalanxes" (which can be thought of as "sub-genera") that in turn are divided into sections and sometimes further into sub-sections (Barneby 1964).

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