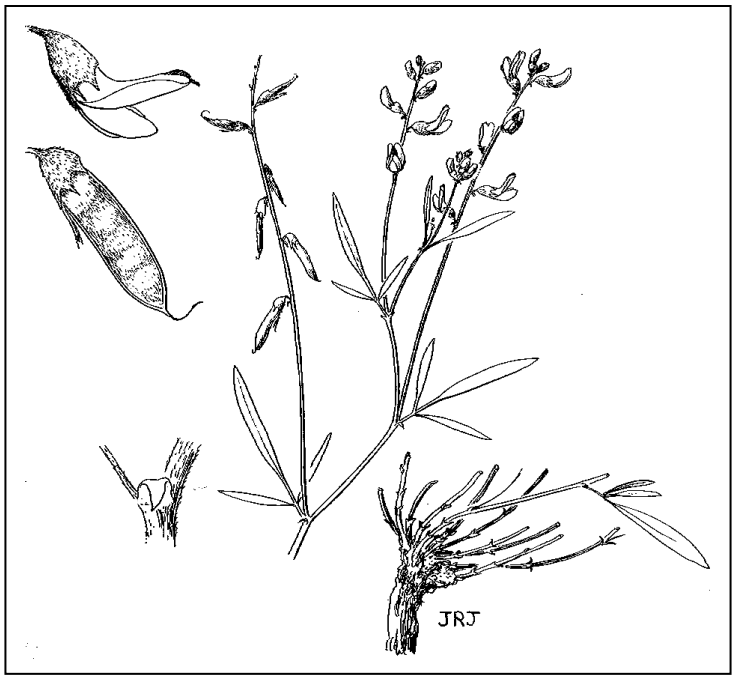
STATUS OF *ASTRAGALUS DIVERSIFOLIUS*

(MEADOW MILKVETCH)

IN SOUTH-CENTRAL WYOMING



Prepared for the Bureau of Land Management
Rawlins Field Office and Wyoming State Office

By Bonnie Heidel
Wyoming Natural Diversity Database
Dept. 3381, University of Wyoming
1000 E. University Ave.
Laramie, WY 82071

May 2009

Cooperative Agreement No. KAA041037, Modification No. 5

ABSTRACT

Systematic surveys of Meadow milkvetch (*Astragalus diversifolius*) were conducted in 2008 using mapping of playa vegetation and digital orthophotographs to identify potential habitat across south-central Wyoming. The species is now known from three extant occurrences in the Great Divide Basin, totaling about 8000 plants that span about 187 acres. The historic occurrence in the Green River Basin was not relocated. The results provide the basis for ranking *Astragalus diversifolius* and assessing its status in the state. The new Wyoming occurrences greatly broadened the known species' distribution. No immediate impacts have been identified under energy and mineral development in the state, but there are a number of existing and potential developments in surrounding lands to which the species may be vulnerable.

Report citation:

Heidel, B. 2009. Status of Meadow milkvetch (*Astragalus diversifolius*) in south-central Wyoming. Prepared for the Bureau of Land Management, Rawlins and Rock Springs Field Offices. Wyoming Natural Diversity Database, Laramie, WY.

Cover: *Astragalus diversifolius*, by Jeanne R. Janish. From: *Vascular Plants of the Pacific Northwest*, Hitchcock L.C., A. Cronquist and M. Ownbey. 1969. University of Washington Press. Seattle, WA.

Table of Contents

APPENDICES

FIGURES AND TABLES

ACKNOWLEDGEMENTS

Stanley Welsh (Brigham Young University) kindly provided species confirmation and information on Utah collections. Lynn Kinter, Lisa Hahn, and Beth Colket (Idaho Conservation Data Center), Ben Franklin (Utah Natural Heritage Program), and Jim Morefield (Nevada Natural Heritage Program) graciously provided data exports, comments or remarks.

Joy Handley (Wyoming Natural Diversity Database; WYNDD) assembled digital orthophotograph sets for fieldwork, prepared the rangewide distribution map, digitized the maps of survey extent, and exported the Wyoming occurrence records. Field surveys were conducted with the able assistance of Jill Larson (WYNDD), Frank Blomquist (BLM), and Phong-Van Nguyen (BLM).

The facilities and resources of the Rocky Mountain Herbarium were fundamental to this study and are gratefully acknowledged. Copyright permission for WYNDD to reprint the illustration of *Astragalus diversifolius* was obtained from the University of Washington Press.

Critical project support and coordination were provided by Frank Blomquist (BLM – Rawlins Field Office), under a challenge cost-share agreement between BLM and WYNDD.

I. INTRODUCTION

Astragalus diversifolius was first collected by Thomas Nuttall on the 1834 Wyeth Expedition from "Sandy plains of the Colorado of the West, near the sources of the Platte", generally referring to the Green River Basin, Wyoming, *Nuttall s.n.* (holotype at BM, isotypes at GH, K, NY, PH). In 2007 it was found in Wyoming at the Chain Lakes area of the Great Divide Basin, Sweetwater County (Heidel 2007, 2008, Heidel and Larson in press). This is about 423 km (265 mi) from the nearest historical station in Bingham County, Idaho and about 450 km from the nearest extant station in Juab Co., Utah. *Astragalus diversifolius* is sparsely distributed in east-central Idaho, at the southwestern edge of the Salt Lake Desert in eastern Juab and western Tooele cos., Utah, and in Spring Valley in southern White Pine Co., Nevada (Barneby 1964, Welsh 2007; Tiehm 1984, Idaho Natural Heritage Program 2009, Utah Natural Heritage Program 2009, Morefield 2001).

The rediscovery *Astragalus diversifolius*, its global rank of globally imperiled (G2), and its sensitive species status on other federal lands where it occurs (Idaho BLM, Region 4 of U.S. Forest Service), were considered when proposing baseline survey to determine its state status. This report summarizes results of the first systematic survey for *Astragalus diversifolius* in Wyoming. This work was conducted under a challenge cost-share agreement between the Bureau of Land Management (BLM) and Wyoming Natural Diversity Database (WYNDD).

II. METHODS

Information on the habitat and distribution of *Astragalus diversifolius* was compiled from out-of-state sources (Idaho Conservation Data Center 2008, Utah Native Plant Society 2003-2008) to interpret the Wyoming collection records and develop a framework for systematic survey. The two original discovery sites are located at or near the margins of areas mapped as having playa vegetation in Gap Analysis (Merrill et al. 1996), so all polygons mapped as playa vegetation and surrounding lands became search targets. The distribution of playa vegetation polygons in Wyoming are concentrated in, but not entirely limited to, the 40-mile center of the Great Divide Basin, much of which occurs on BLM –administered lands of the Rawlins and Rock Springs Field Offices in Sweetwater County (Appendix A).

In addition, digital orthophotographs were used for identifying potential habitat. The habitat signatures at the two original discovery sites on digital black and white aerial photographs included groundwater discharge zones at margins of alkali lakes (dark, discrete band bordering glaring white, unvegetated lakebed) and alkaline meadows downwind from alkali lakes (sparsely-vegetated, fine-textured zones; also cross-checked on topographic maps for topographic context). Photointerpretation covered all areas mapped as playa vegetation in Carbon and Sweetwater counties, plus all intervening habitat, and sites identified by BLM staff with similar attributes on the ground but not mapped as playa, including sites to the north (Picket Lake) and the east (Boggy Meadows).

In preparation for fieldwork, a set of all U.S.G.S. topographic maps with target sites were assembled, and all digital orthophotograhs were printed out at quarter-quad scale (almost the same scale as U.S.G.S. 7.5' maps). In addition, BLM surface management maps (1;100,000) were used as reference for surface management and navigation.

Field surveys were conducted in July 3-4, 13, and 23-25; August 26, and September13 by 1-3 person teams. At each site, the extent of local distribution was mapped by use of Geospatial Positioning Systems (gps). Data on population numbers, habitat, and species biology were collected using WYNDD plant survey forms. Photographs and vouchers were taken. One soils data sample was collected in 2007 as part of the original discovery. Surveys were conducted in over 50 sections with alkaline meadow habitat; including the nine sections where it was found, and all are represented as survey routes (Appendix B). The two original discovery sites were surveyed in greater detail and additional occurrences or greater connectivity was sought between them in traversing both sides of a six-mile valley segment between the Wamsutter-Crooks Road and the Riner Cutoff Road, where no additional habitat was found.

Immediately after the 2008 field season, a representative set of voucher specimens (2007-2008 specimens, representing material in different phenological stages) was sent for confirmation to Stanley Welsh, author of a treatise on the *Astragalus* of North America (2007), and co-author of the pending *Astragalus* treatment in Flora of North America. In his verification remarks, he noted that they are a near-match for those from Utah and consistent with all species characteristics (Stanley Welsh person. commun. to B. Heidel 2008).

Also after the field season, expanded information on the habitat and distribution of *Astragalus diversifolius* was compiled from out-of-state sources (Idaho Natural Heritage Program 2009, Morefield 2001, New York Botanical Garden 2009, Utah Natural Heritage Program 2009, and Utah Native Plant Society 2009) as context for survey results.

III. SPECIES INFORMATION

A. Classification

1. Scientific name: *Astragalus diversifolius* Gray

2. Synonyms: *Homalobus orthocarpus* Nutt. ex T.& G, not *A. orthocarpus* Boiss.; *A. campestris* var. *diversifolius* (Gray) Macbr.; *A. junceus* var. *orthocarpus* (Nutt.) Jones; *A. junceus* var. *diversifolius* (Gray) Jones, *A. ibapensis* Jones, *A. reclinatus* Cronq.

3. Common name: Meadow milkvetch

4. Family: Fabaceae

5. Size of genus: The *Astragalus* genus may be comprised of over 2000 species worldwide making it the largest genus of flowering plants according to some authors (Polhill 1981, Mabberly 1987). It is certainly the largest genus in the Fabaceae (Bean family). There were estimated to be at least 375 species in North America, with 156 in the Intermountain Region (Barneby 1989).

6. Phylogenetic relationships: The *Astragalus* genus is believed to be a mesophytic genus of the Northern Hemisphere, with a proliferation by adaptive radiation into arid and hostile habitats (Barneby 1989). *Astragalus diversifolius* resembles *A. convallarius* in that both are inconspicuous species of rush-like growth, and these two species have been treated as related

varieties in earlier taxonomic treatments. If the mesophytic affinity is ancestral in this particular case, then it is plausible that *A. diversifolius* is ancestral and that *A. convallarius* is derived. In general, the phylogeny within the genus is highly complex (Sanderson 1991). The Section Genistoidei includes both *A. diversifolius* and *A. convallarius* (Barneby 1964).

B. Present legal or other formal status

1. National

a. Legal status: The Idaho Bureau of Land Management recognizes *Astragalus diversifolius* as Sensitive, and in Idaho, it occurs on the Upper Columbia – Salmon Clearwater District of BLM. The Intermountain Region (Region 4) of the U.S. Forest Service also recognizes *A. diversifolius* as Sensitive, and in Idaho it occurs on the Caribou-Targhee National Forest. It is not on national forests of the Intermountain Region in Wyoming.

b. Heritage rank. *Astragalus diversifolius* is ranked G2, globally imperiled.

2. State

a. Legal status: This species is not protected by state government statutes in any of the states within its range.

b. Heritage rank: *Astragalus diversifolius* was ranked SH in Wyoming when it was known from one collection by Thomas Nuttall, dating back to 1834, and interpreted as representing a location in the Green River Basin. The state rank was updated to S1 in 2007 with its discovery in the Chain Lakes area. The state rank was reviewed in 2008 upon completion of status surveys, retaining the S1 rank. It is also ranked S1 in Nevada (Nevada Natural Heritage Program 2009) and in Utah (Utah Natural Heritage Program 2009), and S2 in Idaho (Idaho Natural Heritage Program 2009).

C. Description

1. General non-technical description: Meadow milkvetch is a perennial herb with few to many slender, prostrate or decumbent stems 20-50 cm long radiating from the root crown. The linear to narrowly oval leaf blades are 2-5.5 cm long, and are composed of 1-5 grass-like leaflets, which are 2-5 mm broad. The terminal leaflet is much longer than the lateral leaflets and continuous with the leaf stalk. The inflorescence is a loose raceme of 2-8 flowers. The flowers are white or cream-colored and often faintly lilac-tinged, with calyx tubes 3.2-5.4 mm long. The fruits are oblong (10-17 mm x 3-4 mm) (Barneby 1964, 1989; Dorn 2001, Fertig et al. 1994, Hitchcock and Cronquist 1961, Heidel 2008; Figures 1 and 2).

2. Technical description: Perennial from a slightly subterranean crown, with clustered, decumbent, flexuous, mat-forming stems 2-5 dm, strigulose. Leafstalk 2-6 cm, flattened, 1-2 mm broad; leaflets 1-5(-7), oblanceolate to linear, 3-4.5 cm (or the terminal to 6.5 cm), grass-like, flat, confluent with the rachis; upper leaves sometimes with reduced leaflets or completely phyllodial; lowermost stipules connate. Inflorescence ascending, generally exserted, loose raceme with 4-8 ascending to spreading flowers; pedicels in fruit 2.5 mm. Corolla tube 3.2-5.4 mm; lobes 1-2 mm. Corolla 10-13 mm, white, ochroleucus or with some lavender. Ovules 10-15 m. Fruits pendulous or spreading, sessile or nearly so, unilocular or with an incipient septum to

0.5 mm, persistent, dehiscent; body oblong to oblong-oblanceolate, straight or slightly decurved, laterally compressed, 10-18 mm x 3.5 mm; valves thin, strigulose (Barneby 1989, Iseley 1998).

Figure 1. *Astragalus diversifolius*, by Jeanne R. Janish. From: *Vascular Plants of the Pacific Northwest*, Hitchcock L.C., A. Cronquist and M. Ownbey. 1969. University of Washington Press. Seattle, WA.

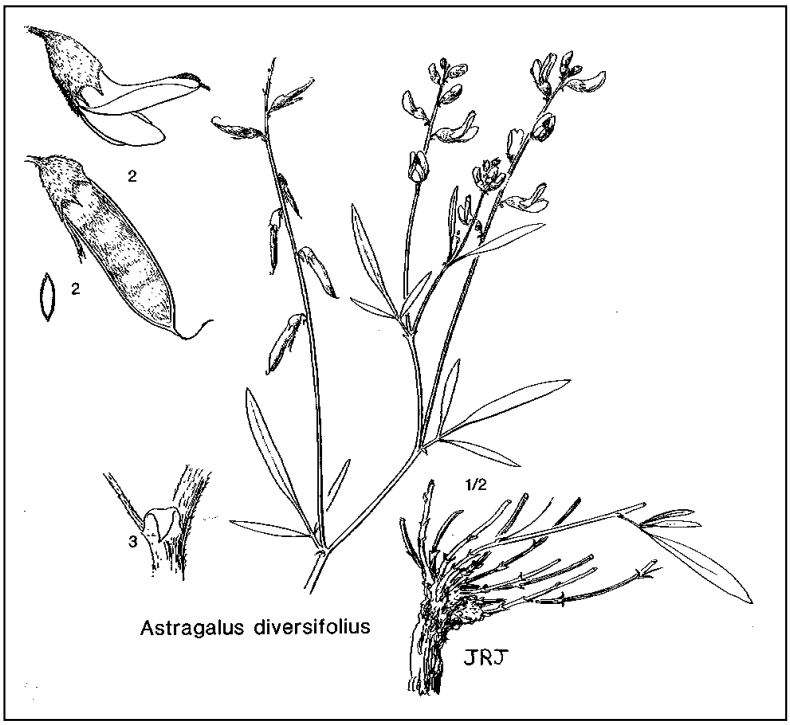


Figure 2. *Astragalus diversifolius* flowering and fruiting specimen, collected 26 August 2008, by B. Heidel.

3. Local field characters: The slender, often sprawling, sparsely leafy habit of Meadow milkvetch makes this species relative easy to identify. However, these same features can make it difficult to see in the field, especially before or after flowering. The upright, narrow leaflets resemble blades of grass and the whole plant becomes seemingly hidden in the vegetation (Idaho Conservation Data Center 2008; Figures 3 and 4). Many Wyoming plants had undivided leaves, so the relative size of the terminal leaflet larger than the lateral leaflets was not consistently available for consideration. The tips of the decumbent or prostrate flowering stems often curve upward (see Figure 4), particularly in dense vegetation.

Figure 3. Prostrate growth form of a many-stemmed *Astragalus diversifolius* plant, by B. Heidel.

Figure 4. *Astragalus diversifolius* flower close-up, by B. Heidel.

4. Similar species: *Astragalus convallarius* (syn. *A. diversifolius* ssp. *campestris* var. *campestris*) has long, narrow fruits that are 2-2.5 mm wide and over 20 mm long. It grows upright or ascending, and occupies dry habitats. Leaf characteristics are difficult to distinguish when lateral leaflets are wanting, but *A. convallarius* generally has leaflets small and remote. However, exceptional plants have leaflets expanded, grasslike and up to 3 mm wide (Barneby 1989).

Astragalus convallarius was previously treated by Barneby (1947) as part of the *A. diversifolius* complex, *A. d.* var. *campestris*. A copy of the key presented by Barneby (1947) was made by C.L. Porter and filed in the folders of *A. convallarius* specimens at the Rocky Mountain Herbarium (RM), and with Porter's added comment made in 1948: "After studying our material and the specimens cited by Barneby – it would seem more reasonable to lump *A. convallarius*

under *A. diversifolius*. The color of flowers, the length of pods, the shape of pods (whether tapering at base or not), and the development of the leaves and leaflets, are so variable as to leave little basis for specific distinction." Barneby elevated *A. convallarius* to species level in more recent treatments (1964, 1989). Barneby (1989) noted: "This uncommon milkvetch has often been misinterpreted as a foliose form of the related *A. convallarius*, but it differs not only in the leaves but in the broad, short pod and distinctive ecology. The pod of Utah and Nevada populations, recently rediscovered by S. Goodrich and A. Tiehm, has the narrow, partial septum described by Jones (as *A. ibapensis*), a feature lacking or vestigial in Idaho; but the plants seem otherwise identical."

In Wyoming, Dorn (1977) originally treated *A. convallarius* as a synonym of *A. diversifolius*, later proposing treatment as a separate variety, *A. d.* ssp. *campestris* (Nutt.) Dorn var. *campestris* (Nutt.) Dorn (described in Dorn 1988). However, these two taxa are recognized as distinct at the species level in the current flora (Dorn 2001), following Barneby (1989). The most current Montana flora is Dorn (1984), it does not address taxonomy below the species level, and in it, *A. convallarius* is treated as a synonym of *A. diversifolius*. This is the basis for false reports of it in Montana as presented in the USDA PLANTS database.

5. Phenology: *Astragalus diversifolius* flowers in late June – August (September), fruits in mid July-August. Fruits are needed for positive identification. The earliest collection made in Wyoming was on 30 June 2007 in flower, when fruits were immature. The phenology of the species in 2007 was a week earlier than in 2008. In 2008 it seemed to have flowered and fruited continuously over the latter part of the growing season, based on observations in early and late July and in late August when flowers were still present (Figure 4).

The earliest phenology associated with collections of this species are from Nevada, when it was flowering in mid-June (17 June 1982 – Tiehm and Williams 7200 NY; and 13 June 1995 – Curto and Smith 1297 NY). It was recollected by Tiehm later in the same year he first discovered it (9 July 1982 – Tiehm and Tucker 7321).

D. Geographical distribution

1. Range: *Astragalus diversifolius* is known from east-central Idaho, the south edge of the Salt Lake Desert in eastern Juab and western Tooele counties, Utah; the Spring Valley area in southern White Pine County, Nevada, and the Great Divide Basin in Sweetwater County, Wyoming. There is one historical report from the Green River Basin in western Wyoming (Sweetwater or Sublette counties) collected by Thomas Nuttall. Barneby (1964) originally questioned whether Nuttall was really in Wyoming when he discovered this species in 1834, but later accepted western Wyoming as the type locality (Barneby 1989).

The extant Wyoming occurrences lie at the eastern limits of species' distribution. The closest extant occurrence is 456 km (285 mi) to the southwest in Juab Co., UT though there is a closer historic station 423 km (265 mi) to the northwest that is presumed extirpated in Bingham Co., ID (Figure 5). It is a regional endemic of the Great Basin, but with such discontinuities in its distribution that it might be more accurately characterized as a sparsely distributed species. The map of its distribution in Wyoming (Figure 6) does not include the historic collection by Nuttall, because the county location of the putative Green River Basin collection is uncertain.

Figure 5. Global distribution of *Astragalus diversifolius*

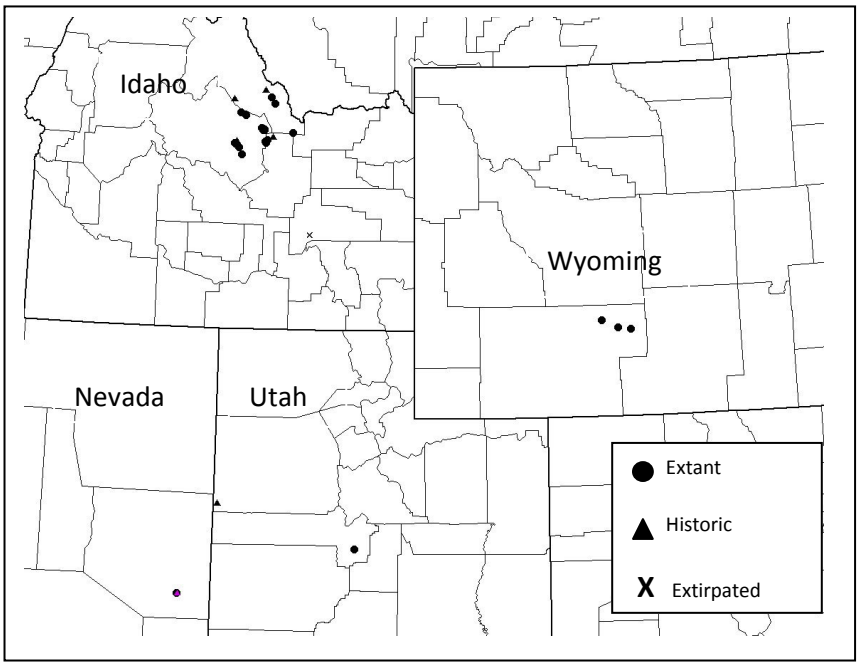
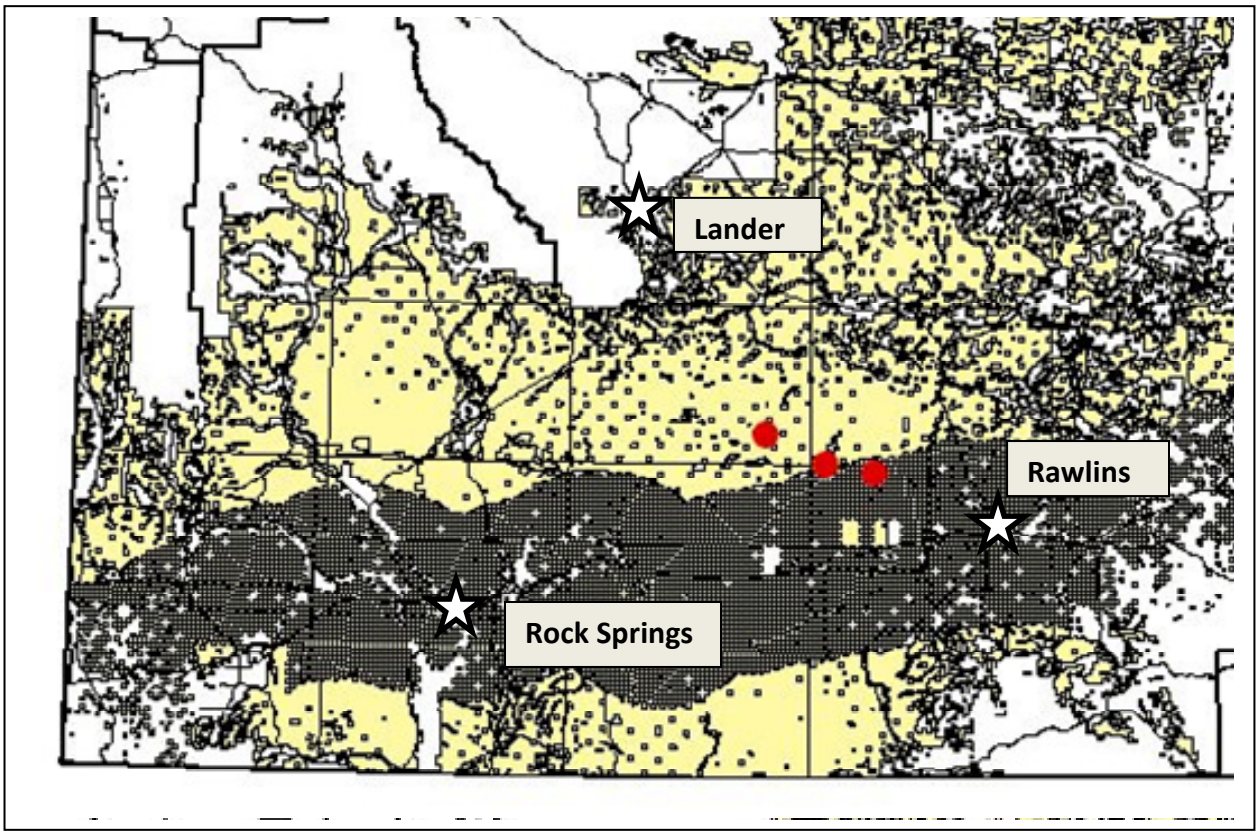


Figure 6. Wyoming distribution of *Astragalus diversifolius*



2. Extant sites: Three extant occurrences of *Astragalus diversifolius* are in the Great Divide Basin, Sweetwater County, Wyoming. They are locate about 20-40 air miles northwest of Rawlins (Table 1, Figure 6). In both Nevada and Utah *A. diversifolius* is known from one extant occurrence. The highest numbers of extant occurrences are in Idaho with 11 extant occurrences (Idaho Conservation Data Center, Nevada Natural Heritage Program 2009, Utah Natural Heritage Program 2009). The addition of three Wyoming occurrences brings the total number of extant occurrences to 16 by current record-keeping conventions.

Table 1. Location information for known occurrences of *Astragalus diversifolius* in Wyoming

EO#[1]	Site Name	County, State	Legal Description	Elevation (ft)	USGS 7.5' Quad	Location
003	Circle Bar Lake	Sweetwater Co., WY	T23N R93W S4 and 5	6500-6510	Hansen Lake	West end of Chain Lakes area, ca 0.5-1 mile east-northeast of Circle Bar Lake, ca 32 air miles north of Rawlins.
004	East Chain Lakes	Sweetwater Co., WY	T23N R91W S7 and 18; T23N R92 W S12 and 13	6545-6560	Larsen Knoll	East end of Chain Lakes area, ca 5 air mi north-northwest of Mud Springs Lake, ca 20 air miles northwest of Rawlins.
005	Mud Lake	Sweetwater Co., WY	T24N R95W S5 and 6; T25N R95W S33	6610-6620	Lost Creek Lake	North side of Mud Lake, ca 2.5 air miles south-southwest of Eagles Nest, ca 3 air miles east of intersection between BLM roads 3210 and 3219, ca 40 air miles northwest of Rawlins.

In 2008, the extent of the first two collection sites were surveyed in detail, surveys were conducted in extensive surrounding habitat, and additional playa landscapes were surveyed, locating one new occurrence.

3. Historical sites: The type collection by Thomas Nuttall was made on the 1834 Wyeth Expedition from "Sandy plains of the Colorado of the West, near the sources of the Platte." Context for interpreting the limited *Astragalus diversifolius* collection information is taken from Williams (2003) based on the journals of John Kirk Townsend, ornithologist who also accompanied the Wyeth Expedition. On June 9, 1834, the westbound Wyeth Expedition camped at Independence Rock. They followed what was later to become the Oregon Trail up the Sweetwater River and across South Pass, reaching the Green River by June 19, 1834. They made camp on the Green River from June 22 – July 2, before travelling up the Ham's Fork to the Bear River and over to Soda Springs, Idaho.

The timing of expedition travels and the phenology of *Astragalus diversifolius* are consistent with a collection in the Green River Basin, possibly while they camped on the Green River, or a

[1] The occurrence numbers start at 003 because they follow after the historic record, once remapped, which is not included in this table.

more westerly station. It is unlikely that it would have been found in flower before June 19 at any more easterly locale.

In addition, there is one historical record in Utah (western Tooele County) and five historical records in Idaho, including one that is considered extirpated (Bingham County).

4. Sites where present status not known: Most potential habitat in the Rawlins Field Office was surveyed in 2008, targeting areas mapped as playa vegetation. Mahoney Lake was not included among targets at the advice of BLM, and other putative playa wetlands at the perimeter of the basin were viewed as less likely to have well-developed alkaline vegetation, including a wetland at the head of Fivemile Ditch, a wetland in the Separation Creek drainage, and a wetland east of Sinclair. Lost Lake was not mapped as playa vegetation and has limited public land but may be appropriate to consider. There are also playa wetlands areas mapped in the Hanna and Laramie Basins, little or none of which appear to be on public lands. Outside of the Rawlins Field Office, there is playa vegetation mapped in the Lander Field Office northeast of Jeffrey City, in the Casper Field Office at Playa Lake, and in the Rock Springs Field Office at Deadman Wash.

The location and status of the original Nuttall collection site in Wyoming are not known. The four additional areas in the Green River Basin that may warrant surveys, besides the unsuccessful survey in 2008 at Sublettes Flat, include: Seedskadie National Wildlife Refuge, which includes the Green River camping site of the Wyeth Expedition, Soap Hole Basin which has alkaline meadows, alkaline wetlands north of Big Sandy Reservoir, and alkaline meadow complexes around the Upper Green River Basin margins that support plants like Meadow pussytoes (*Antennaria arcuata*) and some of which have peatland inclusions, a juxtaposition that may resemble Idaho sites. Aerial photointerpretation would be useful in pursuit of these surveys.

5. Unverified/Undocumented reports: None in Wyoming.

6. Areas surveyed but species not located: All systematic surveys for *Astragalus diversifolius* in 2008 are presented in Appendix B. They lie primarily in the Great Divide Basin (Carbon and Sweetwater counties), but also including sites immediately north of the Great Divide Basin (north of Cyclone Rim) within the upper Sweetwater drainage (Fremont and Sweetwater counties), and in the Green River Basin (Sublette County). The latter two areas are on or near the Oregon Trail, in the vicinity of the Wyeth Expedition itinerary. North of Cyclone Rim lies the Picket Lake area, which was visited at the recommendation of BLM staff reporting extensive alkaline meadow habitat (Frank Blomquist personal communication 2008). Scotty Lake, McKay Lake, and Picket Lake with their extensive alkaline meadows were surveyed. Another species of alkaline meadows, Bodin's milkvetch (*Astragalus bodinii*) was collected near Scotty Lake, but *A. diversifolius* was not found. Farther north, a small alkaline lake supporting alkaline meadow habitat, Lewistown Lake, was not surveyed for this project but there have been brief visits made there in years past by the author and by Walter Fertig. The second area of potential habitat that was surveyed included the Sublettes Flat area, northwest of Farson and west of Big Sandy River, where there is an area mapped as playa vegetation (Merrill et al. 1996). This area lies directly along the Oregon Trail route. However, the sections mapped as playa vegetation do not support alkaline wet meadow.

E. Habitat: *Astragalus diversifolius* is a halophyte in moist, salt-accumulating habitats. It is restricted to low topographic positions within the sagebrush zone of valleys and closed-basin drainages in alkaline meadows, playa shorelines, discharge zones, mounds, and shrub patches.

1. Associated vegetation: *Astragalus diversifolius* often grows in vegetation that is sparse alkaline meadow, but it is also found locally in very dense graminoid cover at abandoned shorelines, around desert shrubs, and in almost unvegetated flats. These vegetation features are often part of an "ecotone" associated with basin margins and groundwater discharge at the perimeter.

Astragalus diversifolius lies in or adjoining areas mapped as playa vegetation by Merrill et al. (1996). However, playa vegetation has not has not been described in detail for Wyoming, its characterization draws mainly from out-of-state studies, and it is referred to as an inclusion of the desert shrubland mosaic (Knight 1994). Playa vegetation as mapped by Merrill et al. (1996) is one of the rarest of the state cover types, but desert shrubland is second only to sagebrush steppe in its extent across Wyoming's intermountain basins (Knight 1994). Figures 7-15 present three images per occurrence, including a digital aerial photograph with population boundaries superimposed, and a pair of habitat photos from each occurrence that highlight the array of vegetation of different habitat zones.

2. Frequently associated species: The species commonly associated with *Astragalus diversifolius* include Alkali sacaton (*Sporobolus airoides*), Clustered field sedge (*Carex praegracilis*), Baltic rush (*Juncus balticus*), Nevada bluegrass (*Poa nevadensis*), Alkali cordgrass (*Spartina gracilis*), Branched wild-rye (*Elymus multicaulis*), Lanceleaf goldenweed (*Pyrrocoma lanceolata*), Colorado thistle (*Cirsium tioganum* var. *coloradense*), Red wooly-plantain (*Plantago eriopoda)*, and Arrowhead thelypody (*Thelypodium sagittatum*). A more complete species list is presented in Table 2.

Elsewhere in its range, *Astragalus diversifolius* has been characterized as a species of alkaline meadows with moist soils and flat or hummocky topography, supporting graminoid or medium height shrub vegetation (Idaho Data Conservation Center 2008). The associated species noted in Idaho included Baltic rush (*Juncus balticus*), Curly bluegrass (*Poa secunda*; note: *P. nevadensis* is included with this taxon by some authors), *Great Basin wild rye (*Leymus cinereus; syn. Elymus cinereus*), Alkali cordgrass (*Spartina gracilis*), *weak-stem groundsel (*Senecio debilis*), *Kelsey's phlox (*Phlox kelseyi*), *Sea milkwort (*Glaux maritima*), Greasewood (*Sarcobatus vermiculatus*) and *Shrubby cinquefoil (*Potentilla fruticosa; syn. Pentaphylloides fruticosa*). Associated Idaho species that have not been noted at Wyoming occurrences to date are indicated by an asterisk.

A detailed list of associated species at the Nevada occurrence has many overlaps with associated species in Wyoming: Inland saltgrass (*Distichlis spicata*), Nuttall's alkaligrass (*Puccinelllia nuttallii*), Lemmon's alkaligrass (*Puccinellia lemmonii*), Alkali cordgrass (*Spartina gracilis*), Nevada bluegrass (*Poa nevadensis*), Clustered field sedge (*Carex praegracilis*), Basin wild-rye (*Elymus cinereus*), and Colorado thistle (*Cirsium tioganum* var. *coloradense*), as recorded on the collection label (*Curto and Smith 1297 NY*). Inland saltgrass and species of rabbitbrush are associated with it in all four states (Table 2).

Table 2. Species associated with *Astragalus diversifolius*

Scientific name	**Common name**	**States**
Agoseris glauca var. *glauca*	Pale false dandelion	WY
Agropyron repens	Quackgrass	ID
Antennaria microphylla	Littleleaf pussytoes	ID
Astragalus leptaleus	Park milkvetch	ID
Carex praegracilis	Clustered field sedge	NV, ID, WY
Cirsium tioganum var. *coloradense (C. scariosum)*	Colorado thistle	NV, WY
Crepis runcinata	Fiddleleaf hawksbeard	ID
Deschampsia cespitosa	Tufted hairgrass	ID
Distichilis stricta	Inland saltgrass	NV, ID, UT, WY
Dodecatheon conjugens	Bonneville shootingstar	ID
Dodecatheon pulchellum	Darkthroat shootingstar	ID
Elymus multicaulis	Manystem wildrye	WY
Elymus smithii	Western wheatgrass	ID
Ericameria nauseosa (Chrysothamnus nauseosus)	Rubber rabbitbrush	ID, WY
Ericameria spp.	Rabbitbrush	NV, UT
Glaux maritime	Seablite	ID, WY
Hordeum jubatum	Foxtail barley	ID
Juncus balticus	Baltic rush	ID, WY
Leymus cinereus (Elymus cinereus)	Great Basin wildrye	ID, NV
Muhlenbergia richardsonis	Mat muhly	ID
Oxytropis deflexa	Nodding locoweed	ID
Phlox kelseyi	Kelsey's phlox	ID
Plantago eriopoda	Red wooly-plantain	ID, WY
Poa juncifolia	(Sandberg bluegrass)	ID
Poa nevadensis	Nevada bluegrass	NV, WY
Poa pratensis	Kentucky bluegrass	ID
Potentilla anserine	Silverweed cinquefoil	ID
Potentilla gracilis	Slender cinquefoil	ID
Primula alcalina	Alkali primrose	ID
Puccinellia lemmonii	Lemmon's alkaligrass	NV
Puccinellia nuttallii (P. airoides)	Nuttall's alkaligrass	NV, WY
Pyrrocoma lanceolata	Lanceleaf goldenweed	ID, WY
Pyrrocoma uniflora	Plantain goldenweed	ID
Salix spp.	Willow species	ID
Sarcobatus vermiculatus	Greasewood	ID, WY
Senecio debilis	Weak groundsel	ID
Sisyrinchium idahoense	Idaho blue-eyed grass	ID
Solidago nana	Baby goldenrod	ID
Spartina gracilis	Alkali cordgrass	ID, NV, WY
Sporobolus airoides	Alkali sacaton	UT, WY
Thelypodium sagittatum	Arrowleaf thelypody	WY
Thermopsis montana	Mountain goldenpea	ID
Triglochin maritimum	Seaside arrowgrass	ID, WY
Triglochin palustre	Marsh arrowgrass	ID

3. Topography: All three *Astragalus diversifolius* occurrences in Wyoming are associated with playa lakes in closed-basin drainages. The associated lacustrine features represent remnants of glacial Lake Wamsutter (Marrs and Grasso 1993), an extensive Pleistocene lake. The present-day playa lakes may or may not have inlets and there are no outlets. The occupied habitat is located mainly downwind (northeast) from evaporated lakebeds slightly above the elevation of the lakebeds, in wet meadow flats or bands. Portions of the East Chain Lakes occurrence are in settings that appear to be ancient shorelines (Figure 11) or near-shore zones with groundwater discharge at the surface (Figure 12). The Mud Lake population reaches the current shoreline of Mud Lake at the far western end of the lake (Figure 13) but its highest numbers are in broad flats separated from the lake by dunes (Figure 14). All three lake basins where the species was found in Wyoming may have held water briefly early in the growing season but were completely evaporated by July 2008. It is possible that these lakes do not hold water due to recent drought (2001-2007). Little is known about the hydrology upon which this species is likely to depend.

Occurrences of *Astragalus diversifolius* in Utah are also in closed basin settings with playa vegetation. However, the Idaho and Nevada occurrences are in river valley settings, though also in open, sagebrush terrain with well-developed alkaline meadows. One of the Idaho occurrences has a unique complex of well-developed alkaline meadow habitat and fen habitat (Moseley 1992), a combination that has not been found elsewhere.

Researchers have been able to reconstruct the paleogeography of Quaternary lake basin features using multispectral Landsat data and multispatial digital elevation and slope information to distinguish unique lacustrine sediment types relative to the former deposition environments of Lake Wamsutter (Grasso 1990, Marrs and Grasso 1993). The same techniques employed by geologists might be applied in identifying potential habitat for *Astragalus diversifolius* habitat, but the mapping of playa vegetation in combination with aerial photointerpretation provided a surrogate.

In general, photointerpretation worked well to identify landscapes with potential habitat, but not always to differentiate the most suitable microhabitats within them. Occupied habitats are marked on the aerial photos in the next three pages. See Figures 7-16 for aerial photographs of occupied habitat and the different habitats present among the three sites, and note the location of the alkali lake compared to occupied habitat in each one. The elevation ranges of Wyoming populations range from 6500-6620 ft, slightly higher than the 4400-6300 ft elevation range in other states.

Some *Astragalus diversifolius* occupied habitat with slight microtopography features, as is the case where the species is present in the low mounds formed around desert shrubland species at part of Circle Bar Lake (Figure 8). The species is almost never in the barren polygonal patterned hummocks formed on alkaline flats, with exception of a part of the Mud Lake population where it is in very low numbers on barren hummocks at the outer perimeter away from the lake (Figure 15). The species is generally not associated with inlets to the lakes, though a small part of the Mud Lake population is along an inlet.

Figures 7-9. *Astragalus diversifolius* at Circle Bar Lake (#003)

Figure 7. Aerial photo

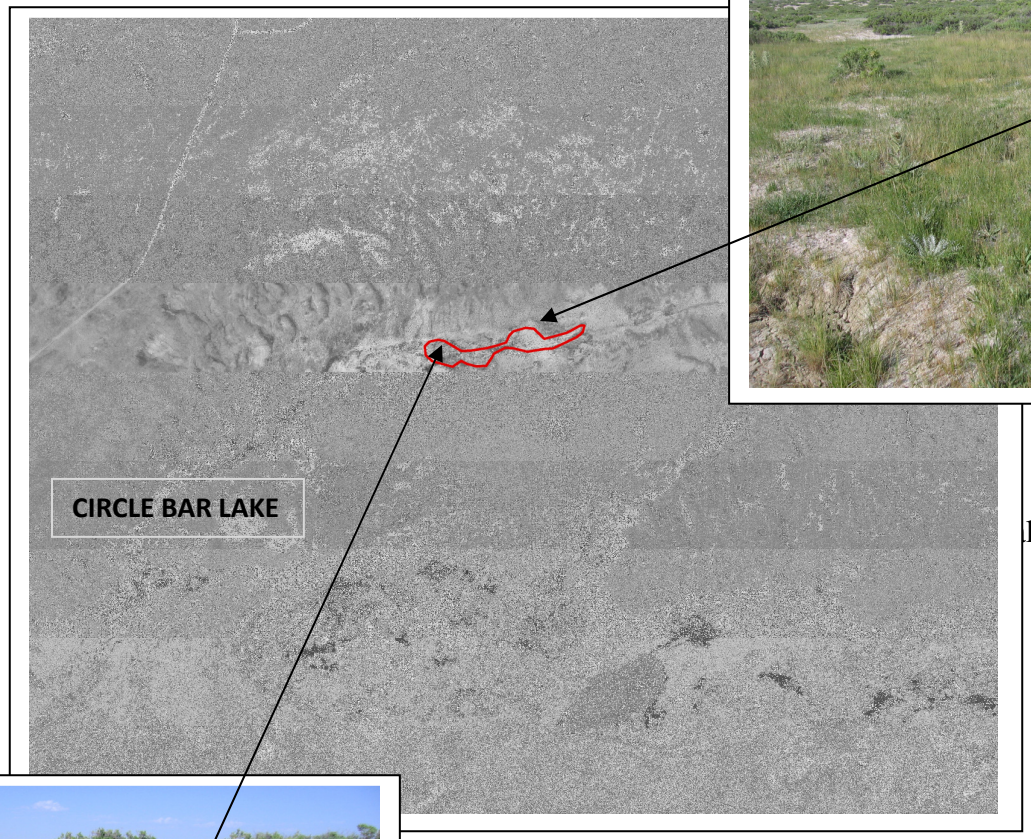


Figure 9. Habitat

le,

by J. Larson

Figure 8. Habitat among desert shrubs, by J. Larson

Figures 10-12. *Astragalus diversifolius* at East Chain Lakes (#004)

Figure 10. Aerial photo

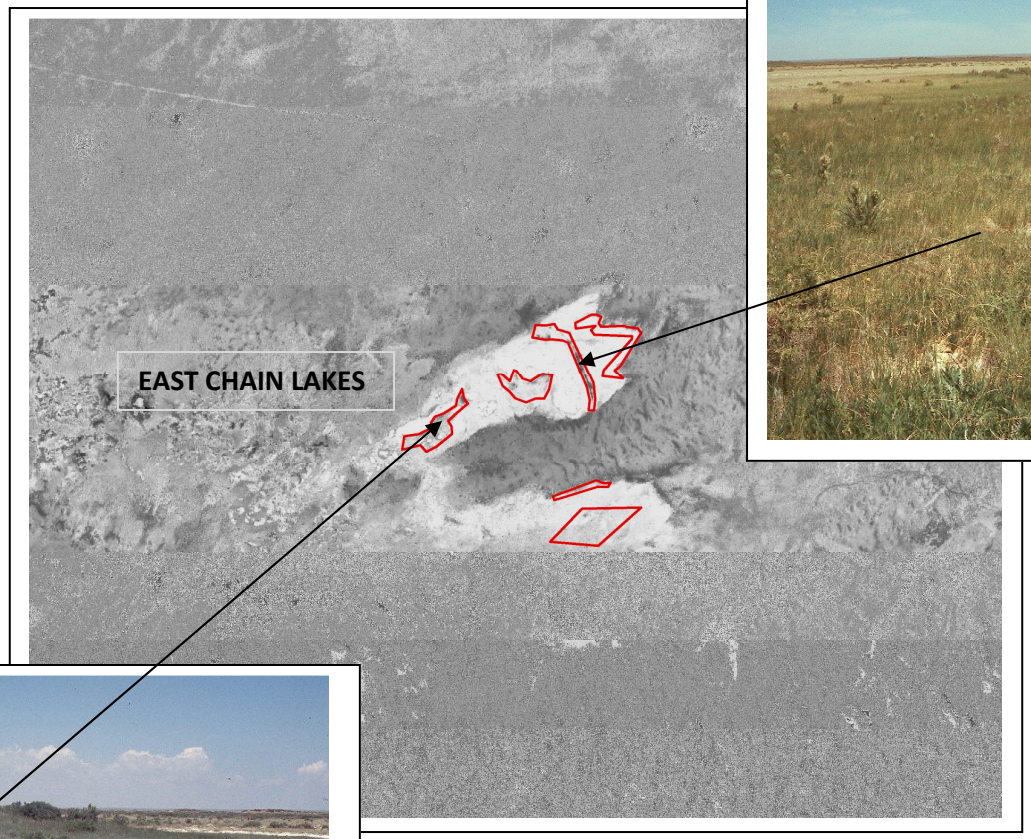


Figure 12. Habitat at groundwater discharge zone of playa lake shoreline

Figure 11. Habitat below playa lake shoreline, by B. Heidel

Figures 13-16. *Astragalus diversifolius* at Mud Lake (#005)

Figure 13. Aerial photo

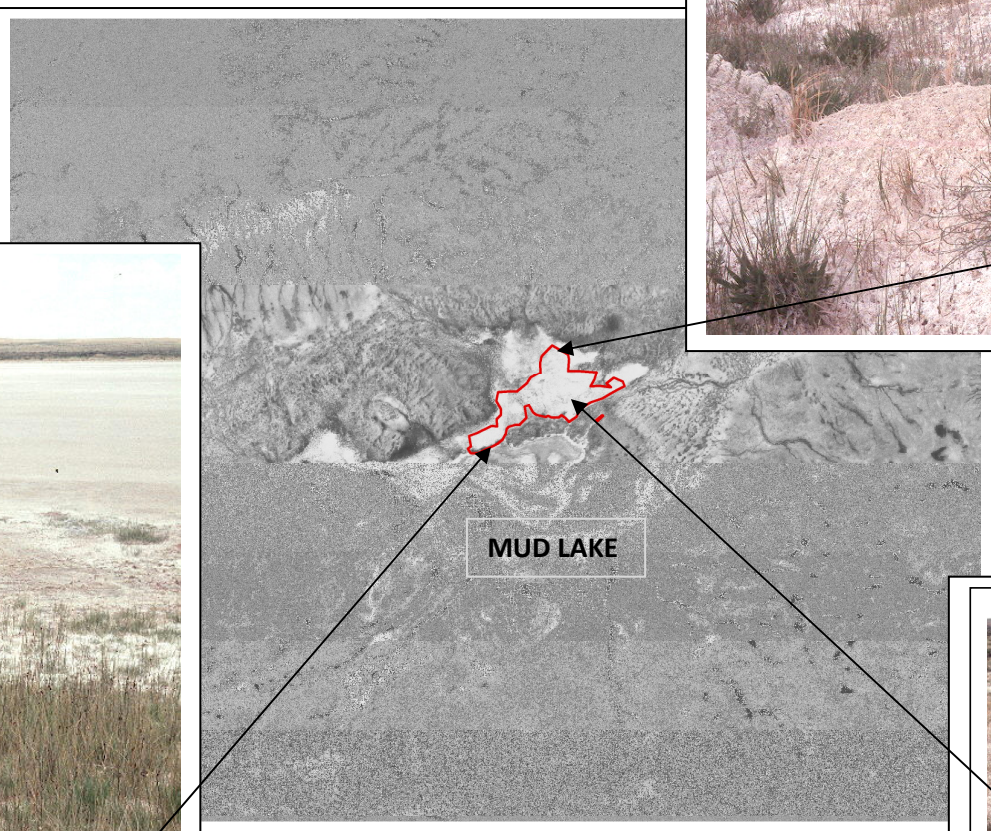
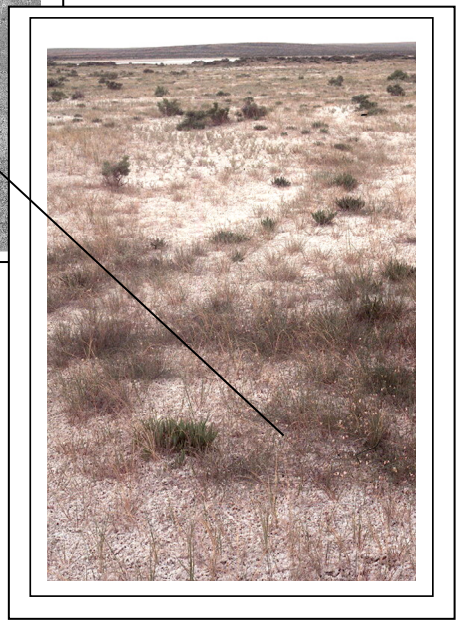


Figure 15. (Above) Marginal habitat on alkaline mounds (note robust plant), by B. Heidel.

Figure 14. Habitat at Mud Lake shoreline (left). The lake is dry. By B. Heidel

Figure 16. Primary alkaline meadow habitat at Mud Lake (right). By B. Heidel.



4. Soil relationships: Soils have salt accumulation migrating up to the surface, as well as wind-borne salt deposits carried from the alkaline lake bed and deposited onto the surface. Soils are in the cryorthent soil order. There was only one soil sample collected over the course of 2007 surveys, taken to represent *Astragalus diversifolius* habitat where first documented (Circle Bar Lake). The single sample was a silty clay loam soil sample, alkaline (pH 8.15), with high electrical conductivity (EC) and high sodium absorption ratio (SAR). Soluble sodium levels were higher than magnesium, which were higher than calcium (Table 2). Nevertheless, calcium carbonate levels were sufficient to evoke strong evanescent reactions to hydrogen chloride in occupied habitat and in surrounding wet meadow substrates.

Table 3. Soil characteristics at one *Astragalus diversifolius* site (Circle Bar Lake)

Property	**Soluble Calcium MEQ/L**	**Soluble Magnesium MEQ/L**	**Soluble Sodium MEQ/L**	**SAR**	**pH**	**EC DS/M**
	28.1	84.9	169.5	22.6	8.15	18.5

5. Regional climate: Wamsutter is the only USDI NOAA meteorological station within the Great Divide Basin (USDI NOAA 2009). It has a high desert climate with annual precipitation of 16.7 cm (6.58 in), with peak precipitation in May, and over 70% of annual precipitation coming during the growing season (April-September). Climate conditions are highly variable within and between years, and annual precipitation totals have ranged from 9.63 cm -34.62 cm (3.79 in -13.63 in) over the 56 years of monitoring (1948-2004). The average annual temperature is 5.2º C (41.35º F), coldest in January and hottest in July.

6. Local microclimate: Habitat of *Astragalus diversifolius* often has a prevalence of bare ground with salt-accumulation at the surface. These soils have high heat reflectance. There is no evidence of a claypan impeding percolation, and the low topographic position probably means that there is a shallow water table with significant groundwater movement upward, ameliorating the arid environmental conditions.

The downwind location of *Astragalus diversifolius* habitat from alkali lakes means that they are getting frequent salt deposition, originally picked up from the evaporated lake beds over much of the growing season.

F. Population biology and demography

1. Phenology: The indeterminate growth of *Astragalus diversifolius* stems prolongs flowering throughout the latter part of the growing season given adequate moisture. The flowering phenology seemed to be synchronous for all three of Wyoming populations in 2008. Plants with immature fruit were collected in Wyoming on 4 July 2008. The phenology of *Astragalus diversifolius* seems to be similar in Idaho, though flowering is possibly earlier in Wyoming. July 25 was the earliest collection date of Idaho plants in fruit. …

2. Population size and condition: There are estimated to be about approximately 8000 plants of *Astragalus diversifolius* in Wyoming, covering an area of about 75 ha (186.7 ac; Table 4). The density and continuity of the species varies greatly within and between occurrences.

Table 4. Size and extent of *Astragalus diversifolius* occurrences in Wyoming

	Numbers	**Digitized Extent (ac)**	**Trends**
Circle Bar Lake	Est. 1000	26.9	Unknown
East Chain Lakes	Est. 2000	99.9	Unknown
Mud Lake	Est. 5000	59.9	Unknown
TOTAL	Est. 8000	186.7	

All three of the Wyoming occurrences of *Astragalus diversifolius* have higher numbers than the largest known Idaho occurrence. The Idaho occurrence having highest tallies of plant numbers is estimated at 200-500 plants (Idaho Conservation Data Center 2009). However, several of the occurrences are split between public and private lands where only those portions of the population on public lands have been surveyed so not all Idaho tallies are complete.

Many of the individual plants noted in 2008 Wyoming surveys about 0.5 m in diameter, and such large plants are readily discerned and simple to census where they are in isolation. Where multiple individuals overlap, or the species is in continuous graminoid cover, the crowns are obscured, its leaves resemble grass leaves, it was difficult to distinguish individuals, and underestimates were likely. Very vigorous plants of *Astragalus diversifolius* were noted in 2008 with over 50 branches radiating out from the crown (Figure 3).

3. Reproductive biology

a. Type of reproduction: *Astragalus diversifolius* is not known to have any form of vegetative reproduction, though some descriptions of the species refer to it having subrhizomes. It appears to be subject to burial from wind depositions and salt accretions, so this may account for it having subterranean buds on the root crowns.

b. Pollination biology: Species in the *Astragalus* genus have laterally-symmetrical flowers with "wing petals" that resemble insect wings. The species in the genus are insect-pollinated, and bees are among the major pollinators in the genus. At East Chain Lakes, a wasp and a small butterfly were observed visiting flowers, but species-specific pollination has not been studied.

c. Seed dispersal and biology: The papery pod of *Astragalus diversifolius* readily dehisces to shed seeds after the fruit matures. It appears that seeds are produced for over two months in favorable years. The *Astragalus* genus in general lacks dispersal mechanisms except for those with palatable fruits. There were no seedlings noted in 2008 surveys.

G. Population ecology

1. General summary: *Astragalus diversifolius* appears to be a perennial that can live for an unknown time longer than a decade, as gauged by its stout, woody root crowns over 2 cm in diameter. It is a habitat specialist in a wide range of harsh conditions, with no competition or facilitation relationships identified to date.

Research comparing the population genetic structure of *Astragalus* species with small ranges compared to those of broad ranges, using enzyme polymorphism, suggested that there are no

consistent differences between the restricted and widespread taxa species with respect to their levels of genetic variation (Karron et al. 1988). Therefore, it is possible that sparsely-distributed species like *A. diversifolius* are at no more inbreeding disadvantage than widely-distributed species.

2. Competition: *Astragalus diversifolius* grows in a range of vegetation cover, from barren flats where there is less than 5% cover, to meadows of less than 20% cover, and in patches or zones that may have over 70% cover and litter accumulation. It is sometimes at vegetation margins or associated with patchy desert shrub vegetation. It seems to be in lowest numbers where vegetation is densest, which might be the result of competition.

There does not appear to be competition between individual *Astragalus diversifolius* plants. Particularly at Mud Lake, there were flowering stems in very high, continuous cover (foreground in Figures 14 and 16). As noted previously, the sprawling form of the plant makes it difficult to differentiate high plant densities from highly-branched plants.

Succession patterns of playa vegetation have not been characterized in Wyoming to address whether vegetation changes are to be expected. The two contrasting lobes of East Chain Lakes (Figure 7) have vegetation and environmental conditions that may provide a basis for further evaluating habitat specificity and succession in *Astragalus diversifolius* habitat. These two lobes also have magnitude differences in *A. diversifolius'* numbers (10X more plants in the north lobe than the south lobe).

3. Herbivory: Signs of herbivory were very rare, and in two instances, the branch fragment was found laying beside the plant it came from, indicating that it was not found to be palatable. Occasional insect herbivory was noted at Circle Bar Lake, where segments of the leaf were skeletonized by an insect that ate everything between the epidermis and left behind just an epidermal hole. Tests have been run on many species of the genus for poisonous organic nitrites (Williams and Parker 1974), and both *A. convallarius* and *A. diversifolius* were reported as accumulating significant levels of organic nitrites that make them unpalatable. However; the locations cited for the *A. diversifolius* collection in Utah may represent some variety of *A. convallarius*.

4. Hybridization: There were no signs of hybridization in the field and there are no reports in the literature. Two upland milkvetches with a cushion plant growth form were noted in the same Chain Lakes landscape as *Astragalus diversifolius*, *A. simplicifolius* and *A. spathulatus*.

5. Land ownership: All Wyoming occurrences of *Astragalus diversifolius* are on public lands managed in part or in full by the BLM Rawlins Field Office. Portions of the East Chain Lakes occurrence also extend onto lands managed by the Wyoming Game and Fish Department, and lie within the Chain Lakes Wildlife Habitat Management Area, under joint management of BLM and Wyoming Game and Fish Department. What is now state land had previously been part of a checkerboard of alternate sections granted to the Union Pacific Railroad. The Circle Bar Lake occurrence is north of the Chain Lakes Wildlife Habitat Management Area as mapped, though an

east-west fenceline runs through the population and the south half of the population appears to be managed as part of the Management Area.

Both of the extant occurrences in Utah and in Nevada are on private lands. Of the eleven extant occurrences in Idaho, at least six are on public lands of the Upper Columbia – Salmon Clearwater Districts of BLM, in part or in full. One of the Idaho BLM occurrences also extends onto Caribou-Targhee National Forest and state land.

IV. ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

A. Potential threats to currently known populations: *Astragalus diversifolius* is considered to be threatened in adjacent states due to habitat loss from agriculture (Idaho Data Conservation Center 2009). Its habitat is arable in some Idaho valley settings. In Wyoming, it may be impacted by mineral and energy developments and noxious weed invasion.

1. Mineral and energy development: *Astragalus diversifolius* is located near areas that are being developed for oil and gas, coalbed methane and uranium. It is also near an area identified as having oil shale deposits. The playa hydrology of its habitat may be affected by drilling that potentially lowers the water table, or by coalbed methane discharge that potentially raises the water table.

The Chain Lakes Wildlife Habitat Management Area is identified as a special management designation in the proposed Resource Management Plan (USDI BLM 2009). Under this designation, the area is still open to oil and gas development, but maintenance of its unique playa habitat and wildlife values are identified as management priorities under the preferred alternatives of the proposed Resource Management Plan (USDI BLM 2009).

2. Roads and recreation: Off-road vehicle tracks were observed in the Chain Lakes Wildlife Habitat Management Area near Circle Bar Lake (Heidel 2006), but it appears that the silt dunes are treacherous for motor vehicle travel and may have limited suitability for recreational use. An evaluation protocol for playa systems has been developed in Colorado (Rocchio 2005), with 21 parameters that provide a framework for evaluating intactness or disturbance of *Astragalus diversifolius* habitat in Wyoming. The metric includes hydrological alteration, as discussed here. There were no observed diversions or augmentations to surface flow. The roads in the area are over 0.25 miles from the occurrences and do not appear to impede surface flow. A new road was constructed within 0.1 mile of the Circle Bar Lake population, apparently to provide public access to the Chain Lakes Wildlife Habitat Management Area. The considerable height of the gravel bed built up to support the new road is indication of the challenges posed by this terrain when wet.

3. Wild horses: Signs of wild horses were present in the vicinity of all three Wyoming occurrences but there was no evidence of grazing upon the species or habitat trampling.

4. Grazing: The three Wyoming occurrences of *Astragalus diversifolius* lie within three large cattle grazing allotments that have included sheep grazing in the past. The prostrate or decumbent growth form means that vascular tissue and active meristems are not readily available

except as the stems sometimes curve upward at the tip. The highly-reduced leaf means that forage values are low. There are reports of nitrite accumulation in the species (Williams and Parker 1974). Livestock grazing was noted on stems of *A. diversifolius* in Idaho, and inference made that the species declines under heaving grazing. Grazing may also alter species' habitat by trampling the plants or by intense trampling changing the movement of water and salts in the soil profile.

5. Noxious weeds: Halogeton (*Halogeton glomeratus*) was noted as widespread but in low numbers at the East Chain Lakes occurrence, especially on bare flats. Its potential for persistence, expansion and competition with *Astragalus diversifolius* are not known. Noxious weeds noted in or near occupied habitat in Idaho included Leafy spurge (*Euphorbia esula*), Whitetop (*Cardaria draba*) and Canada thistle (*Cirsium arvense*). Only the latter was noted as present in the same landscape as Wyoming occurrences, though not in the same habitats.

6. Other: The habitat of *Astragalus diversifolius* seems like it is not readily affected by drought, but the prolonged, multi-year evaporation of alkali lakes upwind may lead to increased salt deposition in its habitat or possibly be associated with long-term shifts in playa hydrology. In previous years, these alkali lakes held water at least in early weeks or months of the growing season (Blomquist personal communication 2009). Comparison of aerial photographs of past decades may put current conditions in better context to understand the playa hydrology trends within and between decades.

One other sensitive species and three additional Wyoming species of concern were documented incidental to *Astragalus diversifolius* surveys, but they are not in the same habitats as *A. diversifolius*. New records were produced for a noteworthy large population of Nelson's milkvetch (*Astragalus nelsonianus*) and a couple new records were produced for Red poverty-weed (*Monolepis pusilla*). Two other species were previously documented at Chain Lakes including Tiny phacelia (*Phacelia tetramera*) and Pale blue-eyed grass (*Sisyrinchium pallidum*).

A. Management practices and response: There are no known management alteration practices slated for the Chain Lakes Wildlife Habitat Management Area or occurrences outside this area.

B. Conservation recommendations: *Astragalus diversifolius* may warrant consideration for designating as sensitive by BLM in Wyoming. It is designated as sensitive by BLM in Idaho and as sensitive by U.S. Forest Service Region 4 in Idaho. Even though Wyoming has fewer occurrences than Idaho, the absolute numbers of plants in Wyoming may be significant.

The level of protection conferred by the Chain Lakes Wildlife Habitat Management Area is an important factor for the East Chain Lakes occurrence, and possibly part of the Circle Bar Lake occurrence. This requires coordination with Wyoming Game and Fish Department. The distribution of this report is intended to contribute to information exchange. The new Wyoming status information will also be conveyed to promote species' status discussion between states.

C. Summary: *Astragalus diversifolius* is a sparsely-distributed Great Basin species. It is known from 16 extant occurrences that span great distances but are associated with discontinuous habitat that seems to be relict in nature. The new Wyoming occurrences greatly broadened the known species' distribution, reducing the endangerment of this species on one hand. No immediate impacts to energy and mineral development have been identified in Wyoming, but there are a number of existing and potential developments in surrounding lands to which the species may be vulnerable. The low species' numbers elsewhere may be reason for a cautionary approach in interpreting *A. diversifolius* status information in Wyoming.

V. LITERATURE CITED

Barneby 1947. *Pugillus astragalorum* VIII: notes on the section *Genistoidei.*. Leaflets of Western Botany 5(2): 25–35.

Barneby, R. C. 1964. Atlas of North American *Astragalus*. Memoirs of the New York Botanical Garden 13(II): 1-1188.

Barneby, R.C. 1989. Fabales, Vol. 3 Part B. IN: A. Cronquist, A. H. Holmgren, N.H. Holmgren, J.L. Reveal, and P.K. Holmgren. Vascular Plants of the Intermountain West, USA. New York Botanical Garden, Bronx, NY. 279 pp.

Benson, L.V. and R.S. Thompson. 1987. The physical record of lakes in the Great Basin, in Ruddiman, W.F. and H.E. Wright, Jr., eds. North America and adjacent oceans during the last deglaciation: The Geology of North America. Vol. K-3, Boulder, CO. Geological Society of America, P. 241-260.

Dorn, R.D. 1977. Manual of the Vascular Plants of Wyoming. 2 volumes. Garland Publ., INC., New York, NY.

Dorn, R.D. 1984. Vascular Plants of Montana. Mountain West Publ., Cheyenne, WY.

Dorn, R.D. 1988. Vascular Plants of Wyoming, 1rst ed. Mountain West Publ., Cheyenne, WY.

Dorn, R.D. 2001. Vascular plants of Wyoming, 3rd ed. Mountain West Publ., Cheyenne, WY.

Driese, K., W.A. Reiners, E.H. Merrill and K.G. Gerow. 1997. A digital land cover map for Wyoming, USA: a tool for vegetation analysis. Journal of Vegetation Science 8: 133-146.

Fertig, W., C. Refsdal, and J. Whipple. 1994. Wyoming Rare Plant Field Guide. Wyoming Rare Plant Technical Committee, Cheyenne, WY.

Grasso, D. 1990. Recognition and paleogeography of Quaternary Lake Wamsutter (A proposed lake in Wyoming's Great Divide Basin) combining LANDSAT remote sensing and digital elevation modeling. Ph.D. Thesis. University of Wyoming, Laramie. 184 pp.

Heidel, B. 2007. Playa plants. *Castilleja* 26(3): 10-11.

Heidel, B. 2008. Chain Lakes Botanical Survey. Prepared for the Bureau of Land Management. Wyoming Natural Diversity Database, Laramie, WY.

Heidel, B. and J. Larson. In progress. Noteworthy collections – Wyoming. Submitted to Madroño.

Hitchcock, C.L. and A. Cronquist. 1961. Vol. 3. Saxifragaceae to Ericaceae. In: C.L. Hitchcock, A. Cronquist, M. Ownbey, and J.W. Thomas. Vascular Plants of the Pacific Northwest. University of Washington Publication in Biology 17(12): 1-597.

Idaho Data Conservation Center. 2008. Species account: *Astragalus diversifolius* (meadow milkvetch). Posted at: http://fishandgame.idaho.gov/cms/tech/CDC/spp_accounts_plants/. Boise, ID.

Idaho Data Conservation Center. 2009. *Astragalus diversifolius* element occurrence data, exported and conveyed by L. Hahn. February 2009.

Isely, D. 1998. Native and Naturalized Leguminosae (Fabaceae) of the United States (exclusive of Alaska and Hawaii). Monte L. Bean Life Science Museum, Brigham Young Univ., Provo, UT.

Karron, J.D., Y. B. Linhart, C.A. Chaulk, C.A. Robertson. 1988. Genetic structure of populations of geographically restricted and widespread species of *Astragalus* (Fabaceae). Am. J. Bot. 75(8): 1114-1119.

Knight, D.H. 1994. Mountains and Plains: The Ecology of Wyoming Landscapes. Yale University Press, New Haven, Conneticut.

Love, J. D. and A. C. Christiansen. 1985. *Geologic Map of Wyoming*. U.S. Geological Survey.

Maberly, D.J. 1987. The Plant Book, 2nd ed. Cambridge University Press. London, U.K.

Merrill, Evelyn H., Thomas W. Kohley, Margo E. Herdendorf, William A. Reiners, Kenneth L. Driese, Ronald W. Marrs, and Stanley H. Anderson. 1996. The Wyoming gap analysis project final report. University of Wyoming, Laramie WY. 109 pp. + appendices.

Marrs, R.W., and D.J. Grasso. 1993. Geologic applications of remote sensing and GIS: A Wyoming landscape perspective. In: Snoke, A.W., Steidtmann, J.R. and S. M. Roberts, eds. Geology of Wyoming. Geological Survey of Wyoming Memoir No. 5, p. 790-814.

Morefield, J. 2001. Nevada Rare Plant Atlas [http://heritage.nv.gov/atlas/atlas.html]).

Moseley, R. 1992. Ecological and floristic inventory of Birch Creek Fen, Lemhi and Clark counties, Idaho. Prepared for Targhee National Forest and Salmon District BLM. Idaho Conservation Data Center, Boise, ID.

Polhill, R.M. `98`. Galegeae. Pp. 357-363. In: Advances in legume systematics, eds. R.M. Polhill and P.H Raven. Kew: Royal Botanic Gardens.

Rocchio, J. 2005. Intermountain basins playa ecological system – ecological integrity assessment. Colorado Natural Heritage Program, Fort Collins, CO.

Sanderson, M. J. 1991. Phylogenetic relationships within North American *Astragalus* L. (Fabaceae). Systematic Botany 16(3): 414-430.

Tiehm, A. 1984. Noteworthy Collections – Nevada. Madroño 31: 123-127.

Welsh, S. 2007. North American Species of *Astragalus* Linnaeus: a taxonomic revision. Brigham Youn University Press, Provo, UT.

USDI National Oceanic and Atmospheric Association. 2009. Wyoming climate summaries. Posted at: http://www.wrcc.dri.edu/summary/climsmwy.html .

Utah Native Plant Society. 2003-2008. Utah Rare Plant Guide. Posted electronically at http://www.utahrareplants.org/rpg.html.

Utah Natural Heritage Program. 2009. *Astragalus diversifolius* element occurrence data, conveyed by B. Franklin. January 2009.

Williams, M.C. and R. Parker. 1974. Distribution of organic nitrites in *Astragalus*. Weed Science 22(3):259-262.

Williams, R.L. 2003. A Region of Astonishing Beauty – the Botanical Exploration of the Rocky Mountains. Robert Rinehart Publishers, Lanham, MD.

Wyoming Natural Diversity Database. 2008. Wyoming Natural Diversity Database. 2008. *Astragalus diversifolius* element occurrence records, exported upon completion of 2008 data entry.