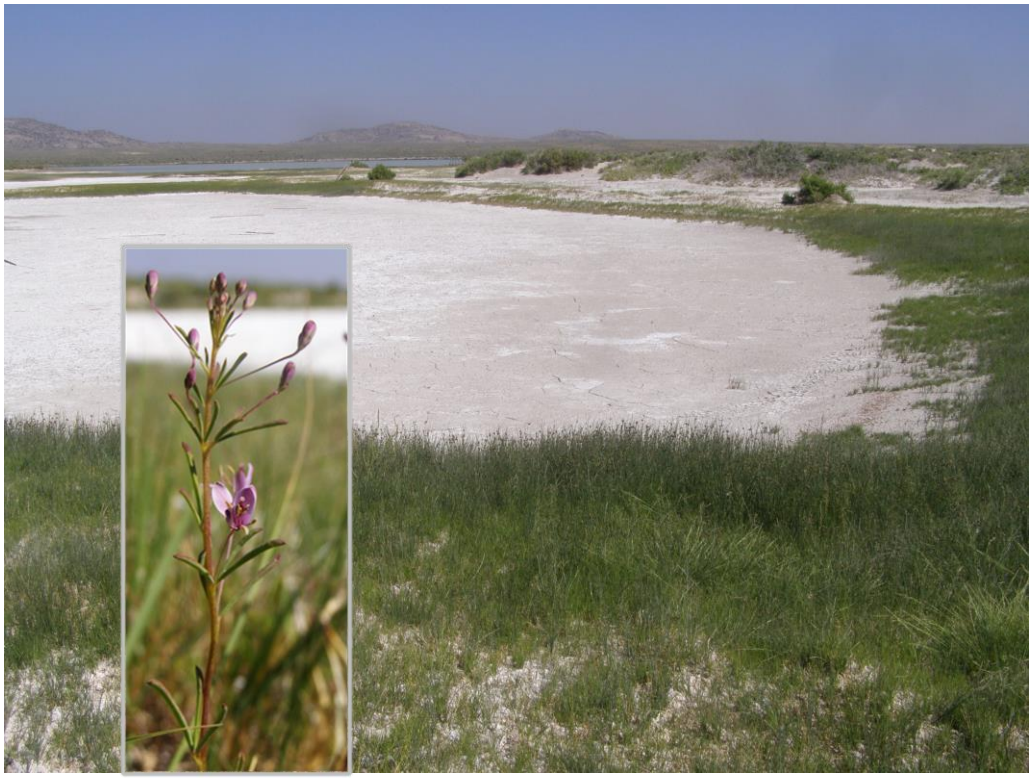
Inventory of Alkaline Meadows for BLM Sensitive Plant Species: *Antennaria arcuata* (Meadow pussytoes), *Astragalus diversifolius* (Meadow milkvetch) and *Cleome multicaulis* (Many-stemmed Spiderflower) with Field-Testing of Potential Distribution Models; Fremont and Sweetwater Counties, Wyoming



Prepared for the Bureau of Land Management – Lander, Rawlins, Rock Springs Field Offices and BLM Wyoming Office

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ABSTRACT

Surveys were conducted for two species designated Sensitive by the Bureau of Land Management in Wyoming: *Antennaria arcuata* (Meadow pussytoes) and *Astragalus diversifolius* (Meadow milkvetch). The project was originally proposed to fill survey gaps. The objective was greatly expanded to test potential distribution models. Both of the two species occupy alkaline meadows and had suspected survey coverage gaps in the BLM Lander Field Office. A third species, *Cleome multicaulis* (Many-stemmed spiderflower) is also known from alkaline meadows and was discovered in the study area for the first time during the course of surveys. In total, one new population of *A. arcuata*, two new populations of *A. diversifolius* and two new populations of *C. multicaulis* were documented by use of photointerpretation. Eighty-two negative survey points were produced and will be used to revise the three species' potential distribution models. This report represents the most current and complete information on the three species as present in Wyoming, drawing from all earlier studies.

ACKNOWLEDGEMENTS

This report reflects the work of Wyoming botanists past and present, including Walter Fertig (Wyoming Natural Diversity Database; WYNDD), Hollis Marriott (WYNDD) and Robert Dorn. Just as much, it reflects interest and work of BLM botanists/biologists over the years, including Tanya Skurski, Frank Blomquist, Adrienne Pilmanis, Jim Glennon and Jeff Carroll. Tanya and Frank provided reviews of this report as a draft.

The modeling narrative and statistically-generated sets of quarter-sections for testing models were provided by Mark Andersen (WYNDD). Proofreading, initial set up of the ArcMap project, and preparation of digital ortho-quarterquads printouts were provided by Joy Handley (WYNDD).

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Cover page: *Cleome multicaulis* (Many-stemmed spiderflower) inset in its habitat at Soda Lakes

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INTRODUCTION

Antennaria arcuata (Meadow pussytoes) and *Astragalus diversifolius* (Meadow milkvetch) are wet meadow plants that are designated as Sensitive by the Bureau of Land Management (BLM) in Wyoming, and there were data to suggest that their distributions in the Sweetwater River drainage were incompletely documented. This was based on first-time discovery of *A. diversifolius* in the drainage in 2013 and additional Sweetwater River drainage discoveries of *A. arcuata* populations since the most recent species status report in the Sweetwater River drainage (Fertig 1996).

Potential distribution modeling work was first undertaken for Wyoming plants by Fertig and Thurston (2003) and more recently by Heidel et al. (in progress). Work on potential distribution models is often hampered by lack of data, especially data documenting the absence of species. Thus, two objectives were coupled in one project: to produce data that would fill survey gaps for these two species and to produce data for potential distribution models.

In the course of survey work, a third BLM Sensitive species was documented from wet meadow habitat that was not previously known from the study area, *Cleome multicaulis* (Many-stemmed spiderflower). The survey results are bundled into updated statewide status reports for all three species, providing the cumulative picture as well as the process. The survey results will also be used to refine potential distribution models in preparation for all three species, as part of a separate study project that addresses all BLM Sensitive species.

STUDY AREA

Study area boundaries were demarcated to meet complementary objectives: filling survey gaps for both *Antennaria arcuata* and *Astragalus diversifolius* and filling data gaps for their potential distribution models. The study area was delimited by watershed boundaries because the 10-digit hydrological unit code (HUC) boundaries are used as the spatial units for range maps in Wyoming (Keinath et al. 2010). This watershed approach is consistent for the two species, both of which have their distributions described in terms of watersheds. The study area is in southern Fremont County and northern Sweetwater County, Wyoming. It lies in the BLM Lander Field Office (ca 60%), the BLM Rawlins Field Office (ca 25%) and the BLM Rock Springs Field Office (ca 15%)(Figure 1).

The study area encompasses the known Wyoming distribution of *Astragalus diversifolius* and much of the known Wyoming distribution of *Antennaria arcuata*. It includes most of the Sweetwater River drainage, much of the upper Beaver Creek headwaters (a tributary of the Wind River), and much of the Great Divide Basin, a closed-basin system. This irregularly-shaped study area has no central landmark but lies between the Wind River Range and Green Mountain. Throughout this report it is referred to simply as the study area.

Study area demarcation was based on potential distribution models for *Antennaria arcuata* and *Astragalus diversifolius* as originally identified in a test run of potential distribution that focused on areas of high predicted probability for the two species. Then a combination of known and potential distribution was superimposed on a basemap of high resolution, 10-digit watershed HUC boundaries from the National Hydrography Dataset (Simley and Carswell 2009), so that species' distribution and HUC units represented a contiguous block. Both species are wet meadow species and the demarcated study area encompassed a long segment of the Sweetwater River watershed, a large portion of the Great Divide Basin watershed and a small fragment of the Wind River Basin watershed (Figure 1). The study area encompasses an area of 810,169.3 km² (3128.1 mi²).

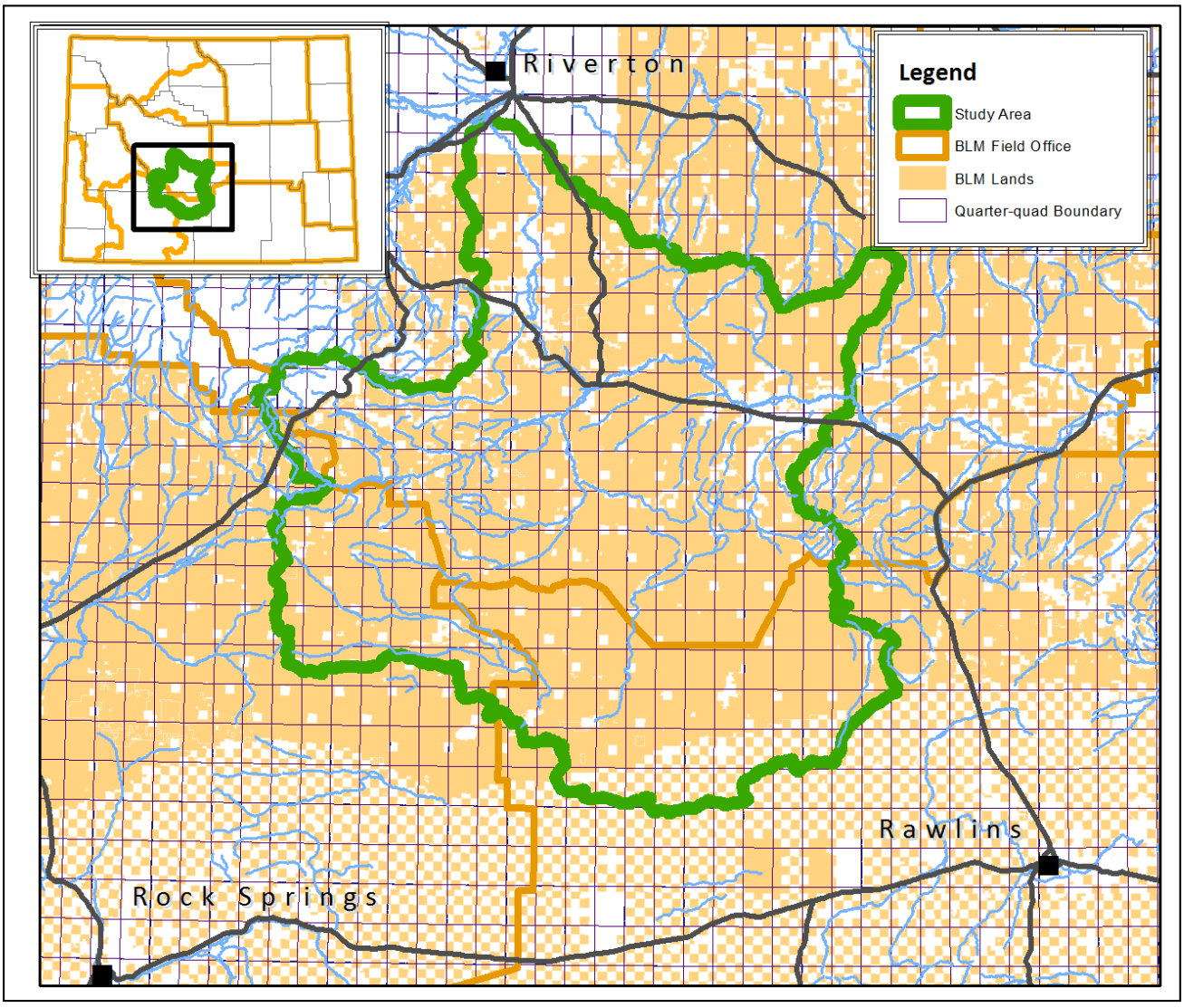


Figure 1. Sensitive species study area

The study area is located in the Wyoming Basins Ecoregion, an arid steppe landscape that is predominantly sagebrush steppe, plus large areas of desert shrubland in southern reaches (from Figure 1.6, in Knight et al. 2014). The cold desert climate is characterized as having a mean annual temperature of 41.5 °F (5.3 °C) and mean annual precipitation of 10.67 in (27.1 cm), based on 1971-2000 NOAA climate data collected at Jeffrey City, as reported in Curtis and Grimes (2004) and USDI NOAA (2006). The prevailing bedrock geology in the Sweetwater River watershed is white, soft tufaceous Miocene sandstone plus locally derived conglomerates; and in the Great Divide Basin is primarily Eocene claystone and lenticular sandstone (Love and Christiansen 1985). In addition, alluvial Quaternary deposits are along the Sweetwater River, and scattered alluvial, colluvial and aeolian Quaternary deposits are in the Great Divide Basin.

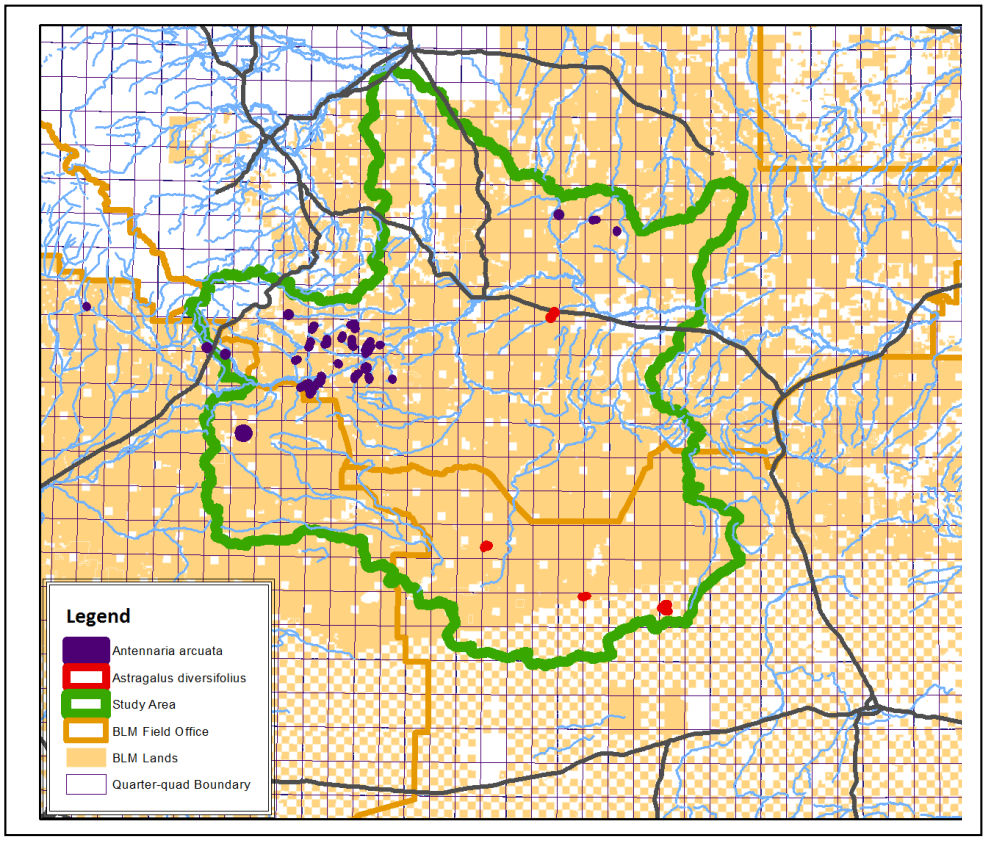


Figure 2. Study area distribution of *Antennaria arcuata* and *Astragalus diversifolius* in study area prior to 2014 surveys

METHODS

Before the field season, all related information resources were compiled, including prior records, prior reports, and GIS files. Three prior systematic surveys had been conducted for *Antennaria arcuata* in Fremont County (Whiskey Basin Consultants 1982, Marriott 1986, Fertig 1996) and one in the BLM Pinedale and BLM Rock Springs Field Offices (mainly Sublette County; Heidel 2013). One prior systematic survey for *Astragalus diversifolius* had been conducted in the BLM

Rawlins Field Office (Heidel 2009). An ArcMap project platform was set up using known distribution of both species (Figure 2), bedrock geology mapping (based on Love and Christiansen 1985), digital ortho-photographs (NAIP 2006), and U.S. Geological Survey mapping. The study area encompasses all Wyoming records of *A. diversifolius* (total=4) and all Fremont County records of *A. arcuata* (total=23) as known prior to 2014 surveys. These two species are not known to overlap even though they occupy related habitat and are present in the same two counties (Figure 2).

Two fundamentally different approaches were taken in this project to target areas for survey: modeling and photointerpretation. The first involved field-testing potential distribution models for both species. Three different distribution models were considered. The primary species distribution modeling for both species used the Random Forest algorithm. Absence data for a given species was created by compiling the presence data for other plant species of concern, assuming any surveys or collecting that were suited for documenting one rare plant species would likely have documented presence of other rare species.

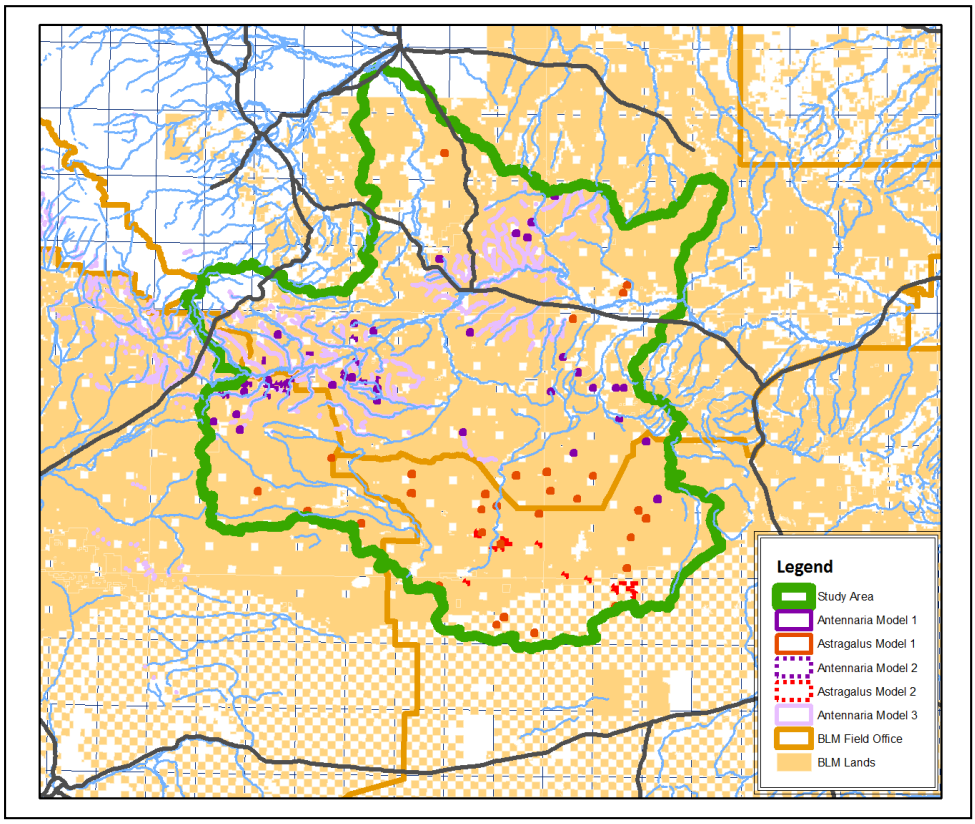


Figure 3. Sensitive species survey targets in the study area as defined by models [1]

[1] This included the top 40 frames for Random Forest models and the top 20 frames for the deductive models, plus the high priority polygons in the classification tree model.

To test the preliminary Random Forest models, 100 random frames of 0.25 mi² (¼ of a section) were generated for both *Antennaria arcuata* and *Astragalus diversifolius* from probability scores. The high probability frames were sorted for purposes of random sampling. For reference purposes, they were divided into 20-frame groups as reflecting probabilities, and thus, a working set of survey priorities. A screen was also added for practical purposes involving proximity of roads. Although the two species do not grow together, the habitat parity between them was such that the frames that had value in refining the potential distribution model for one species had value in refining models for both species. In other words, both species were to be sought in each frame, and though the two species had different frames identified, positive or negative data results would be generated for both species in all frames. By this hierarchical framework, frames needed to be covered in blocks, e.g., analysis of frames 1-20 had less value if frame 13 was skipped than if all 20 were covered. Digital orthoquarterquad coverage and other fieldwork preparation covered the highest priority 40 for both species as feasible (Figure 3).

In addition to this computer-generated set of model-testing quarter-quad priorities, a simple deductive model was implemented to identify the 20 quarter-quad frames having highest likelihood as weighted by known distribution for both species (n=40). This deductive modeling approach was a secondary fieldwork priority incidental to the first set. A couple of targets for the *Astragalus diversifolius* deductive model had already been surveyed in 2008 (Heidel 2009).

Finally, the potential distribution model for *Antennaria arcuata* as generated by a classification tree approach (Fertig and Thurston 2003) was cross-referenced and considered, particularly if it overlapped with quarter-quads in any of the other approaches. That 2003 model reflected distribution of all *A. arcuata* records through that time. It was one of the tools used in *A. arcuata* surveys in the BLM Pinedale Field Office (Heidel 2013) and is likewise referenced in this project. There was no *A. diversifolius* potential distribution model by Fertig and Thurston (2003) because there were no extant occurrences known at that time.

Essentially, there were five unique models that were considered and cross-referenced in the field surveys, including the Random Forest models and resulting quarter-section frames for both species, the deductive models and resulting quarter-section frames for both species, and the polygons of the classification tree model of Fertig and Thurston for *Antennaria arcuata* only. The ArcMap project had the targets identified by all five models, by species, and by priority.

The original plans for photointerpretation were conducted across the study area as originally proposed. Areas of alkaline meadow on public lands were flagged for survey using digital orthophography (NAIP), whether or not they overlapped with model-testing targets. The search image was based on known sites, and focused on riparian and wetland settings with high reflectance indicating salt accumulation at the surface. There were about 45 sites identified by

photointerpretation, and they were characterized as high or medium priorities for one of the two species based on semblance to known sites and extent of potential habitat on public land.

Surveys at known populations were not considered, except as they might inform the modeling work or help produce a better status report. These exceptions included surveys of occurrences that had imprecise or otherwise incomplete mapping. Occurrences were also visited that happened to be located along the routes to other targets.

In preparation for fieldwork, a master list of targets from the five sets of models and photointerpretation for both species was assembled. Under project constraints, the top 25 Random Forest targets were flagged for both species, as were the 20 deductive model targets for both species, the classification tree model (Fertig and Thurston 2003) polygons for *Antennaria arcuata*, and the roughly 45 high, medium and low priorities flagged for either of the two species from photointerpretation. All distribution data and model targets were superimposed on NAIP imagery and cross-referenced by USGS topographic map (7.5') quarter-quads. An accompanying set of digital orthophoto quarter-quads (DOQQs) were printed with section lines, quarter-quad boundaries and roads in addition to distribution and model targets. They were printed onto 8 ½" x 11" pages of paper, representing about the same scale as 1:24,000 USGS topographic maps. Both were used for reference in setting field survey priorities and navigation in the field, with a tabular spreadsheet serving as an index to quarter-quads with ease of searching and sorting. About 54 of the 74 USGS topographic maps spanning the study area had one or more targets prioritized for fieldwork, and over 150 DOQQs were prepared for reference in the field.

Field surveys for *Antennaria arcuata* and *Astragalus diversifolius* were conducted by the author between 22 June - 30 August 2014. When entering a quarter-section target for survey, the first step was to determine whether or not it had wet meadow habitat, which usually meant heading to the lowest elevations in the landscape, placing priority on any salt-accumulation features. After that determination and survey of any such features, the direction and scale of inventory was determined for the rest of the quarter-section using aerial photos. A Global Positioning System (GPS) coordinates were collected to georeference the location and extent.

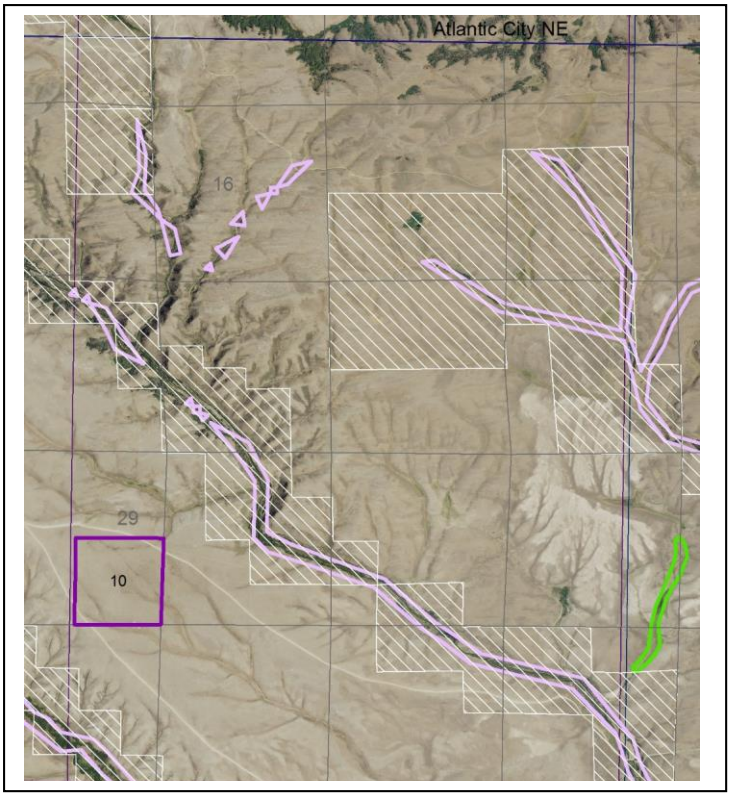


Figure 4. DOQQ example - Atlantic City NE, showing known *Antennaria arcuata* location (green), quarter-quad of *A. arcuata* potential habitat from Random Forest modeling (dark purple), and polygons of *A. arcuata* potential habitat from Fertig & Thurston (2003) modeling (light purple) (Private land is represented by white cross-hatching.)

When *Antennaria arcuata* or *Astragalus diversifolius* were found, determinations were made of population extent, and characterizations were made of environmental setting, habitat conditions, and plant associates. A single GPS point was taken for subpopulations of 10 m radius or less. Multiple GPS points were taken to map larger subpopulations as polygons. Stem counts were not made for *A. arcuata* because the species reproduces vegetatively by stolons. It tended to occur on mounds, and plants do not connect between mounds, so a ballpark estimate of the number of mounds was used as a conservative figure for the number of plants. In the case of *A. diversifolius*, running stem counts were made, boundaries delimited, and numbers rounded up depending on what majority fraction of potential habitat was covered. For both species, frequency was noted (uncommon, common, abundant/dominant) in the total alkaline meadow habitat. Sensitive plant survey forms were completed, and later entered in the WYNDD database. Voucher specimens were collected for every new population and for old populations that were precisely-located and mapped for the first time. All specimens were deposited at Rocky Mountain Herbarium (RM).

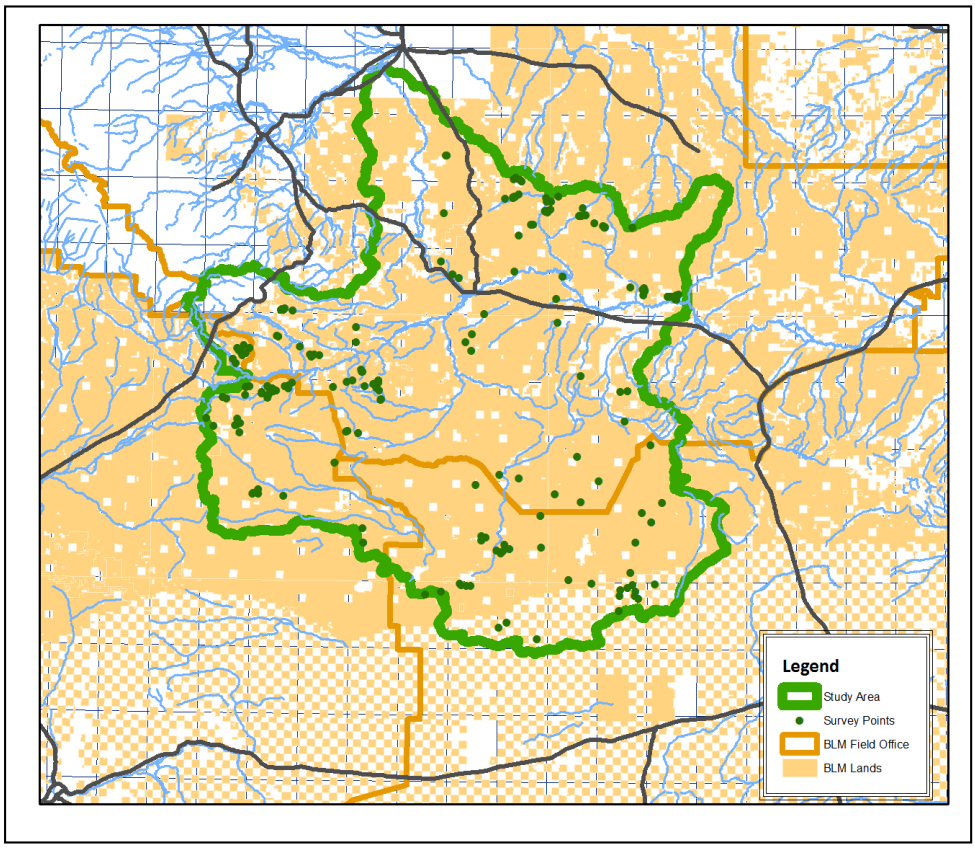


Figure 5. 2014 Sensitive species survey points in the study area[2]

In total, 82 quarter-quads were addressed in model testing (41 Random Forest model-generated quarter-quads and 41 Deductive model-generated quarter-quads) (Figure 4). Four different sets of results are presented in the sections that follow:

- Overview of survey results, both positive and negative
- State species information update for *Antennaria arcuata*
- State species information update for *Astragalus diversifolius*
- State species information update for a third species, *Cleome multicaulis*, a species not previously known in the study area

HIGHLIGHT OF SURVEY RESULTS

Two new occurrences of *Astragalus diversifolius* were documented by photointerpretation. This species had no prior systematic survey in the Sweetwater drainage, and represent range extensions to the north and west. One of the two new occurrences of *A. diversifolius* was in a setting that seemed to resemble that for *Antennaria arcuata*, reinforcing the benefit of addressing

[2] Shows patterns of fieldwork, including all GPS reference points, not just those for collected for model testing.

them in the same project. One new occurrence of *Antennaria arcuata* was documented by photointerpretation, in addition to relocating and surveying the location of the 2010 collection by Robert Dorn (Figure 6). Five other previously-known occurrences of *A. arcuata* were updated or expanded.

In addition, two new Sensitive species records of *Cleome multicaulis* (Many-stemmed spiderflower) were documented in alkaline meadow areas identified by photointerpretation. It had not previously been known in the BLM Lander Field Office, or in Fremont County. Since it occupies alkaline meadow habitats, the positive and negative data points collected in the study area for the original target species serve to update the potential distribution model for this third species. In total, five new Sensitive species records were documented as a result of photointerpretation.

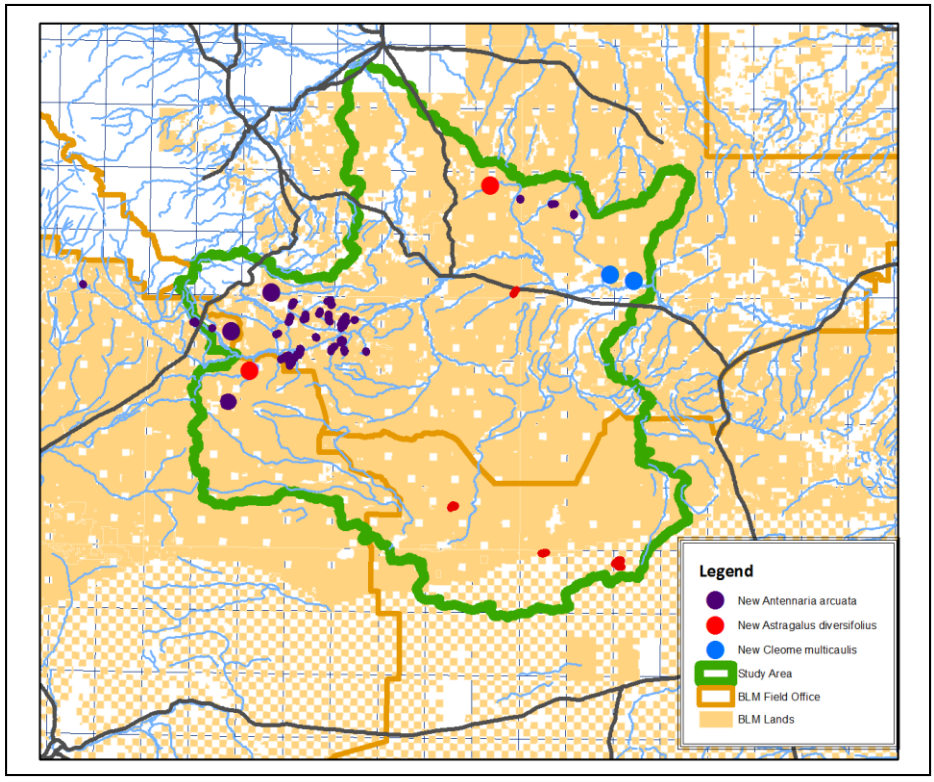


Figure 6. Updated Sensitive species records in the study area

Of the 41 quarter-quads flagged in Random Forest models that were surveyed in 2014, no new species occurrences resulted. Three of the quarter-quads did have alkaline meadow habitat, one of which was extensive and appeared suitable for *Antennaria arcuata* but was not occupied, another of which also appeared suitable for *A. arcuata* but the alkaline meadow habitat barely extended onto public land and it was not occupied, and a third that had marginal alkaline

meadow habitat. The 2014 survey results formed a nearly-contiguous ordination series of quarter-quads flagged for testing and informing Random Forest potential distribution models that will be used to revise the Random Forest models for all three species.

Of the 41 quarter-quads flagged in deductive models for field-testing, most had alkaline meadow habitat but no new species occurrences resulted. The negative data generated in surveying quarter-quad targets generated by these two different modeling methods will be used to update the Random Forest models for the two species. Of the classification tree potential distribution modeling for *Antennaria arcuata* (Fertig and Thurston 2003), one overlapped with a site identified by photointerpretation and corresponded with discovery of a new occurrence of *A. arcuata*.

The pages that follow present the most current status information for each of the three Sensitive species.

RESULTS - SPECIES INFORMATION – *ANTENNARIA ARCUATA*[3]

Classification

Scientific name: *Antennaria arcuata* Cronq.

History of the species: The species was first described by Arthur Cronquist based on a 1946 collection by J.H. Christ (*16065*) from hayfields near Carey in Blaine County, Idaho. A specimen from the Atlantic City – Sweetwater River area was collected by Johnson (*s.n.* NY) in 1905, Fremont County, Wyoming; but not identified as *A. arcuata* until Cronquist annotated it in 1952 (Cronquist 1955). It was discovered in Elko County, Nevada in the late 1970's. The first surveys for it in Wyoming were conducted by Dorn (1979).

Synonyms: None

Common name: Meadow pussytoes (also called Box pussytoes or Arching pussytoes)

Family: Asteraceae

Size of genus: The *Antennaria* genus is comprised of 45 species (34 in North America)(Bayer 2006). The genus is widespread across temperate and arctic/alpine regions of North America, Eurasia and South America, also present in Mexico.

Phylogenetic relationships: *Antennaria arcuata* is a sexual diploid and the only member of the Arcuatae clade within the *Antennaria* genus based on phylogenetic analysis using ITS regions of rDNA (Bayer et al. 1996, Bayer 2006). Before that time, it was placed in the Argenteae clade

[3] This results section incorporates information in Heidel (2013) and all prior work. It represents the most current and complete information for the species in Wyoming.

with two other sexual diploid taxa (Bayer 1992). Its phylogenetic relationships and origins have not been determined.

Present legal or other formal status

U.S. Fish & Wildlife Service: None. In 1975, *Antennaria arcuata* was included in the first list of species considered for designation under the Endangered Species Act (ESA) by the Smithsonian Institution (Ayensu and DeFilipps 1978), and proposed as Endangered (USDI Fish & Wildlife Service 1976). It became a Category 2 candidate for listing under the Act beginning in 1980 (U.S. Fish and Wildlife Service 1980, 1985, 1990, 1993). The recognition of Category 2 species was replaced with a new Species at Risk category in 1996. However, the list is not maintained and species in this category are not considered formal candidates for listing at present. As a result, this species currently has no legal, rangewide, protection status under ESA.

Agency status: Designated Sensitive by Wyoming Bureau of Land Management (BLM 2001, 2010). It is also designated Sensitive by Nevada Bureau of Land Management (though apparently not known from BLM lands) and U.S. Forest Service – Region 4.

Global Heritage rank: G3 (globally vulnerable); previously G2 (globally imperiled). Updating of the global rank to G3 was conducted by WYNDD as part of the prior WYNDD surveys in the Upper Green River watershed (Heidel 2013), in collaboration with NatureServe.

State Legal status: None

State Heritage rank: S3 (state vulnerable); previously S2 (state imperiled). It has been recognized as a rare species in Wyoming ever since the earliest state lists (Clark and Dorn 1979). Updating of the state rank to S3 was conducted by WYNDD as part of the prior WYNDD surveys in the Upper Green River watershed (Heidel 2013). It is ranked S1 (state critically imperiled) in Nevada and in Idaho.

Description

General non-technical description: Meadow pussytoes is a white-woolly perennial herb that spreads by conspicuously arching woolly stolons up to 10 cm long. Flowering stems are 5-40 cm tall with relatively few oblanceolate leaves that are equally grayish-white hairy above and below. Flower heads are numerous, clustered at the tip of the stem, and have membranous, white-tipped bracts and white disk flowers (ray flowers are absent). Individual plants are unisexual. Pistillate plants have involucres 4-6 mm long, and staminate plants have involucres 5-7 mm long (Cronquist 1950; Dorn and Dorn 1980, Dorn 2001; Marriott 1986; Fertig et al. 1994; Fertig 1996; Figures 7-10).

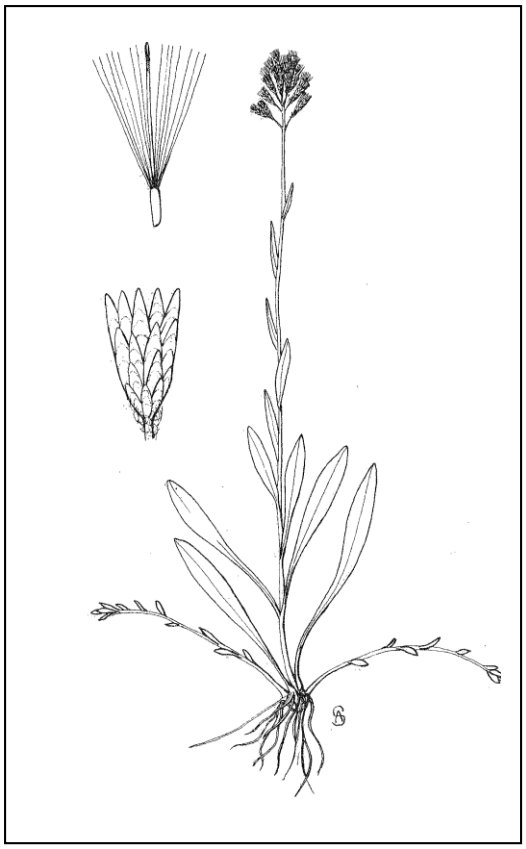


Figure 7 (above): *Antennaria arcuata* by Bobbi Angell (from Cronquist 1994)
Figure 8 (upper right): *Antennaria arcuata* by B. Heidel
Figures 9 and 10 (below): Pistillate and staminate flowers of *A. arcuata*, resp. by B. Heidel

Technical description: Plants perennial, 5-15 (40) cm tall with woolly stems. Stolons 4-10 cm and arched. Basal leaves 1-3-nerved, narrowly to broadly spatulate, or narrowly rhombic-obovate, 20-45 x 3-15 mm, tips mucronate, faces densely white-woolly. Cauline leaves linear, (2-)5-40 mm, not flagged. Heads (4-)7-25, in racemiform to paniculiform or corymbiform arrays. Involucres staminate 3-5 mm; pistillate 4.5-6(-7) mm. Phyllaries distally whitish (mostly staminate) or graying stramineous to light brown. Corollas staminate 2.5-4 mm; pistillate 3.5-5 mm. Cypselae 1-1.8 mm and glabrous, pappi staminate 3-4.5 mm; pistillate 4-6 mm. 2*n*=28. (Bayer 2006). Note: The relative length of pistillate and staminate involucres was first described by Dorn and Dorn (1980) and differs from Bayer (2006).

Local field characters: Recognized by its long, arching, sparsely-leafy, densely white-woolly stolons that develop by flowering time.

Similar species: *Antennaria microphylla, A. parvifolia*, and *A. rosea* have short, non-woolly stolons and densely crowded basal rosettes. *Antennaria flagellaris* has slender, glabrous stolons and inflorescences composed of a single flower head. Other *Antennaria* species in Wyoming lack stolons, have glabrous upper leaf surfaces, or dark-tipped involucral bracts. *Gnaphalium chilense* is an annual or biennial herb with bisexual flower heads and yellowish, membranous involucral bracts (Dorn 2001, Fertig et al. 1994, Fertig 1996).

Phenology: Flowering late June-July; in fruit July-August. *Antennaria arcuata* has been characterized as having a flowering/fruiting period from July through September (Dorn 1980, Marriott 1986, Fertig 1996). It was collected in flower at the Soda Lake (Sublette Co.) population on 24 June 1997 by Steve Laster, and in bud and early flower on 22 June 2014 in Fremont County. The stolons start to elongate at about flowering time, and elongated stolons are needed for determination. After fruiting, the inflorescences may senesce and the flowering stalks break off or fall over.

Geographical distribution

Range: *Antennaria arcuata* is a rare species characterized as a Great Basin regional endemic having small, disjunct populations (Bayer 1992) in south-central and southeastern Idaho, northeastern Nevada, and central to southwest Wyoming (Figure 11-12). Its recent discovery in the BLM Snake River Field Office represents the only other locations where this species occurs on BLM-administered lands. BLM staff (Glenn Guenther, Assistant Field Manager) collected it there in 2012 and the voucher was verified by staff at WYNDD and RM, and deposited at RM.

In Wyoming, it is known from the Sweetwater River drainage and upper Green River drainage (Figure 12). In the Sweetwater River drainage, there are gaps in distribution that were surveyed but the species was not found. As a result of this study, only one new population was found, on Slaughterhouse Creek, and it is the closest of occurrences to the historic South Pass mining town.

Extant sites: *Antennaria arcuata* is now known from 32 occurrences in Wyoming (Figure 12; Table 1). In total, 24 occurrences are in the Sweetwater watershed and eight in the Green River watershed. The locations of *A. arcuata* sites surveyed in 2014 are indicated by the date of the most recent observation and bold-faced on Table 1.

Figure 11 (right). Distribution of *Antennaria arcuata* rangewide

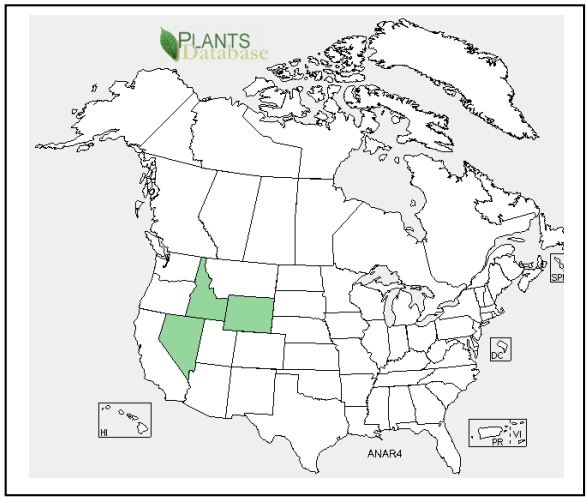
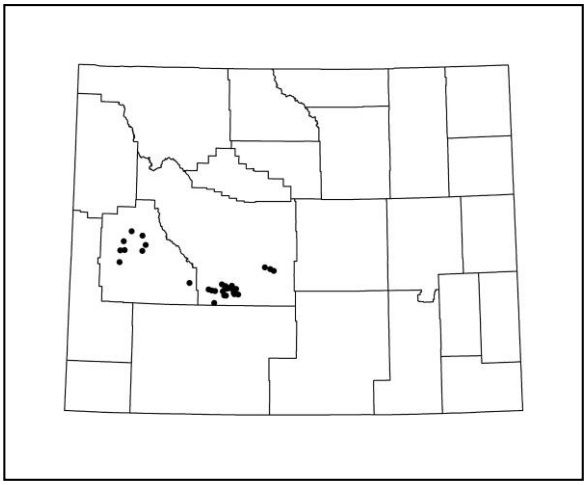


Figure 12 (right). Distribution of *Antennaria arcuata* in Wyoming



Antennaria arcuata has a relatively long history of surveys in Wyoming. It was collected for the first time in the state in 1905 (*Johnson s.n.* NY) and annotated by Cronquist in 1952 (Cronquist 1955). Its recognition under the ESA in 1975 drew the attention of agencies. Wyoming surveys were conducted for the U.S. Forest Service by Barry Johnston in 1977-1978, and for the BLM between 1978-1982 by BLM staff (James Saulmon, BLM State Botanist) and consultants Robert Dorn and Robert Lichvar (Whiskey Basin Consultants 1982). In 1985, its distribution was extended further east in Fremont County as part of floristic surveys by Haines (1988). The first Wyoming status report was produced by Marriott (1986). Survey work was expanded and past population sites revisited to produce a second status report by Fertig (1996), with revisionary

mapping of occurrences by drainage and separation distance standards so that the running tallies of populations and population/site names were revised at that time compared to earlier ones. In 1995, its distribution was extended further west in Fremont County as part of floristic surveys by Welp et al. (1986) and Welp (1987). It was collected at a new Fremont County location by Robert Dorn in 2010 (Table 1; #034). In 2012, surveys were conducted for it in the Pinedale and Rock Springs Field Offices (Heidel 2013). One new occurrence was found in 2014 surveys and model-testing (Table 1; #035). Also in 2014, three occurrences known only from collection records were surveyed, one occurrence was expanded to include additional tributaries and drainage segments, and three more occurrences were surveyed with little change to their mapping. All Fremont County records are presented in Appendix A.

Historical sites: The collection location of the 1905 specimen (Johnson s.n.) is not known but inferred to correspond with more recent collection locations.

Unverified/Undocumented reports: None.

Sites where present status not known: The *Antennaria arcuata* occurrence on Pine Creek (#017) could not be relocated in 1995 and may be extirpated. Two of the four original subpopulations in the Soda Lake area of Sublette County (#024) could not be relocated in 2012. One of those two is in a relatively dry setting affected by both grazing intensity and drought conditions of 2012. The other location either had a location error if on public land, or else fell on private land according to the collection label.

Many occurrences of *Antennaria arcuata* were last surveyed in 1995 as reflected in the report by Fertig (1996). Those occurrences that were last surveyed in the 1990's and re-visited in 2014 were all relocated. The rest are presumed to be extant.

Areas surveyed but species not located: *Antennaria arcuata* was not found in any of the quarter-section areas identified by the Random Forest or the deductive model testing run in 2014. It was sought at 46 locations (21 identified by Random Forest modeling, 15 identified by deductive modeling and 10 more sought by photointerpretation) but not found. In addition, all negative surveys for *Astragalus diversifolius* have merit as negative data for *A. arcuata*. All prior status reports include maps of additional negative surveys (Marriott 1986, Fertig 1996, Heidel 2009).

Land ownership: All Fremont County occurrences are on lands administered by the BLM Lander and Rock Springs Field Offices or the Department of State Lands.

Table 1. Location of *Antennaria arcuata* populations in Wyoming

EO#	County	General Location	USGS 7.5' Quad	Legal	Elev ft (m)	Public Land	Last Obs. Date
1	Fremont	Burr Mine, ca 1 mile N of the Sweetwater River.	Radium Springs	T28N R98W Sec. 8	7300 (2225)	BLM Lander FO	8/12/80
3	Fremont	Granite Creek drainage, ca 1.3 miles S of the Sweetwater River.	Lewiston Lakes; Radium Springs	T28N R98W Sec. 11, 15, 22	7300 (2225)	BLM Lander FO	8/24/95
4	**Fremont**	**Mormon Creek, ca 2 miles S of the Sweetwater River.**	**Lewiston Lakes**	**T28N R98W Sec. 13, 24**	**7200 (2195)**	**BLM Lander FO; State of Wyoming**	
5	Fremont	Willow Creek tributary, ca 3 miles N of the Sweetwater River.	Atlantic City	T28N R99W Sec. 4, 5, 8	7300-7350 (2225-2240)	BLM Lander FO	8/23/95
6	Fremont	Long Slough, ca 1mile S of the Sweetwater River.	Atlantic City; Radium Springs	T28N R99W Sec. 22, 27, 28	7200 (2195)	BLM Lander FO, BLM Rock Springs FO	9/2/95
7	Fremont	Harris Slough, just S of the Sweetwater River.	Circle Bar Lake; Radium Springs	T28N R99W Sec. 13, 23, 24, 26, 27, 34	7200-7300 (2195-2225)	BLM Lander FO;Sweetwater Preserve	8/13/95
9	Fremont	McLean Meadows and adjacent small tributary, 0.5-1miles W of the Lewiston Lakes.	Lewiston Lakes	T28N R98W Sec. 2; T29N R97W Sec. 30, 31; T29N R98W Sec. 36	7200-7340 (2195-2240)	BLM Lander FO	8/22/95
10	Fremont	Level Meadows Creek drainage, ca 5 miles north of the Sweetwater River.	Radium Springs	T29N R98W Sec. 14	7300 (2225)	BLM Lander FO	8/12/80
11	Fremont	Upper Deep Creek, ca 10.5miles ESE of Atlantic City.	Radium Springs	T29N R98W Sec. 22, 27, 28	7500-7560 (2285-2300)	BLM Lander FO	8/20/95
12	Fremont	Diamond Creek, ca 2.25-3.25 miles N of the Sweetwater River.	Radium Springs	T29N R98W Sec. 26, 35	7400 (2255)	BLM Lander FO	8/20/95
13	Fremont	Northeast fork of Upper Strawberry Creek, and ca 0.2 miles N of the Atlantic City·	Radium Springs	T29N R98W Sec. 29, 30	7500-7540 (2285-2300)	BLM Lander FO	8/22/95
15	Fremont	Headwaters of Strawberry Creek at the Crow's Nest, 6-6.5 miles N of the Sweetwater River.	Radium Springs	T29N R99W Sec. 13	7600-7640 (2315-2330)	BLM Lander FO	8/22/95
16	Fremont	Along tributary northeast of Rock Creek, ca 0.5miles N of the Handcart Site on the Oregon Trail.	Radium Springs	T29N R99W Sec. 25, 26, 35	7400 (2255)	BLM Lander FO	8/30/82
17	Fremont	Pine Creek, ca 2.7miles SSW of South Pass City.	South Pass City	T28N R101W Sec. 1	7700 (2345)	BLM Rock Springs FO	8/21/86
18	Fremont	Fish Creek at crossing with WY Highway 28 at southwestern-most turnoff to South Pass City, ca 8.5 miles WSW of Atlantic City.	Anderson Ridge; South Pass City	T29N R101W Sec. 34	7900 (2410)	BLM Rock Springs FO	9/3/95
19	**Fremont**	**Tributary to west of Buffalo Creek, ca 12 miles ENE of Jeffrey City.**	**Muskrat Basin**	**T31N R92W Sec. 8, 17**	**6840-6900 (2085-2105)**	**BLM Lander FO**	**7/22/14**

20	**Fremont**	**East Fork of East Long Creek, ca 14 miles NNW of Jeffrey City.**	**Tin Cup Mountain**	**T31N R93W Sec. 1, 2**	**6900-7000 (2105-2135)**	**BLM Lander FO**	
21	Fremont	Upper end of Chimney Creek, ca 0.2 miles NE of the uppermost of the Lewiston lakes, ca 1.4 miles N of Sweetwater River Canyon.	Lewiston Lakes	T29N R97W Sec. 29, 32	7250 (2210)	BLM Lander FO; Sweetwater Preserve	8/22/95
22	**Fremont**	**Ca 4 miles west of Continental Peak and ca 5 miles NE of Oregon Buttes in Oregon Gulch drainage.**	**Dickie Springs**	**T27N R100W Sec. 29**	**7572-7600 (2305-2315)**	**BLM Rock Springs FO**	**7/31/14**
23	Fremont	South Fork of Willow Creek in vicinity of spring, 2.5 miles south of confluence of Willow Creek and Sweetwater River, ca 1 mile N of Strawberry Creek.	Lewiston Lakes	T28N R97W Sec. 21	7370 (2245)	BLM Lander FO	8/24/95
24	Sublette	Soda Lake area, ca 5 miles N of Pinedale.	Cora, Fremont Lake South	T34N R109W Sec. 3, 4, 9; T35N R109W Sec. 33	7420-7540 (2262-2298)	BLM Pinedale FO	7/7/12
25	**Fremont**	**2 miles N of Long Creek Mtn, ca 9 miles E of WY Hwy 135.**	**Elkhorn Springs**	**T31N R93W Sec. 6**	**6860 (2091)**	**BLM Lander FO**	**6/22/14 and 7/23/2014**
26	Sublette	Brodie Draw and unnamed tributary, ca. 10.2 miles WSW of Daniel Junction.	Halfway, Merna	T33N R112W Sec. 6; T34N R112W Sec. 31; T34N R113W Sec. 36	7500-7560 (2286-2304)	BLM Pinedale FO; State of Wyoming	6/27/09
27	Sublette	Ryegrass Draw, ca 7 miles W of Daniel.	Onion Springs, Webb Draw	T34N R112W Sec. 34	7300-7400 (2225-2256)	BLM Pinedale FO	7/7/12
28	Sublette	Duck Creek, ca. 3.5 miles W of Pinedale.	Mount Airy	T34N R110W Sec. 36	7210 (2198)	State of Wyoming	8/7/12
29	Sublette	Unnamed tributary of Webb Draw, ca. 7.5 miles NW of Daniel Junction.	Webb Draw	T35N R112W Sec. 28	7340-7420 (2237-2261)	BLM Pinedale FO	7/9/12
30	Sublette	Unnamed tributary of Green River, ca. 13-14.5 miles N of Daniel Junction.	Warren Bridge	T36N R111W Sec. 9, 16	7580-7680 (2310-2341)	BLM Pinedale FO, State of Wyoming	7/9/12
31	Sublette	Upper ends of North and South Antelope Draws and unnamed draw, ca 13.5 miles NW of Marbleton.	Halfway, Meadow Canyon	T32N R113W Sec. 22, 27, 34, 35, 36	7560-7790 (2304-2374)	BLM Pinedale FO	8/9/12
32	Sublette	Jensen Meadows, tributary of Lander Creek on east side of Continental Divide, ca. 31 miles NE of Farson	Jensen Meadows	T29N R103W Sec. 6	8000 (2438)	State of Wyoming, BLM Rock Springs FO	8/6/12
33	Sublette	Unnamed tributary of Willow Creek, ca 2.5 miles S of New Fork Lakes, ca. 12.5 miles NNW of Pinedale.	New Fork Lakes	T36N R110W Sec. 36	7480 (2280)	State of Wyoming	8/21/12
34	**Fremont**	**Little Beaver Creek, ca 3 miles ENE of Atlantic City, ca 22.8 mi SE of Lander**	**Miners Delight**	**T29N R99W Sec. 9**	**7700-7720 ()**	**BLM Lander FO**	**6/29/14**
35	**Fremont**	**Slaughterhouse Gulch, ca 3 mi SSE of South Pass City; ca 28.0 mi SE of Lander**	**South Pass City**	**T28N R100W Sec. 4, 5**	**7640-7740 ()**	**BLM Lander FO**	**8/6/14**

Habitat

Antennaria arcuata is a facultative wetland plant throughout its range (Lichvar 2012). It is found mainly in subirrigated, alkaline meadows of drainages with broad, open valleys on Quaternary deposits.

Associated vegetation: In the Sweetwater River valley, the alkaline meadow communities occupied by *Antennaria arcuata* are often found within a matrix of *Artemisia cana* (silver sagebrush) and *Pentaphylloides floribunda* (shrubby cinquefoil) among upland sagebrush steppe. In the Upper Green River Basin, it is sometimes found with *Artemisia cana* var. *viscidula* and *Pentaphylloides floribunda*. It is absent from riparian zones with tall, dense graminoid or shrub cover and where soils are saturated.

Frequently associated species: *Antennaria arcuata* is associated with facultative and obligate wetland species (Lichvar 2012). Dominants in the Sweetwater River watershed were found to overlap with those in the Green River watershed. They included *Deschampsia cespitosa* (tufted hairgrass), *Juncus balticus* (Baltic rush), *Poa pratensis* (Kentucky bluegrass), native bluegrasses such as *P. nevadensis* and *P. juncifolia*; considered by some as a synonym of *P. secunda* (Sandberg bluegrass)*; Carex praegracilis* (clustered field sedge), *Muhlenbergia richardsonis* (mat muhly), and *C. nebrascensis* (Nebraska sedge). A robust list of associated species was reported by Bayer (1992) from six sites used in genetics research, including four in Fremont County, WY and one each in Idaho and in Nevada. It was the template for an expanded list in Heidel (2013), with updates in this study (Table 2).

Table 2. Plants associated with *Antennaria arcuata* throughout its range

Family	Scientific Name[4]	Sublette Co., WY	Fremont Co., WY	Idaho	Nevada
Asteraceae	*Achillea millefolium L.*	x	x	x	x
Asteraceae	*Agoseris glauca* (Pursh) Raf. var. *glauca*	x	x		
Asteraceae	*Agoseris glauca* (Pursh) Raf. var. *dasysepala* (Torr. & Gray) Jeps.		x		
Asteraceae	*Antennaria corymbosa*E. Nels.		x		
Asteraceae	*Antennaria microphylla* Rydb.	x	x		
Asteraceae	*Artemisia cana* Pursh (apparently includes both *A. c.* var. *cana* and *A. c.* var. *viscidula*)	x	x	x	
	Artemisia tripartita var. *rupicola*		x		
Asteraceae	*Aster ascendens* Lindl. (syn. *Symphyotrichum ascendens*)		x	x	
Asteraceae	*Aster falcatus* Lindl. (syn. *Symphyotrichum falcatum*)		x		
Asteraceae	**Aster hesperius* (syn. *Symphyotrichum hesperium*)	x			
Asteraceae	Aster *lonchophyllus* Hook. [probably *Erigeron lonchophyllus*]		x		
Asteraceae	**Cirsium arvense* (L.)Scop.	x			
Asteraceae	*Cirsium hookerianum* Nutt. [possibly *C. scariosum*]		x		
Asteraceae	**Cirsium scariosum* Nutt.	x	x		
Asteraceae	*Crepis tectorum* L.		x		

[4] Synonyms are in parentheses. Questions about prior determinations are in brackets. This list includes all taxa in Bayer (1992), Marriott (1986) and Fertig (1996) following the nomenclature in the latter. Any other associates species found in Sublette County but not previously reported as an associate is set off by an asterisk (*).

Asteraceae	*Erigeron lonchophyllus* Hook.	x	x		
Asteraceae	*Haplopappus lanceolatus* (Hook.) Torr. & Gray (syn. *Pyrrocoma lanceolata* (Hook.) Greene)	x	x	x	
Asteraceae	*Haplopappus uniflorus* (Hook.) Torr. & Gray (syn. *Pyrrocoma uniflora* (Hook.) Greene)	x	x	x	
Asteraceae	*Senecio canus* Hook.		x		x
	Senecio debilis		x		
Asteraceae	*Solidago nana* Nutt.		x		
Asteraceae	**Taraxacum officinale* L.	x			
Cyperaceae	*Carex aurea* Fern.		x		
Cyperaceae	*Carex nebrascensis* Dewey	x	x		
Cyperaceae	*Carex praegracilis* Boott	x	x		
Cyperaceae	*Carex simulata* Mack.		x	x	
Cyperaceae	**Eleocharis quinqueflora* (Hartm.) Schw.	x			
Equisetaceae	*Equisetum laevigatum* A. Br.		x		
Fabaeeae	*Astragalus agrestis* Dougl. ex G. Don		x		
Fabaeeae	*Astragalus bodinii* Sheld.		x		
Fabaeeae	*Astragalus gracilis* Nutt.		x		
Fabaeeae	*Astragalus vexilliflexus* Sheld.		x		
Fabaeeae	*Trifolium longipes* Nutt. var. *reflexum* A. Nels.		x		
Gentianaceae	*Gentiana affinis* Griseb. var. *affinis*	x	x		
	Gentiana calycosa		x		
Iridaceae	*Iris missouriensis* Nutt.		x		x
Juncaceae	*Juncus balticus* Willd. var. *montanus* Engelm.	x	x		
Juncaceae	*Juncus longistylis* Torrey		x		
Liliaceae	*Zigadenus elegans* Pursh		x		
Liliaceae	*Zigadenus venenosus* Wats. var. *gramineus* (Rydb.) Walsh		x		
Malvaceae	*Sida!cea oregana* (Nutt. ex Torr. & Gray) Gray			x	
Poaceae	*Agropyron dasystachyum* (Hook.) Scribn. var. *riparium* (Scribn. & Smith) Bowden (*Elymus lanceolatus* (Scribn. & Sm.) Gould var.	x	x		x
Poaceae	**Agrostis stolonifera* L.	x			
Poaceae	*Bromus ciliatus* L.		x		
Poaceae	*Bromus japonicus* Thunb.				x
Poaceae	*Calamagrostis montanensis* (Scribn.) Scribn. in Vasey		x		
Poaceae	*Danthonia californica* Bolander			x	
Poaceae	*Deschampsia cespitosa* (L.) Beauv.	x	x		
Poaceae	*Hordeum brachyanthenum* Nevski	x	x		x
Poaceae	*Hordeum jubatum* L.				x
Poaceae	*Koeleria cristata* Pers.		x		
Poaceae	*Muhlenbergia cuspidata* (Torr.) Rydb. [Possibly *M. richardsonis*]		x	x	x
Poaceae	*Muhlenbergia filiformis* (Thurb. ex Wats.) Rydb.		x		
Poaceae	**Muhlenbergia richardsonis* (Trin.) Rydb.	x			
Poaceae	*Oryzopsis pungens* (Torr. ex Spreng.) Hitchc.		x		
Poaceae	*Phleum alpinum* L.		x		
Poaceae	*Poa annua* L.			x	
Poaceae	*Poa arida* Vasey		x		
Poaceae	**Poa juncifolia* Scribn.	x			
Poaceae	*Poa nevadensis* Vasey ex Scribn.		x		
Poaceae	*Poa pratensis* L.		x		
Poaceae	*Poa sandbergii* Vasey (syn. *Poa secunda* Presl.)	x	x	x	x
Poaceae	*Trisetum wolfii* Vasey			x	
Polemoniaceae	*Phlox kelseyi* Britton		x		
Primulaceae	*Dodecatheon pulchellum* (Raf.) Merr.				
Ranunculaceae	*Ranunculus acriformis* Gray var. *acriformis*		x		
Rosaceae	*Pentaphylloides floribunda* (Pursh) Love		x		
Rosaceae	*Potentilla anserina* L.	x	x		
Rosaceae	*Potentilla gracilis* Dougl. ex Hook. var. *elmeri* (Rydb.) Jeps.		x	x	
Rosaceae	*Potentilla gracilis* Dougl. ex Hook. var. *pulcherrima* (Lehm.) Fern.				x
Rosaceae	*Potentilla ovina* Macoun var. *ovina*	x	x		

Salicaceae	*Salix geyeriana* Anderss.	x	x		
Saxifragaceae	*Parnassia palustris* L. var. *montanensis* (Fern. & Rydb. ex Rydb.)	x	x		
Scrophulariaceae	*Castilleja cusickii* Greenm.			x	x
Scrophulariaceae	*Orthocarpus luteus* Nutt.	x		x	
Scrophulariaceae	*Penstemon rydbergii* A. Nels. var. *oreocharis* (Greene) Holmgren			x	

Antennaria arcuata is often found growing near *A. microphylla* (Littleleaf pussytoes). Flowering stalks of the two species look similar. In Fremont County, *A. microphylla* was described as bimodal, replacing *A. arcuata* on drier hummocks and on wetter soils (Fertig 1996). Changes in soil moisture-retaining capacity, either through increased soil compaction or increased vegetation density, may shift the competitive balance in favor of *A. microphylla* at many sites. The microhabitat occupied by *A. arcuata* in Fremont County relative to *A. microphylla* is represented in Figure 13. In Sublette County, they are often in the same valley bottom but not consistently overlapping, and usually with *A. arcuata* closer to the center of the valley bottom than *A. microphylla*. They may be found growing together on some of the same hummocks or terraces, in which case, *A. arcuata* tended to be on the edge of the hummock or terrace rather than the center where *A. microphylla* is concentrated.

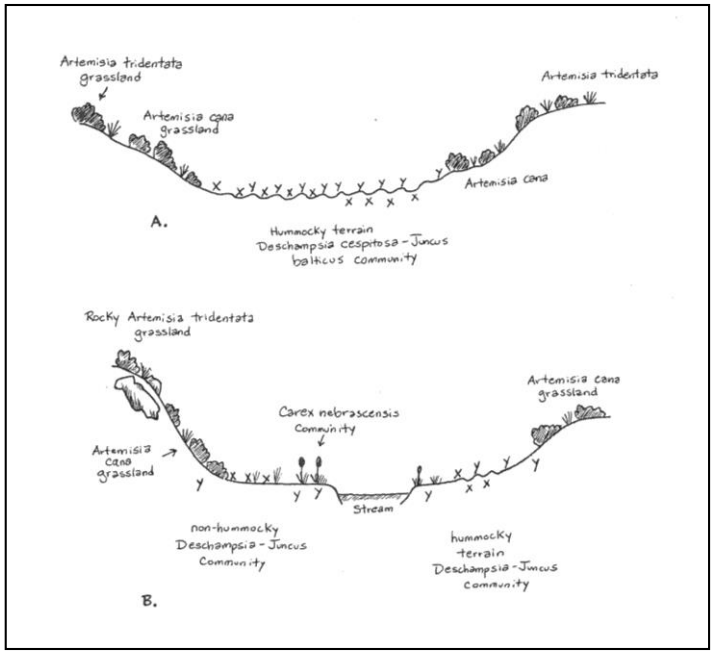


Figure 13. Topographic position of *Antennaria arcuata* in landscapes of the Sweetwater River watershed, where X = *Antennaria arcuata*; Y = *Antennaria microphylla*. Illustrated by W. Fertig, from Fertig (1996).

Topography: *Antennaria arcuata* occupies bottomland settings, usually associated with drainages. The bottomlands may be in headwater positions or along segments with perennial flow (Figures 14-15). The valley settings may be discrete or subtle, accordingly. Known occurrences in Wyoming range in elevation from 1510-2440 m (4950-8000 ft).

Figure 14. Topographic setting of *Antennaria arcuata* EO#035 on Slaughterhouse Creek, looking northwest to Wind River Range

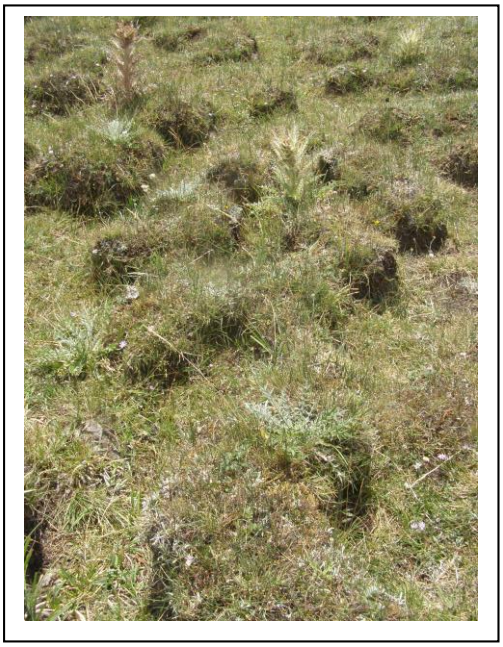
Figure 15. Topographic setting of *Antennaria arcuata* EO#025 east of the West Fork of Long Creek

At any given site, *A. arcuata* it is restricted to a particular microtopographic setting or range of settings, and corresponding vegetation zone. The microtopographic settings of Fremont County populations were said to be in the spaces between hummocks or on their lower sides, occasionally on flat terrain or in shallow swales at the edge of drainage bottoms (Fertig 1996). By contrast, the settings of Fremont County sites surveyed in 2014 and previously-surveyed Sublette County populations are mainly on top or sides of hummocks, even though some populations or subpopulations are also on flat stream terraces that are subirrigated and contiguous with hummocks (Figures 16-17). As noted by Fertig (1996), and observed more recently, plants can also be found extending onto the channel bottom, at the base of small cutbanks of channel bottoms, and in shallow swales of beaded wetlands isolated from streams.

Hummocks provide an array of moisture availability and vegetation conditions over a small area, including exposed soil for stolons to root. They may buffer the species from competition on one hand, or may exacerbate desiccation on the other. All microtopographic settings have subirrigated conditions.

Soil relationships: Known populations of *Antennaria arcuata* in Fremont County, Wyoming are found mainly on soils derived from Quaternary sandy alluvial deposits (Love and Christiansen 1985) as reported by Fertig (1996). Known populations of *A. arcuata* in Sublette County, Wyoming are on a wider range of parent materials based on the same geology mapping including

glacial deposits, fans, and alluvium. In addition, they tend to have high organic content, and some Sublette County sites were found to have histosol inclusions within occupied habitat.



Figures 16 and 17 (above and right): Hummocks occupied by *Antennaria arcuata*, EO#035 on Slaughterhouse Creek

Figure 18 (left): Hummocks occupied in low numbers by *Antennaria arcuata*, EO#025 east of the West Fork of Long Creek

Bayer (1992) analyzed soils from six populations of *Antennaria arcuata* (four in Wyoming, and one in Idaho and one in Nevada). Soils from these sites ranged from neutral to basic, with high concentrations of calcium, magnesium, and sodium, though sodium concentrations were below levels that classify them as sodic or its vegetation as halophytic. Most sites were also found to be high in organic content, ranging between 3-20%. Organic material has very low density so a 3% content by weight is actually a high organic content by volume. Two of the six samples (one in Idaho, one in Wyoming) exceed the 13% threshold at which soils are classified as histosols (organic soils). Low levels of selenium were found in assays of *A. arcuata* plants, suggesting that this compound is present in the soil. No work has been done analyzing soils of Sublette County populations but they generally appeared to have loamy rather than sandy textures.

At three of the Sublette County populations, there were zones bordering *Antennaria arcuata* habitat where marl accumulated. Marl is a calcium carbonate or lime-rich mud that precipitates out of water and accumulates in biological processes of freshwater and marine systems. In temperate latitudes and freshwater systems, species of the submerged nonvascular plant *Chara* spp. are the agents actively precipitating calcium-rich ions. Marl accumulation is restricted to alkaline fens as found in Wyoming, and the three particular Sublette County population sites had fen habitat near occupied *A. arcuata* habitat.

Regional climate: Climate data from five of the nearest meteorological stations are represented below (USDI NOAA 2006). They all represent high, intermontane settings and cold desert conditions. The known species' distribution through 2003 was negatively associated with mean July temperature (Fertig and Thurston 2003).

The meteorological station at Jeffrey City has data from 1964-2005, and is at an elevation of 1930 m (6330 ft). Mean annual temperature is 5.50° C (41.9° F) with mean January temperature at -6.61 °C (20.1 °F) and mean July temperature at 19.44° C (67.0° F). Mean annual precipitation is 25.70 cm (10.12 in), with peak precipitation in May at 5.18 cm (2.04 in).

The meteorological station at South Pass City has data from 1915-2005, and is at an elevation of 2390 m (7840 ft). Mean annual temperature is 1.44° C (34.6° F) with mean January temperature at -10.33° C (13.4° F) and mean July temperature at 20.61° C (58.2° F). Mean annual precipitation is 34.09 cm (13.42 in), with precipitation highest early in the growing season from April-June, ranging between 3.43- 3.66 cm (1.35-1.44 in) as mean monthly average between the three months.

The meteorological station at Pinedale has data from 1948-2006, and is at an elevation of 2192 m (7190 ft). Mean annual temperature is 2.1º C (35.8º F) with mean January temperature at -10.8º C (12.6º F) and mean July temperature at 15.4º C (59.8º F). Mean annual precipitation is 27.61 cm (10.87 in), with peak precipitation in May at 4.19 cm (1.65 in).

The meteorological station at Big Piney has data from 1948-2001, and is at an elevation of 2082 m (6830 ft). Mean annual temperature is 1.7º C (35.1º F) with mean January temperature at -2.1º C (10.3º F) and mean July temperature at 15.5º C (59.9º F). Mean annual precipitation is 18.95 cm (7.46 in), with peak precipitation in May at 2.67 cm (1.05 in). It lays claim to being Icebox of the Nation, based on 1930 weather monitoring data that pre-dates NOAA records.

The meteorological station at Farson has data from 1915-2006, and is at an elevation of 2009 m (6590 ft). Mean annual temperature is 3.06º C (37.5º F) with mean January temperature at -12.4º C (9.7º F) and mean July temperature at 17.7º C (63.9º F). Mean annual precipitation is 18.67 cm (7.35 in), with peak precipitation in May at 2.64 cm (1.04 in).

Local microclimate: The microhabitats occupied by *Antennaria arcuata* remain moist at or below the surface late into summer (Fertig 1996), at least in at most years. In July 2012 when surveys Upper Green River surveys began, there were extreme drought conditions (National Drought Mitigation Center 2012) and subsurface moisture was reduced or wanting. In 2014, there was above-average precipitation bringing hydrological conditions closer to average (National Drought Mitigation Center 2014).

Population biology and demography

Population size and condition: Surveys for *Antennaria arcuata* in 1995 reported an estimated 99,900-130,350 individuals in 20 populations covering ca 400-500 acres (Fertig 1996). He reported densities of 38-105 plants per square meter in demographic plots (belt transects subjectively placed in areas of high density) and individual plants appearing in small, dense, unisexual clusters.

Several new populations with plants numbering in the thousands have been discovered since the 1995 surveys upon which the most recent status report (Fertig 1996) was based. A new population of 1500-2000 plants was discovered by Walter Fertig in Fremont County in 1996. At least six of the newly-documented Sublette County populations surveyed in 2012 have numbers in the 1000's. As a result of 2014 surveys, a large new population estimated at about 20,000 plants was documented on Slaughterhouse Creek, and two others known only from collection records had numbers approaching, or exceeding, 1000 plants. The most recent estimates of total population numbers is about 170,000-220,000 plants if trends are stable.

All prior census information referred to stem counts, i.e., tallying flowering stems (ramets) as separate individual,s and in some cases there are estimates of vegetative plants. Stem counts potentially overcount individual plants if most or all plants in any given square meter represent only one (or few) genetically distinct individuals (genets). The photograph of the species in Figure 8 shows six flowering stems, with patterns of stolon development suggesting past or present connectivity. If basal rosettes and the flowering stems that spring from them are short-lived, then patterns of stolon development are obscured over time. This fundamental question of what constitutes an individual was a major reason for placing a priority on the extensive survey work of mapping rather than the intensive survey work of counting. In 2014 surveys, a conservative approach was taken of estimating the number of hummocks rather than stem numbers, assuming that each mound has at least one unique genet. Considering all the challenges of censusing, and without being able to distinguish genets from ramets, any population size figure can be high or low by an order of magnitude. It is important to note that the low genetic diversity of the species means that putative population size may not be as great a contribution to species' viability as it is for most other species that are primarily sexually reproducing.

The challenge of census is further complicated by seasonal and annual conditions. In the relatively moist 2014 growing season, it was possible that flowering stem numbers were high compared to most years. Early in the growing season or in dry years, there may be inconspicuous flowering stems (Figure 19) or proportionately low numbers of flowering stems.

Figure 19. *Antennaria arcuata* EO#025 census challenge at the earliest 2014 survey site on 22 June, with an abundance of basal rosettes covering a hummock and few inconspicuous flowering stems. Hypothetically, it could represent ~100 basal rosettes, 4 flowering stems, or 1 clone.

Population trends: Trend data from surveys at 12 Wyoming occurrences showed slight downward to slight upward increases between 1986-1995, and total population numbers reflected a slight downward trend (Fertig 1996). BLM monitoring at the Atlantic City and Gilespie exclosures documented downward trend inside the exclosures (1983/1988-2013) with the species disappearing inside the exclosures but persisting outside the exclosures (T. Skurski pers. commun. 2013 It is not known if the species can be restored in such settings. The question of population trends is all the more important if restricted to soils that have histosol origin (i.e., associated with peat formation), a soil type that may not be possible to mitigate. A study proposed for 2015 will analyze soils in the kinds of wetlands occupied by *A. arcuata* (Van Haveren pers. commun. 2015) and results from it may be appropriate to frame the merit of any further exclosure studies and long-range review of their maintenance.

In addition, two permanent belt transects were set up in *Antennaria arcuata* populations (Fertig 1996) for demographic monitoring, with the recommendation that the monitoring be continued and expanded to include a broader range of habitats. It has not been re-read since 1995.

One of the 2014 survey sites was estimated as having 5000-8000 stems in 1997, at the unnamed tributary of Buffalo Creek (#019). In 2014, it was found in exactly the same places as originally mapped and estimated as having 500+ plants. But the recent estimate was based on the number of occupied mounds, and the original estimates probably included the number of basal rosettes. The difference in estimating numbers may account for the difference rather than documenting decline (Figure 19).

Type of reproduction: *Antennaria arcuata* reproduces vegetatively by stolons or sexually as a dioecious, diploid species that produces seed. Many species of *Antennaria* also reproduce

asexually by apomixis (the production of viable seed without fertilization or meiosis) but this trait is limited to polyploid members of the genus and there is no evidence suggesting that *A. arcuata* is apomictic (Bayer 1984). It does have levels of genetic variation that are very low in comparison to all other sexual species of *Antennaria* in North America (Bayer 1992). This characterization is based on mean number of alleles per locus, proportion of polymorphic loci, and observed heterozygosity. The author hypothesized that this reflects its disjunct and restricted distribution and its habitat specificity precluding migration at the end of most recent glaciation.

Vegetative reproduction of *Antennaria arcuata* is by means of stolons. It was noted by Bayer (1992) that rosettes at the base of stems tend to be short-lived. This may mean that connections between plants are short-lived. This above-ground vegetative reproduction might be favored over seed set on substrate that may be anaerobic when moist (as is characteristic of organic soils), and in wetland vegetation that is relatively dense, with limited exposed surface and high competition, except at the edges of hummocks. The near-vertical margins of many hummocks are not well-suited for either seedling establishment or rooting. Vegetative reproduction would be particularly favored in Sublette County, where *A. arcuata* was most consistently found on hummock tops and sides (Heidel 2013) as compared to Fremont County, where it was most consistently found on intervening hummock swales (Fertig 1996). A preponderance of vegetative reproduction over sexual reproduction may also contribute to the low genetic diversity of *A. arcuata* and mainly single-sex hummocks (Figure 25). It is postulated that most flowering stems on any given hummock reflect ramets rather than genets so that effective population sizes are much lower than any flowering stem count would indicate (discussed above).

Pollination biology: Species of *Antennaria* are visited by many different insects even though the reduced flower size and lack of showy, petal-like ray flowers are non-specialized. Wind pollination may also take place. The pollination biology of *A. arcuata* has not been studied, but there may be examples among similar species. In the case of *A. dioica* (stoloniferous pussytoes), another outcrossing diploid species, small-size patches of *A. dioica* tended to have biased sex ratios. Experimental hand-pollinations showed that the degree of pollen limitation increased with increasingly female-biased sex ratios in the closest vicinity of the experimental plants. Thus, even though *A. dioica* is pollinated by many different insects, fragmented population structures impact reproductive performance of *A. dioica* (Oster and Eriksson 2007).

Both pistillate and staminate plants of *Antennaria arcuata* were noted in most but not all populations surveyed in 2012, and the number of staminate plants appeared to make up the minority when present. This is in contrast with prior survey results in which there were ratios between the sexes that were often closer to 50:50 where noted in previous surveys (Fertig 1996). It is possible but not proven that skewed ratios between the sexes observed in 2012 may impede seed set in some populations of *A. arcuata* as they do in *A. dioica* (Oster and Eriksson 2007).

Seed dispersal and biology: Seeds of *Antennaria arcuata* are probably dispersed by wind and gravity (Lorain 1990). Fertig (1996) noted that establishment of seedlings appears to be restricted to relatively mesic microsites within existing colonies. No seedlings were observed in 2014. Fertig also noted that pistillate plants were found to have 20 fruits per head, on average. Despite this apparent fecundity, establishment of seedlings in new habitats outside of the current range of the species is unlikely under present climatic conditions (Bayer 1992).

Population ecology

General summary: *Antennaria arcuata* is a perennial with rosettes that appear to be short-lived. It is possible that vegetative reproduction maintains genetically-identical ramets indefinitely with suitable habitat. It is not known whether or not there are episodes of sexual reproduction that could conceivably foster genotype divergence rather than perpetuation.

Competition: The following narrative is directly from Fertig (1996): "In Wyoming, *Antennaria arcuata* appears to decrease in areas with tall or dense vegetation. Colonies within BLM exclosures have been found to be in decline or locally extirpated where grazing has been prevented and vegetation cover has become denser and taller. High cover may also promote greater water retention in the soil, creating microsites that appear to be too wet for *A. arcuata*. Several Wyoming colonies have also been shown to decline where shrubs have replaced graminoid vegetation over time." If *A. arcuata* relies on bare ground for stolons to colonize, and is a short-lived perennial, it stands to reason that high vegetation cover might interfere with colonization.

Herbivory: No signs of livestock or wildlife herbivory were noted in 2012, but a small percentage of flowering plants were observed to have broken stems in Sublette County and in 2014 Fremont County surveys.

Livestock use is concentrated in and along the bottomland settings, and other potential effects of grazing include the indirect effects of trampling, successional shift in favor of increaser species, eutrophication, and habitat loss from associated range management practices (impoundments, fencing, other). Bayer (1992) noted that the habitat suffers disturbance from domestic animals, and went as far as to say that the hummocks are created by cattle activity. He also noted that the same areas were perhaps also disturbed by plains bison. It is not within the purview of this species survey to determine the origin of the hummocks. Dorn (1986) interpreted historical accounts to indicate that bison were originally present in all areas of the state including the Sweetwater Valley and Upper Green River Basin.

Hybridization: Bayer (1992) reported the presence of allozyme markers normally associated only with *Antennaria microphylla* in *A. arcuata* specimens from Mormon Creek, WY (EO#004), suggesting possibly hybridization or introgression between populations of these species at this site. Unlike polyploidy species of *Antennaria*, hybridization appears to be uncommon among the

diploid species of the genus (Cronquist 1994). No putative intermediates were noted in 2012 surveys.

RESULTS - SPECIES INFORMATION – *ASTRAGALUS DIVERSIFOLIUS*[5]

Classification

Scientific name: *Astragalus diversifolius* Gray

History of the species: The species was first collected in 1834 by Thomas Nuttall and determined by him as *Homalobus orthocarpus* in 1838. It was described by Asa Gray as *A. diversifolius* in 1849 based on the type collection of Nuttall. It was later collected by M. E. Jones in Tooele Co., Utah and described by him as *A. ibapensis* in 1893. It was subsequently collected by J. H. Christ in Custer Co., Idaho in 1938 and described by Arthur Cronquist as *A. reclinatus* in 1943. The latter two species were synonymized by Rupert Barneby, who accepted the treatment by Gray. It was collected in Nevada in 1982. Barneby (1964) questioned whether Nuttall was really in Wyoming when he discovered this species in 1834, though Barneby (1989) later accepted western Wyoming as the type locality. Considering the expedition route and species' phenology, it was considered to be possibly from the Green River Basin in western Wyoming (Dorn 2001). It was relocated in Wyoming in 2007 (Heidel 2008) and the first surveys for it in the state were conducted in 2008 (Heidel 2009). Its discovery at Ice Slough in 2012 along the likely 1834 Wyeth Expedition route provides an alternative interpretation of the type locality location.

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.

Common name: Meadow milkvetch

Family: Fabaceae

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 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).

Phylogenetic relationships: The *Astragalu*s genus is believed to be a mesophytic genus of the Northern Hemisphere, with a proliferation by adaptive radiation into harsh, arid habitats (Barneby 1989). *Astragalus diversifolius* resembles *A. convallarius* in that both are inconspicuous species of rush-like growth. These two species have been treated as related varietie. But the latter occupies dry, upland settings. If the mesophytic affinity is ancestral, then

[5] This results section reprints information in Heidel (2009). It represents the most current and complete information in Wyoming.

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).

Present legal or other formal status

U.S. Fish & Wildlife Service: None.

Agency status: Designated Sensitive by Wyoming Bureau of Land Management (BLM 2010). The Idaho Bureau of Land Management designated *Astragalus diversifolius* as Sensitive, where it occurs on the Upper Columbia – Salmon Clearwater District of BLM and the Snake River 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 in Wyoming.

Global Heritage rank: *Astragalus diversifolius* is ranked G2 (globally imperiled).

State Legal status: None.

State Heritage rank: Results of the 2014 surveys provide basis for updating State Heritage rank of *Astragalus diversifolius* from S1 (critically imperiled) to S2 (imperiled).

Astragalus diversifolius was originally ranked SH (known only from historic records) in Wyoming based on the one historical collection by Thomas Nuttall, made in 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, and is now being updated to S2 in 2015. It is also ranked S1 in Nevada and in Utah, and S2 in Idaho.

Description

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 21-24).

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

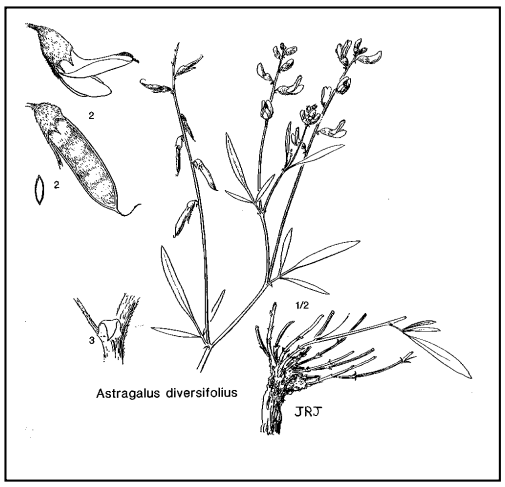


Figure 20. *Astragalus diversifolius*. By Jeanne Janish from Hitchcock and Cronquist 1961

Figure 21 (above): *Astragalus diversifolius* stem - propped up, by B. Heidel

Figure 22 (left): *Astragalus diversifolius* flowers close-up by B. Heidel. Note how its leaves (right arrow) resemble blades of saltgrass (left arrow).

Figure 23 (left): *Astragalus diversifolius*, a robust, sprawling, many-stemmed plant by B. Heidel

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).

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 spot 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; Figure 22). 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, particularly in dense vegetation.

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).
Phenology: *Astragalus diversifolius* flowers in late June – August (September), fruits in mid July-August. The earliest collection made in Wyoming was on 4 July 2008 in flower, when fruits were immature. The phenology of the species in 2007 appeared to have been a week earlier than in 2008 so flowering by the end of June seems likely. 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.

The indeterminate growth of *Astragalus diversifolius* stems appears to prolong 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. The phenology of *A. 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. 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 in Nevada (9 July 1982 – Tiehm and Tucker 7321).

Geographical distribution
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 both the Great Divide Basin and the Sweetwater River drainage in Sweetwater and Fremont Counties, respectively (Figure 24). The most current Montana flora (Lesica 2012) does not include it, though reported there in the PLANTS database due to a misinterpretation of *A. diversifolius* as synonom with *A. convallarius*. Wyoming occurrences of *Astragalus diversifolius* mark the eastern limits of species' distribution.

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.

Extant sites: Three extant occurrences of *Astragalus diversifolius* are in the Great Divide Basin, Sweetwater County, Wyoming and three more are in the Sweetwater River drainage, Fremont County, Wyoming (Table 3, Figure 25; Appendix A). In both Nevada and Utah, *A. diversifolius* is known from one extant occurrence. The highest number of extant occurrences is in Idaho with 11 (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 rangewide.

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. In 2012, it was discovered in Fremont County for the first time at Ice Slough. In the 2014 study, two new occurrences were documented east and west of Ice Slough.

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 Hams Fork to the Bear River and over to Soda Springs, Idaho. The timing of expedition travels and the phenology of *Astragalus diversifolius* were thought to be consistent with a collection in the Green River Basin (Heidel

Figure 24 (right). Distribution of *Astragalus diversifolius* rangewide

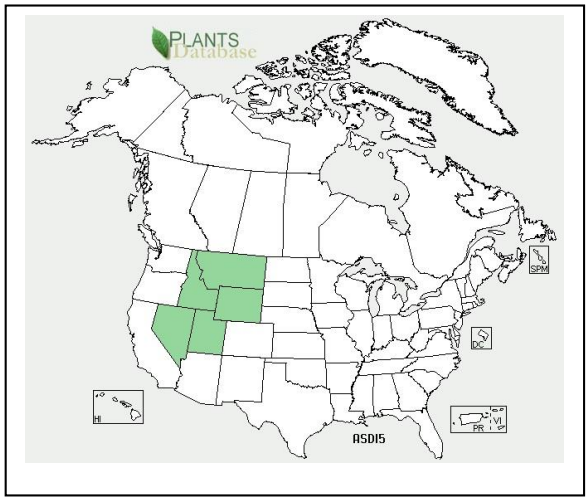
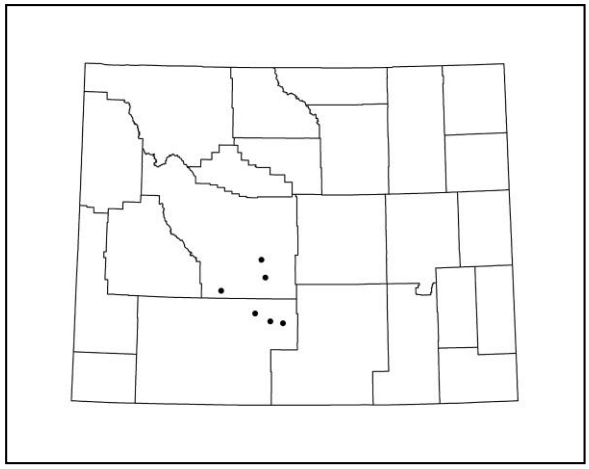


Figure 25 (right). Distribution of *Astragalus diversifolius* in Wyoming



2009). If the 1834 collections was made in the Sweetwater River drainage, then it must have been in flower. 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).

Table 3. Location of *Astragalus diversifolius* populations in Wyoming

EO#	County	General Location	USGS 7.5' Quad	Legal	Elev ft (m)	Public Land	Last Obs. Date
003	Sweetwater	Chain Lakes area, west end, ca 0.5-1 mile ENE of Circle Bar Lake	Hansen Lake	T23N R93W Sec 4, 5	6500-6510 (1981-1984)	BLM Rawlins FO	8/26/08
004	Sweetwater	Chain Lakes area, east end, ca 5 miles NNW of Mud Springs Lake	Larsen Knoll	T23N R91W Sec 7, 18; R92W Sec 12, 13	6545-6560 (1995-1999)	BLM Rawlins FO, Chain Lakes state land	7/3/08
005	Sweetwater	Mud Lake, ca 2.5 miles SSW of Eagles Nest	Lost Creek Lake	T24N R95W Sec 5, 6; T25N Sec 33	6610-6620 (2015-2018)	BLM Rawlins FO	7/4/08
006	**Fremont**	**Ice Slough, ca 8 miles W of Jeffrey City**	**Myers Ranch**	**T29N R94W Sec 1, 12**	**6200-6220 (1890-1896)**	**BLM Lander FO**	**8/27/12**
007	**Fremont**	**Oregon Slough, ca 9 miles SSE of South Pass City, ca 33.2 mi S of Lander**	**Continental Peak**	**T28N R100W Sec 35; T27N Sec 2**	**7310 (2228)**	**BLM Rock Springs FO**	**7/31/14**
008	**Fremont**	**West Fork Long Creek, ca 1.6 miles NE of Findley Lake; ca. 24.2 mi SE of Riverton**	**Elkhorn Springs**	**T32N R94W Sec 28**	**7000 (2134)**	**BLM Lander FO**	**7/26/14**

Sites where present status not known: Most potential habitat in the BLM Rawlins Field Office was surveyed in 2008, targeting areas mapped as playa vegetation. Additional potential habitat in both the BLM Rawlins and Rock Springs Field Offices were surveyed in 2014, includingtargets identified earlier. Many of the largest playa lakes in the BLM Lander Field Office were surveyed, though not all, particularly those with negligible habitat on public land.
There are also playa wetlands areas mapped in the Hanna and Laramie Basins, little or none of which appear to be on public lands.

The location and status of the original Nuttall collection site of *Astragalus diversifolius* in Wyoming are not known. The two Fremont County occurrences close to the Sweetwater River are both possibilities. The field surveys for *Antennaria arcuata* in the Green River Basin did not turn up any additional potential habitat though there is outside possibility of potential habitat in areas mentioned earlier: Seedskadee National Wildlife Refuge, Soap Hole Basin, alkaline wetlands north of Big Sandy Reservoir, and possibly alkaline meadow complexes around the Upper Green River Basin margins that support plants such as *A. arcuata*.

Unverified/Undocumented reports: One collection of *Astragalus convallarius* originally identified as *A. diversifolius* has since been annotated (*Evert 34974*).

Areas surveyed but species not located: *Astragalus diversifolius* was not found in any of the quarter-section areas identified by the Random Forest or the deductive model testing run in 2014. It was sought at 46 locations (26 identified by Random Forest modeling, 10 identified by deductive modeling and 10 more sought by photointerpretation) but not found. In addition, all negative surveys for *Antennaria arcuata* have merit as negative data for *A. diversifolius*. All negative surveys in 2008 for the Great Divide Basin are represented by digitized survey routes in Appendix B of the report (Heidel 2009).

Land ownership: All Wyoming occurrences of *Astragalus diversifolius* are on public lands managed in part or in full by the BLM Rawlins, Lander and Rock Springs Field Offices. 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 the 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 extant occurrences in Idaho, at least eight are on public lands of the Upper Columbia – Salmon Clearwater Districts and Snake River Districts of BLM, in part or in full. One of the Idaho BLM occurrences also extends onto Caribou-Targhee National Forest and state land.

Habitat

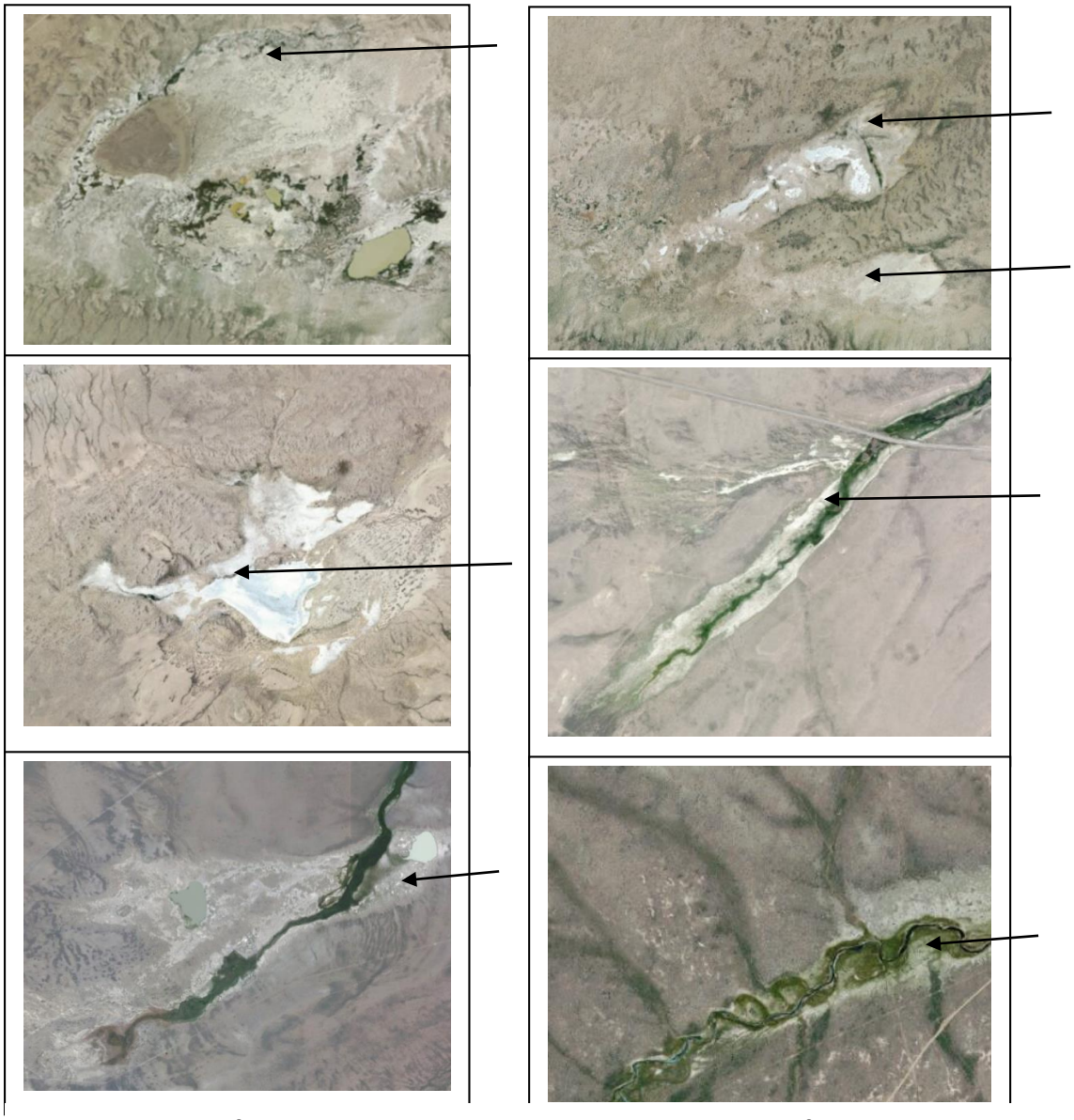
Astragalus diversifolius appears to be a facultative wetland plant throughout its range but is omitted from the National Wetland Plant List maintained by the U.S. Army Corps of Engineers (Lichvar 2012). It is a halophyte in moist, salt-accumulating habitats, restricted to low topographic positions associated within drainages and closed-basins that have alkaline meadows. All of the Great Divide Basin occurrences are in basins, whereas the Sweetwater River drainage occurrences are essentially associated with drainages (Figures 26-31).

Associated vegetation: *Astragalus diversifolius* often grows in sparse alkaline meadow, but is also present in very dense alkaline meadow cover to almost unvegetated flats. These vegetation features are often part of an "ecotone" associated with basin margins and groundwater discharge at the perimeter.

In the Great Divide Basin, *Astragalus diversifolius* lies in or adjoining areas mapped as playa vegetation by Merrill et al. (1996), downwind of a current or dried alkaline lake bed. However, playa vegetation 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 et al. 2014). 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).

In the Sweetwater River drainage, *Astragalus diversifolius* lies in areas that are not mapped separately from the surrounding sagebrush steppe (Merrill et al. 1996). They are on drainages, or else on wetlands associated with drainages. Aerial photographs showing the three Sweetwater River and three Great Divide Basin occurrences are represented in Figures 26-31.



On the ground, vegetation patterns look similar in both settings, although occupied habitat in the Sweetwater River drainage tends to move hummocks.

Figure 32. *Astragalus diversifolius* habitat at EO#008 by a wetland above the Oregon Slough drainage

Frequently associated species: The species commonly associated with *Astragalus diversifolius* include *Sporobolus airoides* (alkali sacaton), *Carex praegracilis* (clustered field sedge), *Juncus balticus* (Baltic rush), *Poa nevadensis* (Nevada bluegrass), *Spartina gracilis* (alkali cordgrass), *Elymus multicaulis* (branched wild-rye), *Pyrrocoma lanceolata* (lanceleaf goldenweed), *Cirsium tioganum* var. *coloradense* (Colorado thistle), *Plantago eriopoda* (Red wooly-plantain), and *Thelypodium sagittatum* (Arrowhead thelypody). A more complete species list is presented in Table 4.

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 *Juncus balticus*, *Poa secunda* (Sandberg bluegrass); note: *P. nevadensis* is included with this taxon by some authors), **Leymus cinereus* (syn. *Elymus cinereus;* Great Basin wild rye), *Spartina gracilis*, * *Senecio debilis* (weak-stem groundsel), * *Phlox kelseyi* (Kelsey's phlox), * *Glaux maritima* (Sea milkwort), *Sarcobatus vermiculatus* (greasewood) and * *Potentilla fruticosa* (syn. *Pentaphylloides fruticosa*; shrubby cinquefoil). 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: *Distichlis spicata* (Inland saltgrass), *Puccinelllia nuttallii* (Nuttall's alkaligrass), *P. lemmonii* (Lemmon's alkaligrass), *Spartina gracilis*, *Poa nevadensis*, *Carex*

praegracilis, *Elymus cinereus*, and *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 4).

Table 4. Species associated with *Astragalus diversifolius* throughout its range

Scientific name	Common name	State
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 anserina	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

Topography: The three original *Astragalus diversifolius* occurrences in Sweetwater County, Wyoming are associated with playa lakes in closed-basin drainages, and the three new occurrences in Fremont County, Wyoming are along drainages. Both the lacustrine and riverine settings have Quaternary deposits.

Occurrences of *Astragalus diversifolius* in Utah are also in closed basin settings that have alkaline meadow vegetation. However, the Idaho and Nevada occurrences are in river valley settings, and though they are surrounded by open, sagebrush terrain, they too have 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.

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 range of Wyoming populations is 1890-2230 m (6200-7310 ft), slightly higher than the 1340-1920 m (4400-6300 ft) elevation range in other states.

Astragalus diversifolius in the Great Divide Basin is often on flats and shoreline. By contrast, in the Sweetwater River drainage, it was often found in habitat with slight microtopography features, as is the case where the species is present in the low mounds as at Oregon Slough and the West Fork of Rock Creek. The species is generally not on streambanks, though there is flowing water in the vicinity.

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 order. There was only one soil sample collected in 2007 surveys as a representation of *Astragalus diversifolius* habitat at Circle Bar Lake. The sample was a silty clay loam soil sample, alkaline (pH 8.15), with high electrical conductivity and high sodium absorption ratio. Soluble sodium levels were higher than magnesium, which were higher than calcium (Table 5). Nevertheless, calcium carbonate levels were sufficient to evoke strong evanescent reactions to hydrogen chloride in occupied habitat and in surrounding wet meadow substrates.

Table 5. Soil characteristics at one *Astragalus diversifolius* site (Circle Bar Lake)

Soluble Calcium MEQ/L	Soluble Magnesium MEQ/L	Soluble Sodium MEQ/L	SAR	pH	EC DS/M
28.1	84.9	269.5	33.6	8.25	28.5

Regional climate: Three meteorological stations provide context for the regional climate of *Astragalus diversifolius* (USDI NOAA 2006). They represent high desert climates that are highly variable within and between years.

The meteorological station at Jeffrey City has data from 1964-2005, and is at an elevation of 1930 m (6330 ft). Mean annual temperature is 5.50° C (41.9° F) with mean January temperature at -6.61 °C (20.1 °F) and mean July temperature at 19.44° C (67.0° F). Mean annual precipitation is 25.70 cm (10.12 in), with peak precipitation in May at 5.18 cm (2.04 in).

The meteorological station at South Pass City has data from 1915-2005, and is at an elevation of 2390 m (7840 ft). Mean annual temperature is 1.44° C (34.6° F) with mean January temperature at -10.33° C (13.4° F) and mean July temperature at 20.61° C (58.2° F). Mean annual precipitation is 34.09 cm (13.42 in), with precipitation highest early in the growing season from April-June, ranging between 3.43- 3.66 cm (1.35-1.44 in) as mean monthly average between the three months.

The meteorological station at Wamsutter has data from 1948-2004, and is at an elevation of 2070 m (6800 ft). The average annual temperature is 5.2º C (41.3º F), with mean January temperature at -8.00° C (17.6° F) and mean July temperature at 19.17° C (66.5° F). Mean annual precipitation is 16.7 cm (6.58 in), with peak precipitation in May at 2.67 cm (1.05 in), and over 70% of annual precipitation coming during the growing season (April-September).

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.

Population biology and demography

Population size and condition: There are estimated to be 8000 plants of *Astragalus diversifolius* in the Great Divide Basin, covering an area of over 75 ha (186.7 ac; Table 6). There are estimated to be 300-600 plants of *A. diversifolius* in the Sweetwater River drainage, covering an area of less than 8 ha (20 ac). The density and continuity of the species varies greatly within and between occurrences.

The three largest 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.

Table 6. Size and extent of *Astragalus diversifolius* populations in Wyoming

EO#	Location	Numbers (estimates)	Digitized Extent ha (ac)	Trends
001	Circle Bar Lake	1000	10.9 (26.9)	Unknown
002	East Chain Lakes	2000	40.4 (99.9)	Unknown
003	Mud Lake	5000	24.2 (59.9)	Unknown
004	Ice Slough	80-200	Less than 0.4 (< 1)	Unknown
005	Oregon Slough	100+	4.3 (10.6)	Unknown
006	W. Fk. Rock Cr.	100-200	2.8 (7)	Unknown
TOTAL		~8500	~82.6 (~204.3)	

Many of the individual plants noted in 2008 Wyoming surveys were about 0.5 m (1.5 ft) in diameter, vigorous plants with many branches that were 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. The plants surveyed in 2014 tended to be smaller, with fewer branches.

Population trends: Monitoring data are not available. The tap-rooted growth form may be conducive to longevity.

Type of reproduction: *Astragalus diversifolius* is not known to have any form of vegetative reproduction, though some descriptions of the species refer to it as 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.

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

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 or 2014 surveys.

Population ecology

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 requires sexual reproduction and has indeterminate flowering. 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 of 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 regarding their levels of genetic variation (Karron et al. 1988). Therefore, it is possible that sparsely-distributed species, such as *A. diversifolius,* are at no more inbreeding disadvantage than widely-distributed species.

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 the taprooted individual *Astragalus diversifolius* plants. 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 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 its numbers (10X more plants in the north lobe than the south lobe).

Herbivory: Stems of *Astragalus diversifolius* were found to be broken midway at the Ice Slough population (T. Skurski pers. commun. 2015). It is not known whether this represents herbivory or some other kind of damage. It was previously noted that branch fragments have been found lying beside the plant where they came from, indicating that they were 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). Both *A. convallarius* and *A. diversifolius* were reported as accumulating significant levels of organic nitrites that make them unpalatable. However, this was based on collections of *A. diversifolius* in Utah that might (?) represent some variety *of A. convallarius.*

Hybridization: There were no signs of hybridization in the field and there are no reports in the literature.

RESULTS – SPECIES INFORMATION – *CLEOME MULTICAULIS*[6]

Classification – mainly from Fertig 2000

Scientific name: *Cleome multicaulis* Sesse & Mocino ex DC.

History of the species: *Cleome multicaulis* (many-stemmed spiderflower) was discovered in central Mexico in the early 1800s by Sessé and Mociño, and was described by DeCandolle in 1824 based on a painting of their specimen (Figure 33). *Cleome multicaulis* was first observed in the United States in 1851 in southern New Mexico and Arizona, and in 1873 in Colorado. A compilation of all public herbarium records for the species was prepared by Jennings (1998).

The first confirmed record of *Cleome multicaulis* in Wyoming was a 1980 collection near Pathfinder Reservoir by Lynn Fisher (*s.n.* RM), but Fertig (2000) made the case that the Stewart Party of 1843 may have collected it in the same area over a century earlier. The first surveys for

[6] This results section reprints information in Fertig (1993, 2000), updating and expanding it to represent the most current and complete information in Wyoming.

it were conducted in 1992 in six areas of the four-county BLM Casper District (Fertig 1993) locating it only at the Pathfinder Reservoir area.

Synonyms: *Peritoma multicaulis* (de Candolle) H.H. Iltis; *P. sonorae* (A. Gray) Rydberg
This species is treated as *P. multicaulis* in the *Flora of North America* (Vanderpool and Iltis 2010), based on Iltis and Cochrane (2007). This nomenclature and treatment are being followed by the RM and will be incorporated in future Wyoming plant species of concern revisions.

Common name: Many-stemmed spiderflower (spiderflower is variously spelled with or without a hyphen); also called playa spiderflower, slender spiderflower. Note: The common name, many-stemmed spiderflower, is a misnomer because the species is usually unbranched or sparingly branched, with only one stem per plant. It was originally described from a painting that showed many branches arising from a taproot of sorts, though Iltis (1957) describes the plant as "unbranched, or with few to many branches from the base, …or more rarely branched above…"

Family: Many floras place *Cleome* in the Caper Family (Capparaceae). More recent treatments segregate the Cleomaceae from the Capparaceae

Size of genus: The *Cleome* genus (*sensu lato*) is comprised of over 200 species centered in the Neotropics, mainly in warm, dry regions of South America, Africa, and to a lesser extent, the Near East and Australia (Heywood et al. 2007). Extensive research has shown it to be an assemblage of distinct groups of species better recognized at generic rank (Iltis and Cochrane 2007). Thus, it has been split into several genera, including the *Peritoma* genus characterized as plants mostly annual, glabrous, unarmed, leaflets 1-6 cm long, entire, flowers borne in the axils of leafy bracts, petals sessile or subsessile, more or less radially arranged in the open flower, and other technical characteristics of anthers, bracts and seeds. The genus is comprised of six western North America species (Vanderpool and Iltis 2010). Two other species of *Cleome* (*Peritoma*) are in the Wyoming flora, *C. lutea* (*P. lutea*) and *C. serrulata* (*P. serrulata*).

Phylogenetic relationships: Based on morphology and habitat, *Cleome multicaulis* appears to be most closely related to *C. serrulata* and relatively ancient; probably near the base of the *Peritoma* clade (Iltis 1957). Alternate hypotheses for *C. multicaulis* as neoendemic or paleoendemic are laid out by Riley (2001), who recommended genetic analysis to compare the genetics of this widely-disjunct species.

Present legal or other formal status

U.S. Fish & Wildlife Service: None. In 1975, *Cleome multicaulis* was included in the first list of species considered for designation under the ESA by the Smithsonian Institution in 1975 (Ayensu and DeFilipps 1978), and proposed as Endangered the following year (USDI Fish &

Wildlife Service 1976). It became a Category 2 candidate for listing under the Act beginning in 1980 (U.S. Fish and Wildlife Service 1980, 1985, 1990, 1993). It was not recognized as part of the Wyoming flora until 1980, and such status applied to plant species throughout their range. The recognition of Category 2 species was replaced with a new Species at Risk category in 1996. However, the list is not maintained and species in this category are not considered formal candidates for listing at present. As a result, this species currently has no legal, rangewide, protection status under the ESA.

Agency status: Designated Sensitive by Wyoming Bureau of Land Management (BLM 2001, 2010). It is also designated Sensitive by BLM in Colorado.

Global Heritage rank: *Cleome multicaulis* is currently ranked G2G3 (vulnerable or imperiled). Prior to that it was ranked G3 (globally vulnerable) but the rank was updated by Colorado botanists in considering threats. It is becoming quite rare in Colorado with the drainage of wetlands (Weber and Wittmann 2012). It has been characterized as widely distributed in parts of Mexico (Weber and Wittmann 2012), but there is no supporting information.

State Legal status: None

State Heritage rank: S1 (critically imperiled).

It is also ranked S1 in Texas. In Colorado it is ranked S2S3 (on the threshold between imperiled and vulnerable). In Arizona and New Mexico it is ranked SH (known only from historic records).

Description - mainly from Fertig 2000

General non-technical description: Many-stemmed spiderflower is a slender, glabrous annual forb with erect, unbranched or sparingly branched leafy stems 20-70 cm tall. The leaves are sessile (or nearly so) and palmately compound with 3 narrow leaflets 1-2 cm long and less than 1.5 mm wide that may be folded along the midrib. Flowers have 4 pink or pinkish-white petals 4-6 mm long and are borne on thin stalks in the axils of reduced leaves. The 6 stamens are equal in length to the petals. Fruits are narrow, multi-seeded capsules up to 2 cm long with a stalk-like base (gynophore) and droop at maturity. Seeds are light brown, smooth, nearly globose, and less than 2.5 mm (Fertig et al. 1994, Iltis 1958; Vanderpool and Iltis 2010).

Technical description**:** Annuals, 20-60 (70) cm. Stems unbranched or sparsely branched; glabrous. Leaves 0.5-1.5 cm with 3 leaflets, blades linear to elliptic, margins entire, apex long-acuminate, glabrous. Racemes 1-3 cm in flower (6-40 cm in fruit), bracts unifoliate, obovate to spatulate, 2-15 mm. Pedicels 7-15 mm. Flowers white, pink or rose, petals oblong to ovate, 4-5 x 1-1.3 mm, stamens yellow, 4-5 mm, anthers 1.9-2.6 mm, style 0.5-0.8 mm. Sepals persistent,

distinct or slightly connate basally, 1.6-2.6 x 0.8-1.2 mm, margins denticulate, glabrous. Capsules reflexed, 1.5-2.5 mm x 1.5 mm, striate. Seeds 10-20, gray to black, triangular and acute at both ends, rugose.

Figure 33. Painting that provided the basis of the 1824 description of *Cleome multicaulis* (from Hunt Institute. 1998)

Figure 34. *Cleome multicaulis* by W. Fertig (from Fertig et al. 1994)

Figures 35 and 36. *Cleome multicaulis* by B. Heidel

Local field characters: Many-stemmed spider- flower is a slender, glabrous annual that grows from 2-6 dm tall. The leaves are composed of three narrow leaflets (less than 1.5 mm wide) that may be folded along the midrib. Flowers have 4 pinkish-purple petals and are borne on thin stalks (peduncles) in the axils of reduced leaves. The fruit is a narrow, multi-seeded capsule with a stalk-like base (gynophore) and droops at maturity.

Similar species: *Cleome serrulata* is a more robust plant, with broader leaflets, larger fruit, and entire (undivided) flower bracts, and has stamens that are much longer than the petals. *Cleome lutea* has yellow flowers (Dorn 2001).

Phenology: Late June to August. Flowering has been observed at the Steamboat Lake site of the Pathfinder Reservoir population from June 24-August 22, and probably extends into early to mid-September, depending on seasonal weather conditions. Flowering observed in 2014 at sites north of the Sweetwater River had plants in early flower and in bud on 2 July. The plant appears to have indeterminate flowering (from the bottom, up) so that new buds might be produced as environmental conditions remain favorable. It is possible, but not proven, that the greater groundwater stability in the Pathfinder population is conducive to prolonged flowering of the species there compared to the populations north of the Sweetwater River. Fruits begin to mature in early July and continue to be produced into September (Graff 1992). Pollination biology is still poorly understood for this species (Riley 2001), but Iltis (1958) has suggested that bees are the probable pollinator of members of the *Cleome* genus. Riley (personal communication) believes that *C. multicaulis* may have a mixed breeding system and has the potential to self-fertilize.

Geographic distribution

Range: *Cleome multicaulis* ranges from central Mexico (near Mexico City) to southeast Arizona, southwest New Mexico, and southwest Texas, with disjunct populations in south-central Colorado and central Wyoming (Fertig et al. 1994; Jennings 1998, Vanderpool and Iltis 2010). Wyoming populations are located nearly 320 miles (515 km) north of the nearest occurrence in southern Saguache County, Colorado. Populations have been documented from the San Luis Valley in Alamosa, Costilla, Rio Grande, and Saguache counties (Colorado), Presidio County (Texas), Hidalgo and Grant or Luna counties where it is only known from historic records (New Mexico), Cochise, Pinal, and Apache counties where it is only known from historic records (Arizona), and the Mexican states of Chihuahua, Durango, Jalisco, Michoacan, and Mexico (Jennings 1998; Colorado Natural Heritage Program 2014).

Wyoming populations are restricted to lakes and wetlands at the northern end of Pathfinder Reservoir in southwestern Natrona County and to lakes and wetlands north of the Sweetwater River in eastern Fremont County. (Figure 4; Table 1; Appendix A). The Pathfinder Reservoir location is the mouth of the Sweetwater River where it reaches the North Platte River, about 48

km (30 mi) downstream of the Fremont County populations. Essentially, its distribution in Wyoming is limited to the Sweetwater River watershed.

Extant sites: Iltis (1977) cites an historical collection by Gordon (*s.n.*) at Kew Botanic Gardens from "Platte River". This specimen may have been collected by Alexander Gordon, one of four botanists (including Karl Geyer) who traveled across central Wyoming in 1843 on the "pleasure excursion" of Scottish adventurer Sir William Drummond Stewart. The Stewart party followed the North Platte River to its confluence with the Sweetwater (today under Pathfinder Reservoir) and then on past Independence Rock (just 3.5 miles southwest of Steamboat Lake) to South Pass in late July 1843 (Cronquist et al. 1972; Dorn 1986). If this specimen is authentic and attributable to Alexander Gordon, it would represent the first record of *Cleome multicaulis* in the United States and dispel rumors that the Wyoming population may be adventive. There are similar rumors that it is "introduced" in Colorado, brought up by Spanish settlers (Weber and Wittmann 2012).

Figure 37 (right). Distribution of *Cleome multicaulis* in North America

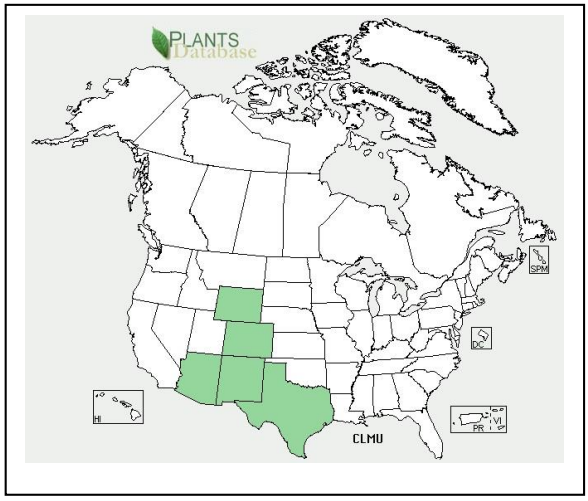
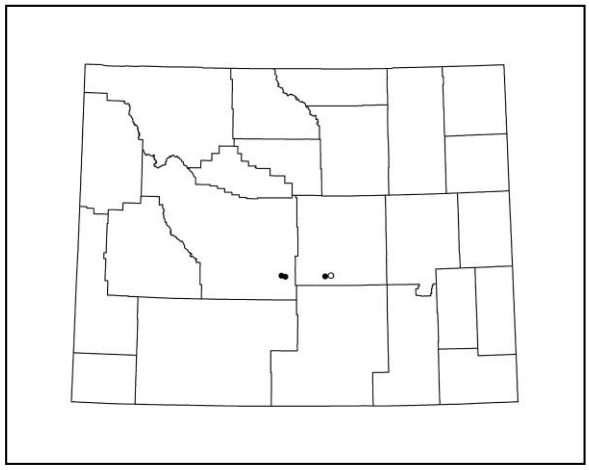


Figure 38 (right). Distribution of *Cleome multicaulis* in Wyoming



The earliest confirmed report of *Cleome multicaulis* in Wyoming is based on a specimen collected by Lynn Fisher on BLM lands just north of Pathfinder Reservoir in July 1980 (EO#001, Table 1; Appendix A). O'Kane (1988) suggested that this population was established by recent long distance dispersal by waterfowl and hypothesized that Fisher's collection site was from the banks of a stock pond. Hollis Marriott and Mary Neighbours of WYNDD were unable to relocate Fisher's collection site (T30N R85W S25 NW4 of NE4) in two visits in 1989 and failed to locate suitable habitat. No stock ponds or playa lakes are indicated at Fisher's collection site on USGS or BLM topographic maps. Fertig (1993) discovered an extensive population of *C. multicaulis* along the shores of Steamboat Lake and adjacent playa lakes north of the northwest arm of Pathfinder Reservoir in June 1992 (EO#002, Table 7; Appendix A). Steamboat Lake is exactly 6 miles west of Fisher's 1980 collection site, suggesting the possibility that the public land survey value for Range reported on Fisher's specimen label may be incorrect (R86W rather than R85W). The record (EO#001) is left in the database as originally entered, representing either an extirpated population or more likely, a mismapped one corresponding to a collection label error.

Historical sites: The location where the 1843 collection was made is not known.

Unverified/Undocumented reports: None.

Sites where present status not known: The location of the Fisher collection is disputed, and it includes some private land areas. Photointerpretation of NAIP imagery supports the interpretation that the wrong public land survey values were recorded.

Table 7. Location of *Cleome multicaulis* populations in Wyoming

EO #	County	General Location	USGS 7.5' Quad	Legal	Elev ft (m)	Public Land	Last Obs. Date
001	Natrona	North of Pathfinder Reservoir, east of Horse Creek	Benton Basin SW	T30N R85W Sec 24, 25	5900 (1798)	BLM Casper FO	7/25/80
002	Natrona	Northwest of Pathfinder Reservoir, including Steamboat Lake and chain of small alkali lakes and playas extending ca 2 miles to the east-southeast	Sanford Ranch	T30N R85W Sec 29, 30, 32; R86W Sec 25	5860 (1786)	Pathfinder National Wildlife Refuge	9/23/08
003	**Fremont**	**Soda Lakes, north side of Sweetwater River, ca 6-8.4 miles east-northeast of Jeffrey City; ca 17.5 mi NW of Muddy Gap**	**Black Rock Gap**	**T30N R91W Sec 25, 26, 34, 35, 36**	**6220-6230 (1896-1899)**	**BLM Lander FO, State of Wyoming**	**7/2/14**
004	**Fremont**	**Alkaline ponds, north side of Sweetwater River, ca 1.5 miles west of Quaking Asp Gap, ca 5 miles northeast of Jeffrey City; ca 20.5 mi NW of Muddy Gap**	**Stampede Meadow**	**T30N R91W Sec 30**	**6320 (1926)**	**BLM Lander FO**	**7/2/14**

Areas surveyed but species not located: All 82 survey points in the study area where Sensitive species were not found represent negative surveys for this species, plus the three new occurrences of *Antennaria arcuata* and *Astragalus diversifolius*, and the six revisited occurrences of the former.

Land ownership: The Pathfinder Reservoir population (EO#002) is on national wildlife refuge lands administered by U.S. Fish and Wildlife Service. The 2014 populations are on lands administered by BLM Lander FO. The Fisher collection site falls on lands administered by BLM Casper FO.

Extent of Surveys in Wyoming: Fertig surveyed areas near Pathfinder, Alcova, Gray Reef, Glendo, and Guernsey reservoirs in 1992, but no populations were found other than the one northwest of Pathfinder Reservoir. In 1999-2000, Neighbours and Fertig revisited the Steamboat Lake area and surveyed other potential sites on public lands along the North Platte River, Sweetwater River Valley, Ferris Sand Dunes, Chain Lakes, Great Divide Basin, and Laramie Plains as identified from maps, but found no new *C. multicaulis* sites (see Appendix C of Fertig 2000 for 1999-2000 survey routes). Recent floristic surveys in central Wyoming by Welp (1997) and Taylor (2000) were also unsuccessful in documenting new occurrences of this species.

Intensive surveys were conducted in the Chain Lakes area by Heidel in 2007, finding instead *Astragalus diversifolius*. The following year, expanded surveys in the Great Divide Basin for *A. diversifolius* were conducted based on photointerpretation with the availability and ease of using digital aerial orthophotography. The surveys uncovered additional alkaline meadow sites not previously surveyed for either species.

In the current study, systematic surveys for *Antennaria arcuata* and *Astragalus diversifolius* were conducted in alkaline meadows in large parts of southern Fremont County and adjoining Sweetwater County, including the Sweetwater drainage and Great Divide Basin. These surveys were based on both photointerpretation and potential distribution modeling and resulted in the discovery of two new occurrences of *Cleome multicaulis*.

Habitat

Cleome multicaulis is a facultative wetland plant throughout its range (Lichvar 2012). In Wyoming, it is restricted to closed basin settings with alkaline lakes and wetlands.

Associated vegetation: The Pathfinder Reservoir population complex of *Cleome multicaulis* is most abundant on damp (at the time of flowering but not flooded) flats. It occupies vegetation zones with a shallow water table and salt accumulation at the surface that may be found at inner or outer alkaline meadow zones around the lakes and wetlands (Fertig 2000). It is sometimes found in mudflats and drier, slightly upslope clayey dunes. The 2014 occurrences of *C. multicaulis* were on similarly damp flats though with lower vegetation cover (less than 50%) of

the same associated species. Their alkaline meadow vegetation was mainly in a narrow band close to the shore, however convoluted the shoreline. The exception was one area that had two zones of occupied habitat where a second outer zone composed of *Sarcobatus vermiculatus* (greasewood) and *Elymus cinereus* (Basin wild-rye) was on a low terrace at the western end of Soda Lakes.

Frequently associated species: The salt-tolerant species associated with *Cleome multicaulis* are similar in both Wyoming and south-central Colorado. The associated species at all three Wyoming occurrences include a local prevalence of *Spartina gracilis* (alkali cordgrass) and *Distichlis stricta* (alkali saltgrass) that may form a discrete zone (Table 8). Commonly associated species include *Juncus balticus* (Baltic rush), *Puccinellia nuttalliana* () and *Amphiscirpus nevadensis* (Nevada bulrush). *Cleome multicaulis* may also be found in localized patches of *Carex praegracilis* (clustered field sedge), *Hordeum jubatum* (foxtail barley), *Elymus smithii* (western wheatgrass), *and Sarcobatus vermiculatus*. At Pathfinder Reservoir, populations of *C. multicaulis* are less abundant on clayey dunes surrounding alkaline lakes with less than 50% cover of *Spartina gracilis, Triglochin maritima* (seaside arrowgrass), and *Sporobolus airoides* (alkali sacaton), or on low dunes, hummocks or terraces of *Sarcobatus vermiculatus.* Small patches may also occur in dry alkaline depressions with 20% cover of *D. stricta, S. gracilis, Suaeda calceoliformis* (seablite), *Crepis runcinata* (meadow hawksbeard), and *Pyrrocoma lanceolata* (lanceleaved goldenweed).

Table 8. Species associated with *Cleome multicaulis* in Wyoming and Colorado

Scientific Name	Common Name	Growth form	State
Aster pauciflorus	Alkali marsh aster	Annual Forb	CO
Carex praegracilis	Clustered field sedge	Perennial Graminoid	WY
Crepis runcinata	Meadow hawksbeard	Perennial Forb	WY
Distichlis stricta	Alkali saltgrass	Perennial Graminoid	CO, WY
Elymus cinereus	Great Basin wild-rye	Perennial Graminoid	WY
Elymus smithii [*Agropyron smithii*]	Western wheatgrass	Perennial Graminoid	WY
Erigeron philadelphicus	Philadelphia fleabane	Biennial Forb	CO
Hordeum jubatum	Foxtail barley	Perennial Graminoid	CO, WY
Juncus balticus	Baltic rush	Perennial Graminoid	CO, WY
Puccinellia nuttalliana	Nuttall's alkali-grass	Perennial Graminoid	WY
Pyrrocoma lanceolata [*Haplopappus lanceolatus*]	Lance-leaf goldenweed	Perennial Forb	WY
Sarcobatus vermiculatus	Greasewood	Shrub	CO, WY
Scirpus nevadensis	Nevada bulrush	Perennial Graminoid	WY
Scirpus pungens var. *polyphyllus*	Three-square bulrush	Perennial Graminoid	WY
Spartina gracilis	Alkali cordgrass	Perennial Graminoid	WY
Sporobolus airoides	Alkali sacaton	Perennial Graminoid	WY
Suaeda calceoliformis (*S. depressa*)	Seablite	Perennial Forb	CO, WY
Triglochin maritima	Seaside arrowgrass	Perennial Graminoid	WY

Three other plant species that are or were Wyoming species of concern were documented at the Soda Lakes population of *Cleome multicaulis* including *Monolepis pusilla* (Red poverty-weed), *Phacelia tetramera* (tiny phacelia), and *Sisyrinchium pallidum* (blue-eyed grass). The latter

represents a county record. They were in different playa vegetation zones than *C. multicaulis*. As in Wyoming, *Cleome multicaulis* populations in the San Luis Valley are typically found in communities of *Distichlis stricta*, *Sarcobatus vermiculatus*, or *Juncus balticus* (Riley 2001). Elsewhere in the southwest and Mexico, *C. multicaulis* has been reported from saline or alkaline soils surrounding sinks, ponds, meadows, or old lake beds in salt desert scrub, *Scirpus*, *Sarcobatus*, or *Distichlis* communities at 3000-8000 feet (915-2450 m) (Iltis 1958; New Mexico Native Plant Protection Advisory Committee 1984; Graff 1992; Colorado Natural Heritage Program 2014). Its habitat description in Flora of North America is given as: "Dry to moist open ground, often in saline or volcanic soils" (Vanderpool and Iltis 2010).

Topography and hydrology: All Wyoming populations occur at an elevation of approximately 5860-6320 feet (1786-1926 m). They are in closed basin settings that include shallow playa lakes which are semi-permanent on Pathfinder Reservoir, and which appeared to be seasonal north of the Sweetwater River. All three extant Wyoming occurrences are in wetland complexes where wetland depth, water table depth and the duration of standing water levels vary, as do the resulting vegetation composition and salt migration patterns.

It is possible that the Pathfinder Reservoir habitat has artificially-maintained high surface- and groundwater levels due to the nearby reservoir. Alternatively, it is possible that the habitat north of the Sweetwater River had drought-induced low water levels in 2014 that, despite the wet conditions of the year, were still in a low precipitation cycle. At Soda Lakes, all but the lowest (easternmost) lake was completely evaporated – the easternmost lake supported high waterfowl numbers. At the alkaline ponds west of Quaking Asp Gap, almost all ponds were completely dry. Only the two largest ponds had a tiny puddle or two of water persisting in the center of the basin.

Figure 39. *Cleome multicaulis* habitat, EO#002, at Pathfinder NWR by Walter Fertig. Note standing water.

Figure 40. *Cleome multicaulis* habitat at Soda Lakes, EO#003, by B. Heidel.

Soil relationships: In Wyoming, *Cleome multicaulis* is found primarily on alkali rich, often hydrogen sulfide scented soils where salts accumulate (Figures 39-40). Soils are derived from Miocene age, white, soft tufaceous sandstones (Love and Christiansen 1985). Riley (2001) conducted a 3-year study of soil characteristics at *C. multicaulis* sites in the San Luis Valley of Colorado and found that these plants were typically found on saline-sodic soils with an upper crust of salts produced from intense evaporation of subsurface moisture. *Cleome multicaulis* was most common on sites with a pH of 9.33, but could persist at a pH of up to 9.95. Electrolytic conductivity (EC) of San Luis Valley soils ranged from 0.79 to 67.68 dS/m (mean 8.507), but *C. multicaulis* plants were most abundant where mean EC was 10.63 and absent where EC was greater than 41.92 dS/m. Soils were primarily sandy clay loams, loamy sands, or sandy clays with moisture values ranging from 1.23% to 144.24 % (mean 31.7%). *Cleome multicaulis* was typically predominant in sites with lower soil moisture than *Distichilis spicata* or *Juncus balticus.* Major soil cations were Na^+ and K^+, while Cl^- and SO_4^- were the major soil anions present (Riley 2001).

Regional climate: Two meteorological stations provide context for the regional climate of *Cleome multicaulis*. They represent high desert climates that are highly variable within and between years.

The meteorological station at Jeffrey City has data from 1964-2005, and is at an elevation of 1930 m (6330 ft). Mean annual temperature is 5.50° C (41.9° F) with mean January temperature at -6.61 °C (20.1 °F) and mean July temperature at 19.44° C (67.0° F). Mean annual precipitation is 25.70 cm (10.12 in), with peak precipitation in May at 5.18 cm (2.04 in).

The meteorological station at Muddy Gap has data from 1949-2005, and is at an elevation of 1900 m (6240 ft). Mean annual temperature is 6.89° C (44.4° F) with mean January temperature at -5.17° C (22.7° F) and mean July temperature at 20.61° C (69.1° F). Mean annual precipitation is 25.45 cm (10.02 in), with peak precipitation in May at 4.93 cm (1.94 in).

Local microclimate: Habitat of *Cleome multicaulis* 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.

Population Size: In Wyoming, the extant Pathfinder Reservoir population was conservatively estimated at 200,000-300,000 individuals during surveys in June and August 1992 (Fertig 1993). This estimate was increased to 500,000-1,000,000 plants during a revisit to the site by Fertig and Neighbours in July 1999. The latter included an additional 25,000 individuals at three previously unsurveyed playas at the south end of the wetland complex in August 2000 (Fertig 2000). The entire population covers an area of approximately 200 acres in several wetlands that span over 2 miles. *Cleome multicaulis* is thought to be stable to increasing at the Steamboat Lake site, at least over the decade in which it was observed. In Fremont County, the Soda Lakes population was conservatively estimated at 12,000-70,000 plants and conservatively mapped as spanning about 30 acres, in several wetlands that extend over 2 miles. By contrast, the population lying west of Quaking Asp Gap has as few as 200 plants at two different places along a single wetland; it was absent at other wetlands. The 2014 figures are preliminary because the survey priority was to determine the extent of the population and habitat conditions and because the surveys were conducted in early flower and any plants in bud may be overlooked. Pronounced density differences across the range of habitats also made it difficult to estimate. On some of the ant mounds at Soda Lakes, there was *Cleome multicaulis* growing as the only species on the mound, in such high density that it was not practical to tell if there were 100 individual plants or 1000 plants present.

The largest known populations of *Cleome multicaulis* are found in the San Luis Valley of south-central Colorado. Surveys in 1986 by O'Kane, Anderson, and Dixon (Colorado Natural Heritage Program records) and Graff (1992) documented approximately 1.5-10.5 million plants at 20 main wetland sites in the valley. Current census figures are unavailable for other populations across the range of this species, many of which are historical and perhaps extirpated (Jennings 1998).

Population Trends: As an annual species with a seed bank, numbers might be expected to vary from year to year. Trend data are not available in Wyoming, except as revisits were made in 1999 to Pathfinder Reservoir locations first observed in 1993 and numbers appeared to be stable or increasing (Fertig 2000). Photo monitoring points were set up in 1999 to serve as visual references to assess qualitative changes in habitat condition but have not been revisited.

Detailed monitoring was conducted at Colorado populations, every two weeks during the growing season for three growing seasons (Riley 2001). It documented that the species has a seed bank. Riley (2001) considered the San Luis Valley colonies of *Cleome multicaulis* to represent a "remnant population" maintained by a long-lived seed bank, rather than a series of subpopulations within a metapopulation maintained by periodic immigration of seeds from an outside source. Thus, *C. multicaulis* is capable of withstanding periods of shifting environmental conditions over space and time through *in situ* recruitment from its seed bank rather than shifting its local range in response to environmental changes. This population structure necessitates a conservation strategy that preserves the integrity of the seed bank (Riley 2001).

Population biology and ecology

Population size and condition: *Cleome multicaulis* colonies at Steamboat Lake and connected playa lakes occur at high densities, even in somewhat marginal habitat. In 1999, typical *C. multicaulis* density ranged from 135-1300 individuals per square meter, depending on habitat quality (with denser populations found on moister soils and sites dominated by *Distichlis stricta/Spartina gracilis* vegetation). Riley (2001) observed even higher *C. multicaulis* densities in sample plots in the San Luis Valley (3-356 individuals in .4 x .4 m plots, or 19-2225 plants per square meter). In Wyoming, dense patches of *C. multicaulis* may represent up to 10% of the total plant cover in a localized area. Individual plants in dense patches typically are shorter and less branched than those found in more open sites and may produce fewer seeds (Riley 2001). Density may vary from year to year, depending on seedling recruitment, available soil moisture, and soil pH (Riley 2001).

By comparison, *Cleome multicaulis* colonies in the Soda Lakes area were typically in low density in nearly all occupied habitat, with often less than 10 plants per square meter. Plants were found in highest densities on tops of ant mounds. It is not known how much the species' density can change annually, as a function of germination level differences between years.

In the San Luis Valley, seeds may persist in the seed bank for at least 3 years, and probably more (Riley 2001). Once seeds have germinated, individual plants may pass through 1-4 different above-ground growth stages: seedling (<15 cm tall with no buds), juvenile (>15 cm tall with no buds), small reproductive (<15 cm tall with < 4 flower buds), and large reproductive (>15 cm tall with > 4 flower buds) (Riley 2001). By censusing plants in sample plots every two weeks, Riley was able to estimate population growth rates using a Periodic Matrix model. She found that population growth rates varied widely between plots, ranging from 0.08 (a decline) to 10.11 (a sharp increase). The highest rates of population increase were found in sites that began with a low population density, suggesting that fecundity is highest in disturbed or newly colonized areas (Riley 2001). Overall, seedling survivorship to reproductive age was high, following a Deevey Type I pattern, and was not constrained by population density (Riley 2001).

Type of reproduction: *Cleome multicaulis* reproduces by sexual reproduction. Riley (2001) found that large reproductive individuals produce an average of 7.3 seeds per fruit, while small plants produce 2.6 seeds per fruit, on average

Pollination biology: Iltis (1977) suggested that bees are the probable pollinator of members of the *Cleome* genus. Riley (pers. commun. to Fertig) suggested that *C. multicaulis* may have a mixed breeding system with not only cross-pollination but also the potential to self-fertilize (Fertig 2000).

Seed dispersal and biology: Among the highest density settings where *Cleome multicaulis* was observed in 2014 surveys were on top of ant mounds. These isolated points on the landscape were flush with *C. multicaulis* plants. It seems that either the mounds promote branching to create the illusion of density, or more likely, that the seeds are harvested by ants.

In discussing dispersal mechanisms, Riley (2001) indicated that seeds are likely to be dispersed by wind, possibly water, and possibly with assistance by waterfowl. She observed that the seeds float, both in the lab and in the field. In addition to waterborne dispersal, the seeds may be transported in mud attached to the hooves of bison or cattle and other wildlife.

There has been debate whether the distribution of *Cleome multicaulis* represents accidental dispersal, as a fluke of nature or of human intervention. Weber and Wittmann (2012) speculate that *C. multicaulis* was possibly brought to Colorado by the early Spanish settlers. O'Kane (1984) hypothesized that the plant is a recent introduction by birds in Wyoming, an idea that was challenged by the apparent 1843 collection in what is now Wyoming (Fertig 2000). It is entirely possible that wildlife dispersal of seeds is a natural phenomenon that is no less natural than wind or water dispersal, without human intervention.

Population ecology

General summary: *Cleome multicaulis* is an annual with a seed bank that retains viable seed for at least three years if not longer (Riley 2001). It is a habitat specialist in harsh conditions.

Competition: Vegetation sampling collected in Colorado populations by Riley (2001) suggests that there may be both competition and facilitation from other vegetation. Rhizomatous graminoids such as *Juncus balticus* are apt to be the most competition, and in at least some cases, *Sarcobatus vermiculatus* may act as a nurse plant.

Herbivory: There are no reports of herbivory for *Cleome multicaulis*. Species in both the Brassicaceae and the Capparaceae (Cleomaceae) produce secondary chemical compounds (mustard oils) that deter most herbivores.

Hybridization: *Cleome multicaulis* co-occurs with *C. serrulata* at Steamboat Lake and in the San

Luis Valley, but no evidence of hybridization has been documented. The latter expanded into *C. multicaulis* habitat with pipeline repair work (Cline 2008). The two taxa typically occur in slightly different habitats, with *C. serrulata* often favoring better drained, sandy soils in Wyoming.

COMPARISONS BETWEEN THE THREE SENSITIVE SPECIES

Antennaria arcuata, Astragalus diversifolius and *Cleome multicaulis* are three of the most enigmatic plant species on the Wyoming BLM Sensitive species list because they are not state endemics, unlike the majority. They do not have their geographic distribution centered in Wyoming. All three are globally rare at some level, and have an interrupted distribution that includes two-four other states. The nature of high alkalinity habitats is one of discontinuity.

The extent of their distributions can distort an understanding of their status. It is worth pointing out that Wyoming harbors the largest populations for *Antennaria arcuata* and *Astragalus diversifolius* and among the largest populations of *Cleome multicaulis*. So, whatever their geographic breadth, geographic center and status elsewhere, their status in Wyoming is important when considering their rangewide status.

All three of the Sensitive species are restricted to alkaline meadow habitat that have salt accumulation at the surface and salt-tolerant, predominantly graminoid vegetation. There is not a vegetation map of the state showing alkaline meadows, but these habitats often fall within general playa vegetation types (Knight et al. 2014). They have received limited attention in Wyoming vegetation classification and differentiation. Studies elsewhere have found that soil moisture is the dominant factor in determining plant presence in playa communities (Haukos and Smith 1996). None of the three are found together, and at the most basic level, they sort out in their settings and respective environmental conditions. *Antennaria arcuata* is mainly in riverine settings, *Cleome multicaulis* is only in palustrine settings, and *Astragalus diversifolius* is now known from both palustrine and riverine settings.

Two of the three species have habitat characteristics in common that may warrant further evaluation. Both *Antennaria arcuata* and *Astragalus diversifolius* occupy soils that may be high in organics. The *A. diversifolius* population at Ice Slough occupies a setting that represents one of the few locations in the state with pollen profile research in local peat deposits (Beiswinger 1987). The *A. arcuata* soils analysis by Bayer (1992) pointed to organic content as high as 20% and its populations in Sublette County were occasionally found to have peatland inclusions (Heidel 2013). Cursory examination of National Wetland Inventory (NWI) mapping shows that there are portions of the Sweetwater River system mapped as having saturated soil conditions at the surface. In general, peat accumulates under cool conditions that remain saturated, and wetlands with peat deposits of over 40 cm are classified as peatlands. Such wetlands have severe limitations on whether or not they can be mitigated for management purposes.

All three of the species addressed in this study have life history strategies that enable them to endure and avoid the direct effects of their harsh environments. The above-ground shoot of *Antennaria arcuata* does not appear to live more than a year, but the species reproduces vegetatively, and may have a capacity to continue vegetative reproduction indefinitely by such means ("somatic immortality" as it has been called; De Kroon and Van Groenendael 1997). It grows on soils that may be saturated part of the year, so aboveground stolons confer ready vegetative reproduction despite these conditions. The level to which it reproduces vegetatively has not been examined. *Astragalus diversifolius* life history has not been studied, but past specimen collecting that included the stout taproot indicates that it lives longer than a decade, if not decades. Its longevity and highly reduced leaves seem to confer as much or more photosynthetic surface area on the sprawling stems as on the leaves, an efficiency of resources. *Cleome multicaulis* is an annual with indeterminate flowering and forms a seed bank that may confer resilience through unfavorable years, and the shifting of suitable shoreline habitat between wet and dry years.

It is important to recognize the afore-mentioned habitat and species biology differences between the three species, understanding that they have bearing on potential threats and conservation. Updated information on the three species and highlights of the information in this report are encapsulated in state plant species abstracts (Appendix B).

ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

Potential threats to currently known populations

The following information draws from 2014 survey results and builds upon prior status reports.

Water development: The primary threats to the three Sensitive species, in Wyoming and throughout their ranges, is probably loss and alteration of habitat due to water developments and activities that affect water tables. For *Cleome multicaulis*, draining of wetlands for expansion of farmland or new subdivisions has been identified as a major threat in the San Luis Valley, Colorado (Riley 2001). Specifically, Riley (2001) interpreted that soils where *C. multicaulis* is currently present will not continue to support *C. multicaulis* if they dry out, interfering with plant growth and seed bank maintenance, and soils that are too wet will promote the growth of *Juncus balticus* and other vegetation that may outcompete it. In Wyoming, it is not known if the Pathfinder Reservoir inundated any habitat of *C. multicaulis*, but on a local scale, it is possible that the impoundment increased groundwater stability that might possibly have expanded suitable habitat in the Steamboat Lake area.

For *Antennaria arcuata* and *Astragalus diversifolius*, the most frequent water development activities have been stock pond development. Stock dams seems to affect habitat suitability both upstream and downstream beyond the zone of inundation (Heidel 2013). Ditching and draining

has occurred at Ice Slough (Blomquist pers. commun.), and though *Astragalus diversifolius* EO#006 is not near any such features, the water table may still be affected. Surveys have not been conducted on private lands, where development pressures and habitat conversions are more likely.

Drilling activities: There is the potential for oil and gas development in parts of the three species' distributions, and there are other drilling activities in the landscape, including drilling for uranium. It is not known if these deep drilling activities potentially lower water tables or if their effluent might be discharged into the catchments harboring the three Sensitive species. It appeared as though one occurrence of *Astragalus diversifolius*, EO#007, had unusually high stream channel flows that might be associated with effluent discharge (Figure 41). Not all drilling activities affect groundwater levels. It is also possible that widespread infrastructure developments associated with extractive developments in the landscape (roads, pipelines, transmission lines) indirectly alter its habitat.

An exemplary study was conducted by BLM regarding the effects of replacing segments of the Pathfinder Pipeline on *Cleome multicaulis* (Cline 2008). Surveys were conducted in the right-of-way (ROW) before construction, determining that about 2.1 ha (5.4 ac) of occupied habitat was within the proposed pipeline corridor. Construction stipulations were added and reclamation protocol outlined for three different "treatments": 1) Normal construction technique (rip and seed) in wide ROW with reclamation, 2) No pit liner/narrowed ROW/no reclamation, and 3) Pit liner/narrowed ROW/no reclamation. Monitoring was conducted in 2008, the year after construction work. In general, the treatments where no reclamation was done were the areas that maintained high density of *C. multicaulis*. It is not known if this was due to the particular location of these treatments or to the construction technique. It was also demonstrated that *C. multicaulis* was absent and replaced by both *Atriplex* spp. (seepweed) and *C. serrulata* (Rocky Mountain beeplant) in the areas where reclamation occurred. Recommendations were made that monitoring continue for at least five years post construction, and though *C. multicaulis* may be suited to establishing on recently disturbed soils, that reclamation standards were still appropriate (Cline 2008). It may or may not be significant that construction work in occupied habitat introduced weeds (later treated with herbicides) and the related *C. serrulata* (ordinarily an upland plant) into the same settings.

Noxious weeds: Exotic species were notably scarce or absent in surveying alkaline meadow habitat in 2014. *Poa pratensis* (Kentucky bluegrass), a non-native species, was reported as common in Fremont County habitat of *Antennaria arcuata*, where it may directly compete and contribute to the desiccation of habitat. However, it was low or absent from those *A. arcuata* occurrences surveyed in the county in 2014. The one noxious weed that has immediate potential for encroachment is *Cirsium arvense* (Canada thistle) as observed in the Green River habitat of *A. arcuata*. *Cirsium arvense* is favored in sites of fluctuating water level, as found at impoundments on the same drainages (Heidel 2013). A small patch of *C. arvense* was observed

in *Cleome multicaulis* habitat at Pathfinder Reservoir (Fertig 2000), and other species such as *Cardaria* spp. (whitetop) were identified as potential threats.

There are a limited number of noxious weeds that can tolerate high salinity. One of them, *Halogeton glomeratus* (Halogeton) is currently present in very low levels within *Astragalus diversifolius* habitat at Chain Lakes, but has exploded in numbers on nearest county roads since the time that the species was surveyed in 2007, and might be expected to expand further. In addition, *Cardaria* spp., *Lepidium latifolium* (Broad-leaved pepperweed) and *Tamarix chinensis* (Tamarisk) are tolerant of alkali and have been collected very close to the Pathfinder Reservoir population of *Cleome multicaulis*, as determined by an online data search of the RM specimen database.

In general, hummocky terrain, with variable moisture availability, may be especially vulnerable to encroachment of persistent, rhizomatous noxious weeds. Salt-tolerant noxious weeds pose direct competition to these species, which are typically poor competitors, particularly at key stages of life history such as seedling establishment. Moreover, noxious weed colonization may contribute to habitat alteration by way of water loss or succession.

Grazing: Throughout the range of these three Sensitive species, livestock grazing is the dominant land use. Almost all of the their populations fall within grazing allotments, and those that do not, e.g., at Pathfinder National Wildlife Refuge, may still have fence maintenance issues that result in intermittent livestock use (Fertig 2000). At Soda Lakes, large portions of *Cleome multicaulis* lake shore habitat appeared to be fenced off from grazing. All three species are wetland plants, and livestock use is ordinarily concentrated in their habitats as primary range and in accessing water. Fenceline comparisons have been made to infer that *Antennaria arcuata* in particular does not tolerate heavy grazing and Marriott (1986) identified overgrazing as one of the potential threats to it.

However, exclosure studies by the BLM suggest that grazing is less of a threat to *Antennaria arcuata* than originally thought. Populations of *A. arcuata* often abruptly stop inside of ungrazed exclosures where graminoid cover is too dense and soils are too moist. Under appropriate stocking levels and rotation, grazing may be beneficial to this species by maintaining low cover and moist (but not too wet) soil conditions, though trampling may still be a concern (Fertig 1996).

None of the three Sensitive species appears to be palatable or directly grazed by cattle. In the case of *Antennaria arcuata*, it is wooly and produces little leaf material, most of which grows close to the ground. *Astragalus diversifolius* produces almost no leaf material and most of it grows close to the ground. *Cleome multicaulis* is likely to have anti-herbivory secondary chemical compounds in the foliage.

Dorn (1978) discussed the potential effects of grazing on *Antennaria arcuata* and noted that "It is possible that the problem is more a distribution problem rather than overstocking per se." In 1982, the BLM Lander Field Office set up a one acre exclosure for monitoring *A. arcuata* (Winnepenninkx 1984a), the Atlantic City Exclosure (in EO#005), with frequency and productivity data collected inside and outside the exclosure. The original plans were to take readings every five years. The original plot sampling was set up in places of high *A. arcuata* frequency (20-80%). It was first read in 1983 and reread in 1988. Overall *A. arcuata* frequency changed from 75% to 0% inside the exclosure (1983 and 1988, respectively), and from 74% to 8% outside the exclosure (USDI BLM *A. arcuata* monitoring files). A second exclosure, the Gilespie Exclosure, was set up in 1984 (Winnepienninkx 1984b), but apparently not sampled until 1988 (in EO#012; USDI BLM *A. arcuata* monitoring files). In addition, an exclosure study was set up in 1987 near, if not in, the Long Creek population north of the Granite Mountains (EO#025). It was read in 1988 (USDI BLM *A. arcuata* monitoring files). In 1985, an expanded evaluation of the effects of grazing on *A. arcuata* was proposed, addressing seven study objectives as master's thesis research (Dodd and Mihlbachler 1985), but was not pursued.

In more recent reviews of potential grazing threats, Fertig (1996) cited the above mentioned BLM exclosure studies as indicating that removal of grazing may result in habitat changes that are detrimental to the continued existence of *Antennaria arcuata*. He noted that the chosen exclosure sites may not be representative of conditions at all sites (based on the personal communication of A. Warren to H. Marriott; Marriott 1988). He also noted that populations of *A. arcuata* often abruptly stop inside of ungrazed exclosures where graminoid cover is too dense and soils are too moist. Under appropriate stocking levels and rotation, some degree of vegetation cover removal by grazing appears to be beneficial to this species (Fertig 1996).

Trampling may contribute to formation of hummocks in *Antennaria arcuata* habitat and associated succession, nutrient balance, water loss, and oxidation. Bayer (1992) went as far as to say that "*Antennaria arcuata* occurs on the sides of hummocks that are created by cattle activity in the moist sloughs." He also characterized the settings as disturbed from domestic animals, primarily range cattle, which are "attracted by moisture and the relatively lush vegetation. These same areas were perhaps also disturbed by plains bison during precolonial times," in keeping with statements by Dorn (1986) about the widespread distribution of bison in Wyoming historically. It is possible, but not proven, that the affinity of *A. arcuata* for hummock habitat is an adaptation to natural disturbance, and that hummocks may be pre-settlement features. The high organic content in occupied habitat soils poses a special challenge for interpretation, and in sorting out cause from effect.

Perhaps the most perplexing management question is how to interpret the hummocks that are regularly present in *Antennaria arcuata* habitat and at some level in the Sweetwater River drainage portion of *Astragalus diversifolius* habitat. If they are caused by livestock grazing, then

this indicates they are a product of disturbance from concentrated livestock use. If they are caused by native ungulates that are no longer present (e.g., bison), then this indicates they are a product of a natural disturbance that has shaped microhabitat availability. They are also near, if not in, the National Historic Trails landscape where hundreds of thousands of people travelled with their wagons, horses and other livestock over a century ago. In any case, the presence of hummocks greatly increases the area of exposed soil surface area and makes the alkaline meadow habitat particularly prone to desiccation that may contribute to habitat vulnerability, decline or loss.

Drought: The conditions required to maintain stability of occupied habitat are not known, and it is possible that drought periods are associated with prolonged dessication that can degrade and permanently alter habitat.

Roads and ORV Use: Damage by off-road vehicles and proliferation of two-track roads were reported as frequent in Fremont County surveys for *Antennaria arcuata* (Fertig 1996) but were generally absent from Sublette County populations and scarcely observed in the limited 2014 surveys. One of the population records added since Fertig (1996), EO#035, is crossed by Fort Stambaugh Road, with an elevated road bed that hydrologically cuts the population into two parts. Work on US Highway 287 caused disturbance in and above the channel and wet meadow habitat of Fish Creek, but it appeared to be downstream from the population (Heidel pers. obs.).

Mining and quarrying: Based on potential threats to *Antennaria arcuata* in Fremont County, Whiskey Basin Consultants (1982) recommended withdrawing known areas of *A. arcuata* habitat from mineral development. Uranium mining is occurring in the study area, and wastewater handling is a potential concern akin to drilling activity threats.

Recreational activities: The Pathfinder Reservoir population of *Cleome multicaulis* is currently managed primarily for wildlife habitat and viewing (USDI Fish and Wildlife Service 2009). Public access for wildlife viewing and interpretive developments have also been proposed, and it would be appropriate to avoid concentrations of *C. multicaulis* and consider any potential indirect effects of such developments.

Habitat management: Areas of sagebrush steppe directly adjoining *Astragalus diversifolius* habitat at EO#007 were dead (Figure 41). The cause of mortality and potential influence on habitat of *A. diversifolius* were not clear.

Figure 41. Dead sagebrush beside *Astragalus diversifolius* habitat at EO#007 on the West Fork of Long Creek

Conservation recommendations

Recommendations regarding present or anticipated activities: It is not known whether the alkaline meadow habitats of all three BLM Sensitive species can be mitigated. Even in the case of *Cleome multicaulis*, which was at least temporarily showed an increase in numbers after the disturbance of pipeline repair, this does not mean that hydrological conditions can be maintained or mitigated by restoration under other disturbances. *Antennaria arcuata* is the most extensive of the three species and poses a special challenge to address its status because its soils are high in organic content and may have formed under conditions that that differ from current climate conditions.

Many occurrences of the three species are in multiple-use land management. One occurrence of *Antennaria arcuata* is protected on The Nature Conservancy's Sweetwater River Preserve. Other occurrences are split between public and private parties, or between multiple agencies as with the Soda Lakes occurrence of *Cleome multicaulis*, split between BLM and State of Wyoming lands.

Fertig (1996) stated that demographic monitoring studies he had initiated for *Antennaria arcuata* in 1995 should be continued and expanded to include a broader range of habitats. He added that existing BLM exclosure studies may need to be modified to test whether renewed grazing can help recolonize once occupied habitat. There is a need to ensure that existing information is compiled/archived, and then priorities are to be set for maintaining or expanding it throughout the Green River and Sweetwater drainages if appropriate. The photo point monitoring studies he initiated for *Cleome multicaulis* in 2000 should be revisited on a trial basis and monitoring needs of the species considered among all populations.

Special designations might be considered for the largest populations of at least *Astragalus diversifolius* and *Cleome multicaulis*, and the complementarity of the national historic trail

system and these natural resources in close proximity. It is not known whether these three wetland Sensitive species fall within any complementary management policy with regards to wetlands and riparian mandates.

Notification of BLM personnel of locations on BLM lands: To evaluate impacts to known populations of these three Sensitive species, all appropriate BLM personnel involved in on-the-ground management activities that include range management, weed control, wetland delineation and water resources should have access to the supporting location data. The updated state species abstracts and this report will also be posted online for reference.

Status recommendations: *Antennaria arcuata* and *Astragalus diversifolius* have their largest populations in the world in Wyoming, and *Cleome multicaulis* has one of the largest populations known. So their status in the state is significant for their overall conservation. The salt affected habitats that they require are sometimes thought of as wasteland, and may or may not be adequately represented in Ecological Site Descriptions and management mandates. There are some lines of evidence to suggest that these three species tolerate harsh conditions, and can tolerate some level or forms of disturbance in those conditions. Underlying hydrology needs to be evaluated to fully address habitat vulnerability. This report provides a venue for discussions within BLM and natural resource experts at large.

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