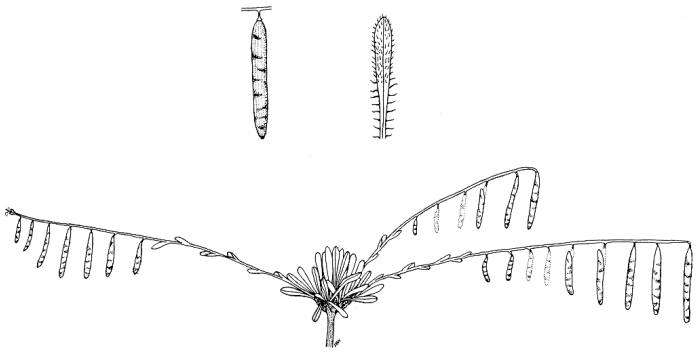
# Status and Monitoring of *Boechera pusilla* (Small Rockcress; Fremont County Rockcress) in Wyoming



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## ABSTRACT

*Boechera pusilla* is designated sensitive by the Bureau of Land Management in Wyoming, and is a Candidate species (Category 1) recognized by the U.S. Fish and Wildlife Service. It is known from one population throughout its range, and has been the subject of some of the most concerted sensitive species protection in the state of Wyoming but limited monitoring work. A monitoring study was set up in 1988 as exhaustive census within part of the largest subpopulation but not repeated. A revised monitoring study was set up in 1993 to similarly census a slightly smaller part of the largest subpopulation but not repeated. Funding for surveys to test a new potential distribution model was provided in 2003 and monitoring work was included with objectives, using the 1988 framework, documenting a drop from 671 flowering plants in 1988 to 87 flowering plants. Monitoring was conducted in some of the following years based on provisional support, and funding became available in 2011. Results were then analyzed for the first time, covering data from 2003, 2004, 2008, 2009, 2010, and 2011. The number of flowering plants in the plot area rose to 195 plants by 2011, though there was no clear trend among 2003-2011 numbers. Information is presented that the data from the original monitoring area may represent a smaller fraction of the total population than originally inferred. The most complete census conducted to date was in 2011, in which there were a total of 1451 flowering plants tallied (1256 outside the original plot). The climate associated with most or all annual census results, including 1988 numbers, may have been atypical. Plants of *B. pusilla* had high fruit production in 2011, so seeds were collected to deposit in a conservation seed bank. A life history transition matrix description, climate datasets, and more detailed habitat information are presented as a framework for understanding trends. As part of this, the report expands on the rest of status information that goes into Category 1 review.



## ACKNOWLEDGEMENTS

*Boechera pusilla* monitoring work was supported as a joint project of the Bureau of Land Management (BLM) and the Wyoming Natural Diversity Database. Emma Stewart, Chicago Botanic Garden intern for BLM, assisted in conducting the 2011 expanded census. Victoria Pennington, Wyoming Natural Diversity Database, assembled climate data sets. This study draws heavily from the previous monitoring work of Hollis Marriott and the status review work of Marriott and Robert Dorn. Their foresight is reflected throughout their reports, while any shortcomings of the current report rest with the author.


Literature citation:

Heidel, B. 2012. Status and monitoring of *Boechera pusilla* (small rockcress; Fremont County rockcress). Prepared for the Bureau of Land Management. Wyoming Natural Diversity Database, Laramie, WY.

Cover: *Boechera pusilla*, illustration by Isobel Nichols

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## Introduction

*Boechera pusilla* (Rollins) Dorn (syn. *Arabis pusilla*) (Small Rockcress; also called Fremont County Rockcress) is designated a sensitive species by the Bureau of Land Management (BLM) in Wyoming (2001, 2002, 2010) and is recognized as a Candidate species (Category 1 species) for listing under the Endangered Species Act (USDI Fish and Wildlife Service 2011). It is known from only one population throughout its range, and is a species of Very High Wyoming contribution rank, with Global and State ranks of G1/S1 (Heidel 2007).

The primary purpose of this project was to monitor *Boechera pusilla*. The first half of this report presents monitoring data, updating the information in Heidel (2005). The second half presents a status report update, following the topic outline used by USDI Fish and Wildlife Service (2011). The monitoring results contribute to the second half of the report.

## Monitoring Methods

A monitoring design suited for *Boechera pusilla* was set up and executed in 1988 as a complete census within a given area of the largest subpopulation (Marriott 1988). It covered an area of 16 m x 25 m (400 m²). The census was conducted by laying a 25 m measuring tape at 2 m intervals, and all flowering plants were counted and categorized within 1 m of the tape, by a two-person team. It was time-consuming, and covered a fraction of the subpopulation. The 1988 researchers mapped the subpopulation as almost fitting within a 50 m x 25 m area (1250 m²), and proposed expanding the monitoring to that 50 m x 25 m area, converting it into a random sampling design. Detailed photo documentation and monitoring notes accompanied the raw data. It was set up for annual monitoring but not repeated.

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A separate monitoring design for *Boechera pusilla* was set up and executed in 1993 as complete census covering nearly the same area of the largest subpopulation (Amidon 1993). It spanned an area of 40 ft x 100 ft (4000 ft²; 371.6 m²). A series of tapes were spaced 5 ft apart and referred to as transects. A one-page summary copied from agency files was available for reference. It was set up for annual monitoring but not repeated.

The same subpopulation of *Boechera pusilla* was next monitored by the author in 2003. It was readily apparent that the species was no longer in high density, and nowhere random in its distribution. The schematic maps and photo records that accompanied 1988 monitoring were available for reference. It was possible to pound rebar in at corners that were within a meter of the mapped and photographed boundaries delimiting the starting line of the 16 m x 25 m original plot and the ending line of the 50 m x 25 m expanded plot area. Thus, the 1988 design was replicated, expanded, and the corner points were marked. Small modifications were made in carrying out the census for quality control and execution by just one person. Two 50 m tapes were run on opposite sides of the 50 m plot length, and two other metric tapes were stretched perpendicular at 1 m intervals to set off lanes for conducting complete census. Rocks were used to anchor the tapes to prevent shifting with wind, and carefully laying/anchoring the lanes was required to get accurate tallies. The zero axis was in the northeastern corner, so the first lane was the northernmost, and lane numbers increased to the south.

Five other logistical questions and design considerations in monitoring *Boechera pusilla* were explored in some detail. First, a second species of *Boechera* is present repeatedly in parts of the same area, and there is no absolute spatial or environmental factor that can consistently distinguish them. Instead, each plant was closely inspected, with a hand lens if necessary. Previous monitoring researchers did not leave a record of how they handled it as part of monitoring, though Marriott had previously mentioned the sympatry (Marriott 1986). No intermediates were found. Character sets were written in 2003 for differentiation of plants at both flowering and vegetative conditions (presented in the latter half of this report). Second, vegetative plants are also present as stemless rosettes with clusters of basal leaves, even tinier than the fruiting *Boechera pusilla* plants. They can both be reliably discerned from all other species present. Inventory was expanded to include vegetative plants in 2003 on a trial basis to get more life history information even though the rosettes do not represent reproductive individuals. Third, mapping of individual plants, both flowering and vegetative, was conducted on a trial basis in 2003. This proved to be very time-consuming and not satisfactorily replicable when conducted as a one-person operation. The number of flowering stems for each plant continued to be counted most years (2003, 2004, 2008, 2011). This reflects fecundity, given that there are an average number of fruits per stem and seeds per fruit. Finally, the plot size was expanded in 2008 to the full 50 m x 25 m. Weather thresholds for doing this work were also identified, including good lighting, no more than moderate winds, and little or no rain and snow. Essentially, the addition of vegetative plants and the expansion of plot size provided more robust data but made the census work appreciably longer rather than shorter. Total monitoring time exceeded 8 hours.

Monitoring of *Boechera pusilla* was repeated for a total of six years, including consecutive monitoring for the past four years (Table 1). The monitoring numbers that are reported in this study focus on flowering plant numbers, but include vegetative plant numbers for life history context. They represent the entire 50 m x 25 m plot (50 - 1 m lanes) unless otherwise stated, those exceptions being when it was important to make direct comparisons with results from the original sample area of 16 m x 25 m (16 - 1 m lanes).

Table 1. *Boechera pusilla* monitoring overview (2003-2011)

| Date | Monitoring extent (400 m² vs. 1250 m²) | Inclusion of vegetative plants in addition to flowering plants |
|---|---|---|
| 6-Jun-03 | 400 m² | Yes |
| 15-Jun-04 | 400 m² | Yes |
| 2-Jun-08 | 1250 m² | No |
| 1-Jun-09 | 1250 m² | Yes |
| 31-May-10 | 1250 m² | Yes |
| 6-Jun-11 | 1250 m² | Yes |

The 50 m x 25 m monitoring plot covers roughly 90% of the *Boechera pusilla* subpopulation area. But the subpopulation occupies an area that is more or less oval-shaped and there are small extensions on all sides. The counts in these peripheral areas are incorporated in subpopulation tallies of 2009-2011. The contributions of these peripheral areas approach or exceed 10%. In other words, the census data are variously represented at three different scales: the original

monitoring area (400 m²), the expanded monitoring area (1250 m²), and the entire subpopulation area.

The monitoring phenology window is open once *Boechera pusilla* plants have finished sending up flowering stalks but before the fruits have shattered and stem breakage is possible, essentially any time in June, and possible in at least part of late May and early July as annual phenological variation permits. A premium was placed on conducting monitoring early in the growing season. In this report, the term "flowering plant" is used interchangeably with "reproductive plant" and "fruiting plant" as compared to vegetative plant. In every year of monitoring, all reproductive plants had finished flowering by the monitoring date except in 2011. Traces of snow persisted around the plot area in 2011 for the first time among recent monitoring years.

Data summaries were compiled for the original and expanded area (16 - 1 m lanes vs 50 - 1 m lanes), and for both stages (flowering/vegetative/total). Climate datasets were assembled for comparison with trend data, using the nearest standard SNOTEL station at South Pass (Site No. 775 @ 9040 ft; USDA NRCS 2012) and the nearest meteorological station at South Pass City (488385 @7880 ft; USDI NOAA 2012).

In 2011, *Boechera pusilla* flowering stem numbers per plant were noticeably higher than in previous years, prompting the question whether 2011 was a year when the population could support collection for conservation seed bank purposes, as identified in the *Arabis pusilla* Habitat Management Plan (USDI BLM 1994). The 12-month finding (USDI Fish and Wildlife Service 2011) came out at the same time as 2011 monitoring was underway, adding new impetus for this question. Papers on file indicated that *B. pusilla* seeds were previously collected in 1993 by Barbara Amidon and sent to Denver Botanic Garden, but they were no longer in storage at present, for whatever reason. Therefore, the matter was discussed with U.S. Fish and Wildlife Service and with Denver Botanic Garden, agreeing on the merit of collecting *B. pusilla* seeds for conservation seed bank purposes, and outlining the administrative process.

To carry out this added task, a second visit was made on 28 June to collect seeds of *Boechera pusilla*, with the assistance of Chicago Botanic Garden intern, Emma Stewart. However, all fruits were still immature at this time and not appropriate to collect. A third visit was made by the author on 8 July, collecting 1-2 siliques per plant (generally from multi-stemmed plants, but no collections in the monitoring plot), for a total of about 400 siliques from the two largest subpopulations. Depending on the average number of stems per plant and fruits per stem, there between about 10,000-20,000 fruits produced last year, so the sample size represents 1-3% of 2011 fruit production.

The premature visit on 28 June provided an opportunity to pursue *Boechera pusilla* flowering plant census that was not part of original monitoring objectives, censusing the larger three of the seven other subpopulations. Censusing was carried out by a two-person team, dividing each subpopulation into lanes.

*Boechera pusilla* occurs in the southern Wind River Range, Fremont County; about 3.5-4.5 miles southwest of South Pass City. It lies on both sides of Pine Creek, about 0.7 – 1.7 miles west of State Highway 28, in T.29N R.101W Section 26 N½ of SW¼ and SW¼ of NW¼ in addition to

Section 27 NE¼ of SE¼ and SE¼ of NE¼. The monitoring plot position on maps and aerial photos, and baseline photographs are represented in Appendix A along with the original establishment record, and a printout of the full records is presented in Appendix B. More detailed information on distribution, geology, vegetation and climate are presented in the second half of this report.

**Monitoring Results**

A replication of 1988 monitoring shows that *Boechera pusilla* flowering plant numbers in the monitored part of the largest subpopulation declined since the start of monitoring, and have been in the range of 13%-34% of 1988 levels within the past decade (Figure 1). There is no clear trend within the recent period.

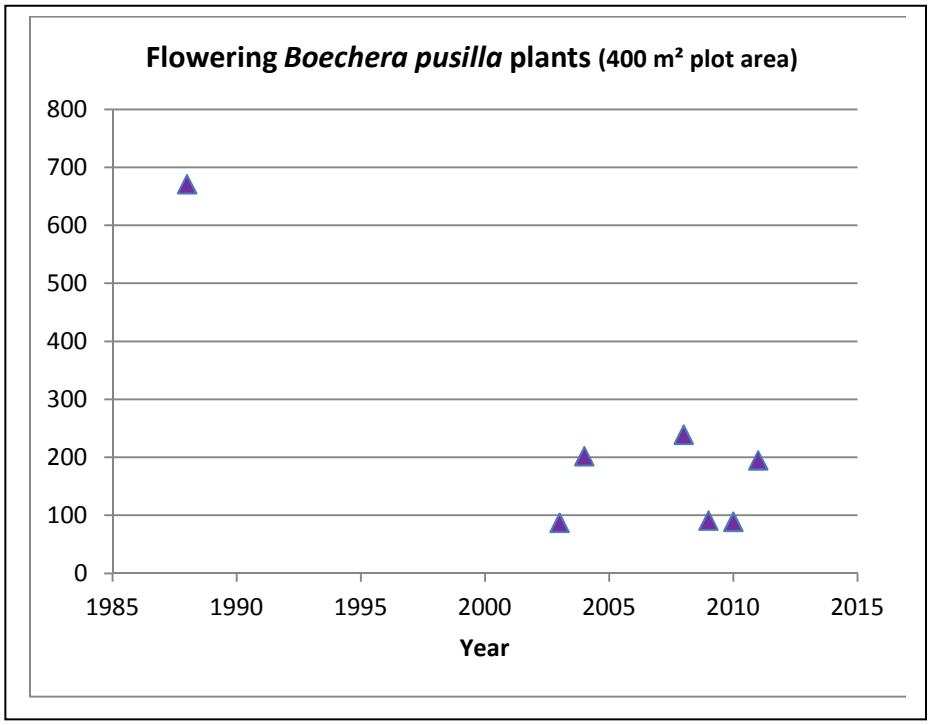



Table 2. Flowering *Boechera pusilla* plant numbers over time

| | 400 m² | 1250 m² |
|---|---|---|
| 1988 | 671 | |
| 2003 | 87 | |
| 2004 | 202 | |
| 2008 | 239 | 400 |
| 2009 | 91 | 223 |
| 2010 | 89 | 238 |
| 2011 | 195 | 505 |

Figure 1. Flowering *Boechera pusilla* plant numbers over time (see Table 2, first column)

There have been preliminary statements made about plant numbers in recent years, but it was not until 2011 when raw data sheets were tabulated. This report provides the synthesis. Expansion of the monitoring area shows a difference in census numbers from 195 plants to 505 plants by covering a 50 m x 25 m area in 2011 (Table 2). By extending census even further outside of the dermarcated 50 m x 25 m block, complete census of the subpopulation in 2011 documented a total of 615 flowering plants, in which the original monitoring area represented less than 33% of the total.

The number of *Boechera pusilla* flowering stems per plant had ranged from 2.1-2.9 in earlier years (2003-2010) within the original plot, but had risen to 4.3 in 2011. This flowering stem average per plant is all the more significant in that it looked like some of the 2011 flowering

plants were really first-year plants that would not ordinarily flower at all, and which were generally small, single-rosette plants putting out a single stem. These precocious plants would tend to lower the average number of flowering stems rather than raise it. The high proportion of flowering to vegetative plants in 2011 (Figure 3) supports the idea that flowering was favored overall.

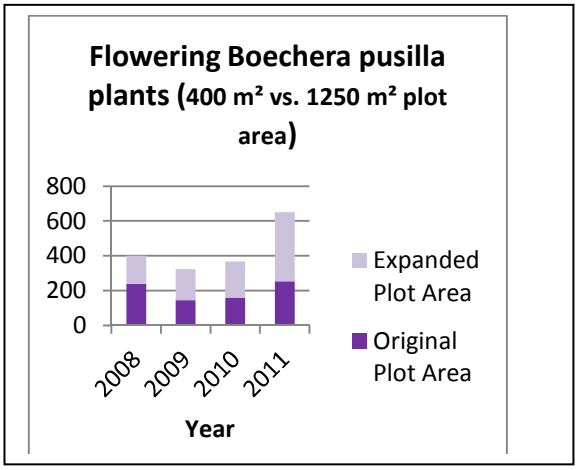



Figure 2. Comparison of flowering *Boechera pusilla* plant numbers inside vs. outside the original plot area

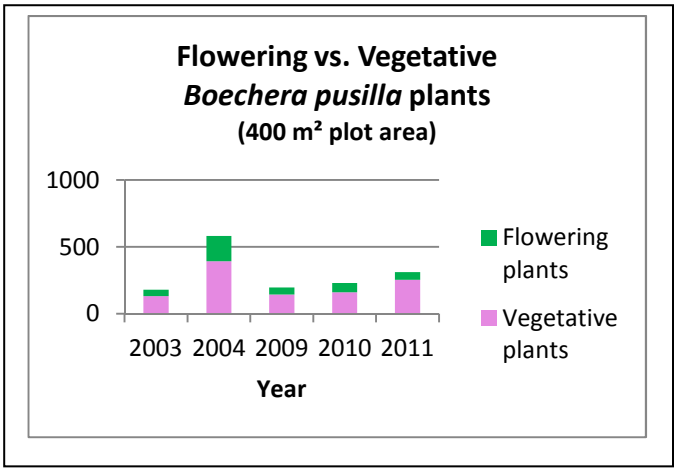



Figure 3. Comparison of flowering and vegetative *Boechera pusilla* plant numbers in the original plot area

**Monitoring Discussion**

The expansion of plot size in 2008 and the new censusing of *Boechera pusilla* that was added to 2011 work provided significant new information that helped put monitoring results into context. The complete census of the subpopulation containing the original monitoring plot tripled numbers. One of the subpopulations that I had roughly estimated as having 50-60 flowering plants in 2003 was censused in 2011 and had 726 flowering plants. The two other subpopulations that were censused totaled 110 plants. These census numbers more than doubled the population numbers known from the monitored subpopulation. The 2011 census total, including the monitored subpopulation, is 1451 plants, based on the four largest of eight subpopulations (in terms of plant numbers). The other four subpopulations that were not censused in 2011 generally had much lower numbers in each previous year.

The decline in *Boechera pusilla* numbers is significant between 1988 and the past decade, representing a drop no matter how the information is considered. However, trends may not be as grim as the 2003 results (Heidel 2005) indicated because they were incomplete representation of the subpopulation and of the population as a whole (Figure 2; and previous paragraph). By expanding the scope of census in 2008 and 2011, it was determined that the monitoring area as delimited in 1988 does not represent over half of the population.

Another reason that 2003 results are not quite as alarming as they initially seemed is because 1988 results were inferred to represent population numbers in a drought year (the year of the

Yellowstone Fires). Climate data was reviewed to look for drought patterns in and around 1988, and in the past decade (2001-2011). Climate data as they have bearing on trend are presented as part of habitat information in the second half of this report, challenging the original inference.

The monitoring data have been used in combination with estimates of population size to characterize *Boechera pusilla* trends (USDI Fish and Wildlife Service 2011). Caution is warranted in using estimates of *B. pusilla* numbers to indicate trend. Two central points are developed in the latter half of this report. First, *B. pusilla* has irregular distribution that remains more or less consistent between years, but its distribution is patchy and population boundaries do not consistently start and stop with outcrop boundaries or other distinct features. Thus, estimates that do not have accompanying location information have limited merit. Second, the species is inconspicuous, and there are no vantages from which one can see most plants in a subpopulation, so without spending considerable time and taking a systematic approach, estimates are apt to be low.

Since BLM protection measures have been deemed necessary and sufficient for species' conservation (USDI Fish and Wildlife Service 1981), and the recent Category 1 designation is based on trend information, this places a premium on getting accurate, robust trend information that requires at least two more years if not a more intense monitoring. The 2003-2011 results do not establish *Boechera pusilla* trend within this period, but they modify interpretations to date. It is recommended that BLM census flowering plants of *Boechera pusilla* in the full 50 m x 25 m plot (excluding vegetative plants), conducted by a team of appropriate permanent BLM staff to ensure standardization, for a minimum of two additional years. It is also recommended that the other large subpopulation be included in 2012-2013 monitoring in order to collect census data that indeed reflects the majority of the population.

The rest of this report provides status information as update to all information in previous reports (Marriott 1986, Dorn 1990, Heidel 2005) while also commenting on or expanding on information in the 12-month finding (USDI Fish and Wildlife Service 2011) as part of the updated Category 1 status review.

To understand *Boechera pusilla* monitoring work in the context of other status evaluations and protection measures, a chronology of salient events is presented below. It includes all major studies, status changes, conservation initiatives and related monitoring (Table 3). This timeline is cited throughout the rest of the report.

Table 3. *Boechera pusilla* timeline

| | |
|---|---|
| 1981 | First discovery - Rollins |
| 1982 | Published description - Rollins |
| 1982 | Completion of exclosure for Pine Creek Special Management Area (originally approved for designation in 1978) |
| 1985 | First placement under the Endangered Species Act in Category 2 status - USDI FWS [Category 2 designation was discontinued in 1996] |
| 1986 | First status report – Marriott |
| 1988 | First monitoring and management framework presented – Marriott 1988 a, b |
| 1990 | First inclusion in a field guide – Weynand and Amidon |
| 1990 | Second status report – Dorn |
| 1993 | Second monitoring in a different design – Amidon raw data |
| 1994 | Second inclusion in a field guide – Fertig et al. |
| 1994 | *Arabis pusilla* habitat management plan (started in 1993) – James Dunder |
| 1995 | Notice of proposed withdrawal from mineral entry (first posted in 1994) – USDI BLM |
| 1997 | First petition for listing *Arabis pusilla* as Endangered and placement in Category 1 status – USDI FWS |
| 1997 | Establishment of a BLM ACEC to protect *Boechera pusilla* as part of Green River RMP – USDI BLM |
| 1998 | Designation of Special Recreation Management Area closed to mineral and energy development – USDI BLM |
| 2000 | Withdrawn from mineral entry to protect *Boechera pusilla* – USDI BLM |
| 2001 | First removed from Category 1 status protection measures – USDI FWS |
| 2001 | Placed on first BLM sensitive species list and maintained on updates - USDI BLM (2001, 2002, 2010) |
| 2003 | Revisionary taxonomic work that built on early genetics work separating New World *Arabis* from Old World *Arabis* and transferring them to the *Boechera* genus – Al-Shehbaz |
| 2003 | First potential distribution model – Fertig and Thurston |
| 2003 | Expanded survey using potential distribution model – Heidel |
| 2007 | Also - replication and expansion of 1988 monitoring – Heidel (2003, 2004, 2008, 2009, 2010, 2011) |
| 2007 | Second petition for listing as part of a petition to designate all G1 species in the USFWS Region - USDI FWS |
| 2011 | 12-month finding and second placement in Category 1 status – USDI FWS |

**Species Description**

General Description: *Boechera pusilla* (Small rockcress or Fremont County rockcress) is a perennial herb with one-to-several slender, decumbent flowering stems 5-17 cm long. The plant has a cluster of linear, erect basal leaves with relatively sparse, simple, biforked or triforked spreading hairs. Flowering stems generally have 3-5 widely-spaced, nonauriculate stem leaves. Flowers are small, light lavender and four-petaled, The fruits are linear siliques that spread at right angles from the decumbent stems on short pedicles usually less than 3 mm (up to 5 mm), usually strongly secund (one-sided on the stem). The fruits are relatively short: 1-1.5 (--3.8) long and 1.5- 2 mm wide. (Rollins 1982, 1993; Dorn 2001; Fertig et al. 1994; Al-Shehbaz and Windham 2010).

The following page of images represents key characteristics of the species (Figures 4-9).

Phenology: There are reports that *Boechera pusilla* flowers from May to mid-June (USDI Fish and Wildlife Service 2011). However, it only found in fruit during monitoring visits conducted between 31 May – 15 June (2003-2010). This changed in the moist, late growing season of 2011, when it was still in flower and early fruit on 6 June, indicating that there may be a phenology shift of three weeks or more between years depending on climate conditions, or else a curtailment of flowering under unfavorable climate conditions; see Figures 8 and 9 for a comparison of phenology between 2010-2011.

The flowers are indeterminate, flowering from the base to the tip, with only slightly staggered phenology. Most flowering stems of the same plant are at similar phenological stages, but under moist conditions, a late flowering stem may be produced. Most plants in the same setting are at similar phenological stages, but different subpopulations may be at slightly different phases, as was observed in monitoring and in repeat visits of 2011.

Similar species: There are a striking number of different *Boechera* species in and near the South Pass area. One other species is common in parts of the *B. pusilla* population, *B. pendulocarpa*. They are most readily distinguished by the green vs. gray color of leaves and stems, associated with sparse vs. dense hairs, respectively. Two other *Boechera* species are present but rare in occupied *B. pusilla* habitat, *B. microphylla* and *B. grahamii.*

Collections were made of all *Boechera* in the habitat and the vicinity incidental to surveys (Marriott 1986, Heidel 2005) to ensure that all species characteristic differences are addressed. The Rocky Mountain on-line specimen database (2008) was also queried in 2012 for species in the area. A table of characteristic was expanded from Heidel (2005) that represents *B. pusilla,* three overlapping species, four other species in the same or surrounding sections, and one species in nearby townships. The current comparison incorporates specimen reviews and verifications of all Rocky Mountain Herbarium collections in the genus provided by Al-Shehbaz. The only redetermination he made among the 2003 collections was annotating the *B. demisa* var. *languida* voucher to *B. pendulocarpa* (syn. *B. exilis* in Dorn 2001). The latter is in the same habitat, and the former has been collected in nearby sections. Marriott (1986; Table A) presented the first concise table of distinguishing characteristics between *B. pusilla* and putative parent species. The comparative table has been updated with all current nomenclature, the redetermination, and associated characteristics for *B. pusilla* and the eight other species in or near the area (Table 4).

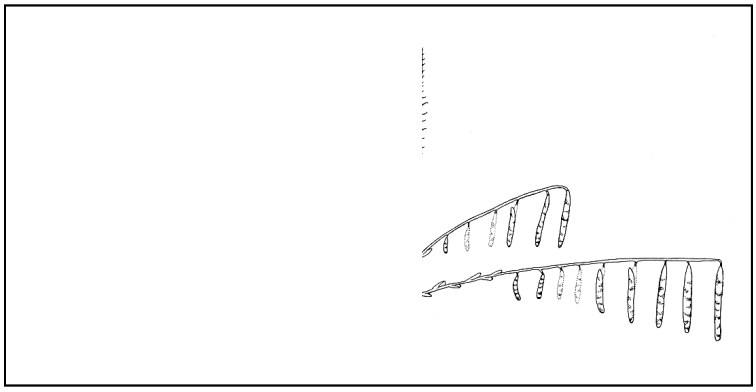


Figure 4. *Boechera pusilla*, illustration by Isobel Nichols, from Fertig et al. 1994

Figure 5. *Boechera pusilla* flower

Figure 6. One vegetative *Boechera pusilla* plant with four rosettes.

Figure 7. The flowering stalks of *Boechera pusilla* become more one-sided and prostrate as they mature.

Figure 8-9. The same individual *Boechera pusilla* plant, photographed in two consecutive years (left – 31 May 2010 in fruit, and right – 6 June 2011 in flower).

**Discovery and Taxonomy**

*Boechera pusilla* was first collected near South Pass in Fremont County, Wyoming by Reed and Kathryn Rollins in 1981 (Rollins 1982). It was named *Arabis pusilla*; the species epithet "*pusilla*" refers to its small size. It has been recognized in the state flora (Dorn 1988, 1992, 2001), the Rocky Mountain Herbarium checklist for Wyoming (Hartman and Nelson 1994), and the *Flora of North America* (FNA; Al-Shehbaz and Windham 2010).

*Arabis* has often been treated as a synonym of *Boechera* (e.g., Rollins 1993) but FNA authors maintain that morphological similarities between these are due to evolutionary convergence rather than shared ancestry (Al-Shehbaz and Windham 2010). The *Boechera* genus is restricted to North America and Greenland, whereas the *Arabis* genus is mainly an Old World genus. The body of research upon which this is based is presented mainly in Al-Shehbaz (2003). The rationale and implications for this change in Wyoming have been presented to the state botanical community (Dorn 2002).

The genus *Boechera* is receiving attention as a model system for studying ecological, evolutionary, and related genetic characteristics of numerous species in the same genus at a continental scale (Rushworth et al. 2011). There is work underway to determine the embryology, karology, and modes of reproduction in every *Boechera* species that exists (Dobes et al. 2006), and an on-line database of chromosome counts and literature is maintained. This work will not only fathom taxonomic relations but provide insights into speciation.

Rollins (1982) and Dorn (1990) postulated that *Boechera pusilla* is genetically closely related to *B. demissa* var. *languida* (syn. *B. languida*; nodding rockcress), *B. pendulina* var. *russeola* (treated as *B. pendulina* in FNA; Daggett rockcress), and *B. oxylobula* (Glenwood Springs rockcress). On the other hand, Al-Shehbaz and Windham (2010) state that morphological evidence suggests that *B. pusilla* is an apomictic species that arose through hybridization between *B. lemmonii* and *B. pendulina*. They also state explicitly that "morphological evidence suggests that *Boechera pusilla* is an apomictic species that arose through hybridization between *B. lemmonii* and *B. pendulina*". Elsewhere they note that apomictic species in *Boechera* appear to be of relatively recent origin and generally have not migrated beyond regions where their parents are sympatric.

The FNA authors also discuss the distinctions between the primary products of divergent evolution, the sexual diploids, and the secondary products of reticulate evolution, the apomictic species such as *Boechera pusilla*, most of which are inferred to be polyploids (Al-Shehbaz and Windham 2010). The lab of Dr. Michael Windham (Duke University) has done microsatellite analyses from four *Boechera pusilla* plant specimens to date, including the holotype, one of the isotypes, and a cytogenetic voucher collected in 1999. There is minimal genetic variability in this sample, and all work done so far indicates that the species is an apomictic triploid with genomes derived from *B. pendulina, B. lemmonii*, and (probably) *B. oxylobula* (Windham pers. commun. 2012).

Table 4. Characteristic features of *Boechera pusilla* and other *Boechera* species in the same area of the Wind River Range[1]

| Species | Synonym | BH Coll. No. | Proximity to *B. pusilla* | Basal leaf shape/ pubescence | Silique disposition | Silique dimensions | Pedicel length | Growth form |
|---|---|---|---|---|---|---|---|---|
| *Boechera grahamii* | *Arabis confinis; A. x divaricarpa; Boechera brachycarpa* | 2288, 2296 | Among | Oblanceolate, sparsely to densely pubescent, trichomes 2-4 rayed | Divaricately ascending to descending, usually gently curved downward | 3.5-9 cm long; 1-1.8 mm wide | 6-12 mm | Solitary or few stems from simple caudex; biennial or perennial |
| *Boechera pauciflora* | *Arabis holboellii* var. *pinetorum and Boechera pinetorum* – misappl. | 2294 | Vicinity | Oblanceolate; densely pubescent, trichomes 2-5 rayed | Horixontal, divaricate-descending or widely pendent, not second, curved | 5.5-10.5 long; 1.5-2.2 wide | 4-13 mm | Solitary or few stems from simple caudex; biennial or perennial |
| *Boechera retrofacta* | *Arabis holboellii* var. *secunda; Boechera holboelli* var. *secunda* | 2284 | Vicinity | Oblanceolate, densely pubescent, trichomes 5-10 rayed | Straight-descending or at least sharply bent near base, sometimes ~secund, straight | 3.5-9 cm long; 0.9-1.8 mm wide | 7-12 mm | Solitary or few stems from simple caudex; biennial or perennial |
| *Boechera languida* | *Arabis demissa* var. *languida* | none | Vicinity | Linear oblanceolate to oblanceolate, densely pubescent; trichomes simple, 2-4 rayed | Pendent; straight to slightly curved | 3-4.5 mm long; 1.8-2 mm wide | 3-13 | Few-several stems from a simple or branched caudex; perennial |
| *Boechera lemmonii* | *Arabis lemmonii* | none | Alpine species of nearby townships | Oblanceolate to obovate, densely to sparsely hairy, trichomes 3-9 rayed | Divaricately ascending to slightly descending, secund, straight or curved | 2-4.4 cm long; 1.6-2.3 mm wide | 2-6 | One-many stems from woody caudex, somewhat cespitosa; perennial |
| *Boechera microphylla* | *Arabis microphylla* | 2585 | Among | Oblanceolate to linear-oblanceolate; densely pubescent, trichomes 4-8 rayed | Ascending to divaricately-ascending, not second | 3-7 cm long; 1-1.5 mm wide | 5-15mm | Usually many stems from a much-branched caudex; perennial |
| *Boechera pendulina* | *Arabis pendulina* var. *russeola* | 2293 | Vicinity | Oblanceolate or obovate; pubescent, essentially all simple, trichomes 2-rayed | Widely pendent, not secund, curved to nearly straight | 2-4 cm long; 1.5-2 mm wide | 5-8 mm | Few-several stems from a simple or branched caudex; perennial |
| *Boechera pendulocarpa* | *Arabis holboellii var. pendulocarpa; Boechera exilis,* | 2283 | Among | Narrowly oblanceolate; densely hairy, trichomes 4-8 rayed | Erect to pendent, not secund, straight | 2.5-3.8 long; 1.5-2.2 wide | 3-8 mm | Solitary or few stems from branched caudex; perennial |
| *Boechera pusilla* | *Arabis pusilla* | 2301 | NA | Linear-lanceolate or linear-oblanceolate; sparsely pubescent, trichomes 2- to 3-rayed | Spreading at right angles to rachis, slightly ascending or descending, secund, straight | 1-3.8 cm long; some fruits up to 2 mm wide | 2-5 mm | Solitary or 2-6 stems per caudex branch, perennial |

[1] Nomenclature follows Al-Shehbaz and Windham (2010)

**Biology and Life History**

*Boechera pusilla* is a short-lived perennial. Seeds are likely to germinate in fall. Seedlings have never been observed early in the growing season in the course of monitoring despite close inspection. It is not known whether seeds have an after-ripening or dormancy requirement and produce a seed bank. It has been grown in the greenhouse at the University of Wyoming, and the seeds were germinated without a cold treatment (Bill Higgins pers. commun. 2012).

Established first-year plants produce a single cluster of basal leaves (rosette) and most first-year plants growing in the wild remain in a vegetative condition. There is not a fixed ratio of vegetative to flowering plants (Figure 3). Plants appear apt to produce flowering stalks in wet years and less likely to produce flowering stalks in dry years (discussed further with climate data). Plants have been observed in the field to transition back and forth one or more times from flowering to vegetative states. It appears that it takes more than one growing season to produce plants that have multiple basal rosettes (connected by caudex branches), unless the vegetative plant of four rosettes as shown in Figure 6 is actually a first year plant. The slender flower stalks do not ordinarily persist between years, but vestiges have been observed. Demographic studies in the field or in the greenhouse have not been conducted to determine mean or maximum life expectancy of established plants.

Plants have been characterized as typically 2-6 stems with an average of 3.0 flowering stems per plant, and 10.4 fruits per plant (Marriott 1988). This is fairly consistent with stem estimates over the course of recent monitoring, varying from 2.1-2.9 stems per plant, except for 2011 with an average of 4.3 stems per plant. In 2003 and some subsequent years, it was observed that the numbers of fruits per stem was low (1-5), and that not all fruits matured. Flower abortion and curtailment of fruit seed set may reduce numbers further under stress, and observations suggest that reproductive investment varies greatly between years.

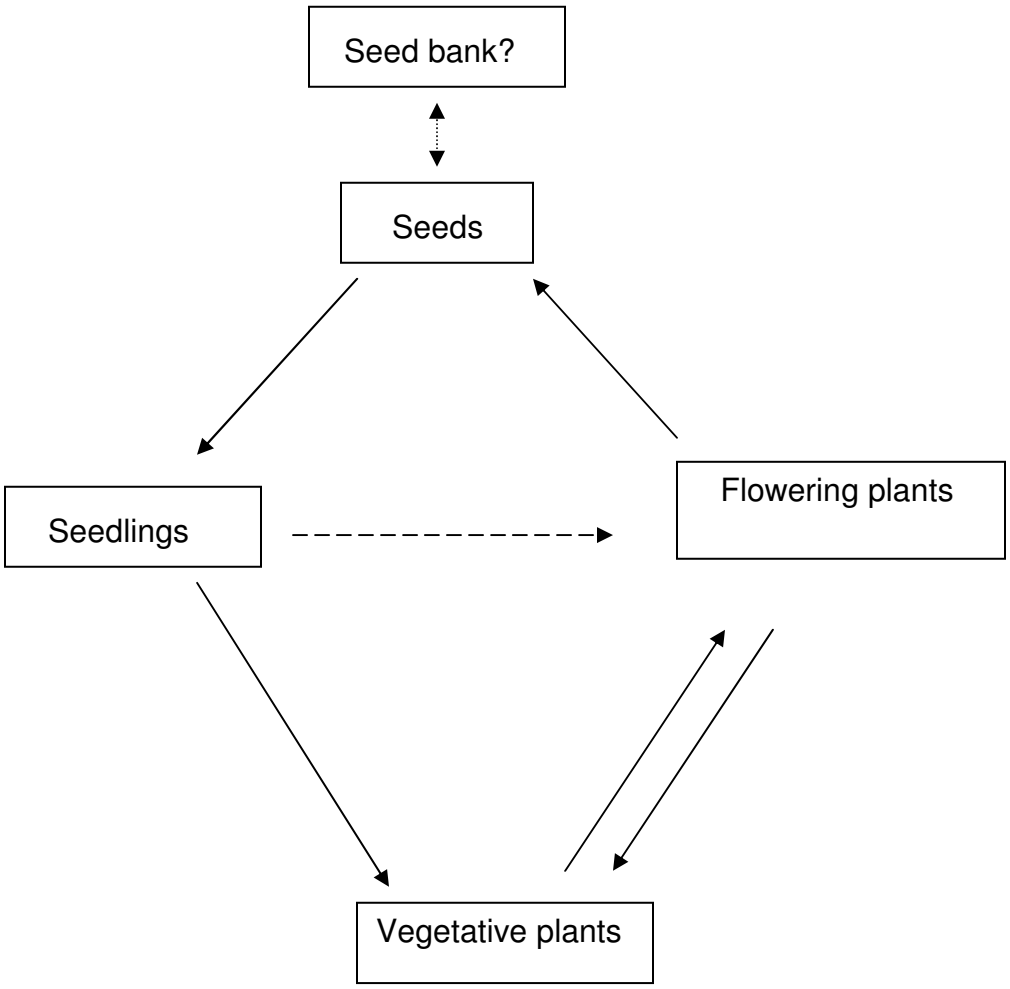
Repeat visits were made in 2011 and indicated that the length of time that it takes *Boechera pusilla* plants to develop from mid-flowering (6 June) to mature fruit (8 July) was over four weeks. The moist, late 2011 growing season was not necessarily typical and 2011 was the only monitoring year in which traces of snow were present in adjoining habitat at the time of monitoring. The mature fruit dries out and ruptures over a short period. The seed does not have wings, and there are no known dispersal mechanisms, though wind and water have been suggested as possible vectors (Dorn 1990). The small seed is only 0.05-0.1 mm (Al-Shehbaz and Windham 2010).

*Boechera pusilla* has been characterized as an apomictic species by Al-Shehbaz and Windham (2010). Some apomictic *Boechera* species have a mixed-mating system, but no information on *B. pusilla* reproduction is available. Insect visitations were not noted when briefly inspecting flowers in 2011.

*Boechera pusilla* plants may flower more than once (Figures 8-9), but it is not known whether most plants flower more than once. A schematic life history transition matrix is presented in Figure 10. From observations in the field, it seems that most established plants do not flower until their second year. The rare phenomenon of seedlings establishing and producing floweris in

their first year, as observed in 2011, is represented by the dashed line. Signs of mortality have rarely been noted in monitoring, suggesting that mortality is concentrated in other times of year.

Figure 10. *Boechera pusilla* life history transition matrix




Some flowering plants in the monitoring plot failed to produce any fruits whatsoever in 2003 (12 of 87 plants had flowering stalks with 100% aborted fruits). This could have been influenced by freezing conditions during spring or by drought. Flowering plants in 2003 had a maximum of six flowering stems per plant and up to 28 fruits per plant. By contrast, almost no flowering plants lacked fruits in 1988 and there were up to 11 flowering stems per plant and up to 37 fruits per plant.

**Habitat**

*Boechera pusilla* occupies sparsely vegetated soil pockets on exposed granite-pegmatite outcrops, on flat or gentle sloping barren settings. The soils are sandy to loamy, with variable gravel content, poorly developed, very shallow, and possibly subirrigated by runoff from the

adjacent exposed bedrock (Dorn 1990). *Boechera pusilla* is restricted to microhabitats in this setting, including outcrop fractures, the margins of outcrops where surrounded by gravel pavement, and the gravel pavement itself. Elevation of the population as mapped ranges from 2425-2460 m (7960-8080 ft). A pair of representative habitat photographs are presented in Figures 11 and 12.

The first habitat description for *Boechera pusilla*, recorded on the collection label and in the Rollins publication (1982), described the setting as "cracks and crevices of huge metamorphosed rocks." However, the bedrock is igneous rather than metamorphic, essentially granitic material with phenocrysts (giant crystals) slowly cooled deep below the surface. The occupied habitat does not have deeply incised fractured terrain, as one usually thinks of crevices, but does have fractured/cracked outcrops surrounded by gravel pavement (Figures 11 and 12). The "huge" rocks may refer to contiguous pluton landmarks (prominent knolls formed by solidification of a molten magma deep within the earth) rather than the occupied habitat itself. The habitat description for *B. pusilla* was slightly modified in Al-Shehbaz and Windham (2010), described as "cracks and crevices of granite outcrop."

The list of species directly associated with *Boechera pusilla* has been expanded from prior reports to include almost all that are present (Table 5). The moist 2011 conditions and repeat visits afforded opportunity to expand the roster. This list includes many perennial montane species, a few intermontane annuals, a plains grass and others. This list is based mainly on the composition at the monitored subpopulation.

Table 5. Plant species associated with *Boechera pusilla*

| **Scientific Name** | **Common Name** | **Growth Form** |
|---|---|---|
| *Achnatherum hymenoides* | Indian ricegrass | Perennial grass |
| *Androsace septentrionalis* | Pygmy rock-jasmine | Annual herb |
| *Antennaria dimorpha* | Cushion pussytoes | Perennial herb |
| *Antennaria parvifolia* | Littleleaf pussytoes | Perennial herb |
| *Artemisia arbuscula* | Dwarf sagebrush | Shrub |
| *Artemisia tridentata ssp. vaseyana* | Mountain big sagebrush | Shrub |
| *Artemisia tripartita var. rupicola* | Three-tip sagebrush | Shrub |
| *Balsamorhiza incana* | Hoary balsamroot | Perennial herb |
| *Boechera grahamii* | Graham rockcress | Perennial herb |
| *Boechera microphylla* | Small-leaf rockcress | Perennial herb |
| *Boechera pendulocarpa* | Drooping-fruit rockcress | Perennial herb |
| *Camissonia scapoidea* | Paiute suncup | Annual herb |
| *Carex douglasii* | Douglas' sedge | Perennial graminoid |
| *Carex rossii* | Ross' sede | Perennial graminoid |
| *Chaenactis douglasii* | Douglas' dusty-maiden | Perennial herb |
| *Collinsia parviflora* | Blue-eyed Mary | Annual herb |
| *Crepis modocensis* | Siskiyou hawksbeard | Perennial herb |
| *Cryptantha spp.* | Miner's candle | Perennial herb |

| | | |
|---|---|---|
| *Danthonia unispicata* | Few-flower wild oatgrass | Perennial graminoid |
| *Draba oligosperma/ D. calcifuga?* | Few-seed whitlow-grass | Perennial herb |
| *Elymus elymoides* | Bottlebrush squirreltail | Perennial graminoid |
| *Elymus griffithsii/spicatus* | Bluebunch wheatgrass | Perennial grass |
| *Eremogone congesta var. congesta* | Ballhead sandwort | Perennial herb |
| *Erigeron caespitosus* | Tufted fleabane | Perennial herb |
| *Erigeron composites* | Cut-leaved fleabane | Perennial herb |
| *Eriogonum caespitoum* | Matted wild-buckwheat | Perennial herb |
| *Eriogonum ovalifolium var. purpureum* | Cushion wild-buckwheat | Perennial herb |
| *Eriogonum umbellatum* | Sulfur-flower wild-buckwheat | Perennial herb |
| *Eremogone hookeri* | Hooker's sandwort | Perennial herb |
| *Festuca idahonis* | Idaho fescue | Perennial grass |
| *Gymnosteris parvula* | Small-flowered starlet | Annual herb |
| *Ivesia gordonii* | Ivesia | Perennial herb |
| *Juniperus communis* | Common juniper | Shrub |
| *Lithophragma parviflorum* | Prairie woodlandstar | Annual herb |
| *Navarretia breweri* | Yellow pincushion-plant | Annual herb |
| *Paronychia depressa* | Spreading nailwort | Perennial herb |
| *Penstemon humilis* | Low beardtongue | Perennial herb |
| *Phlox hoodii* | Hood's phlox | Perennial herb |
| *Phlox multiflora* | Rocky mountain phlox | Perennial herb |
| *Pinus flexilis* | Limber pine | Tree |
| *Poa fendleriana* | Muttongrass | Perennial grass |
| *Poa secunda var. secunda* | Curly bluegrass | Perennial grass |
| *Potentilla pensylvanica* | Pennsylvania cinquefoil | Perennial herb |
| *Purshia tridentata* | Bitterbrush | Shrub |
| *Rhus trilobata* | Fragrant sumac | Shrub |
| *Sedum lanceolatum* | Lance-leaf stonecrop | Perennial herb |
| *Selaginella densa* | Dense spike-moss | Fern ally – perennial |
| *Senecio integerrimus* | Western groundsel | Perennial herb |
| *Stenotus acaulis* | Stemless mock goldenweed | Perennial herb |
| *Taraxacum laevigatum* | Red-seed dandelion | Perennial herb |
| *Trifolium gymnocarpon* | Holly-leaf clover | Perennial herb |

Vegetation cover is very patchy in the setting, and *Boechera pusilla* is generally absent from areas of high cover (Figure 11). The question has not been raised whether associated plants might have greater competitive ability that could successionally encroach upon *B. pusilla* habitat. The abrupt vegetation boundaries suggest this is not the case. The recent monitoring years provide no evidence of encroachment but do provide succession information anecdotes. One of the associated species that seems most problematic in the local successional picture is dense spike-moss (*Selaginella densa*). It is a colonizer in the same microhabitats as those occupied by *B. pusilla*. It appeared that *S. densa* plants had habitat-wide dieback in the past four years. *Boechera pusilla* plants were rarely seen growing in live *S. densa* mats, but a few were noted in dead ones in 2010-2011 (Figure 13-14). This large-scale dieback of *S. densa* is uncommon and may have resulted from drought.


Figure 11. *Boechera pusilla* microhabitats

Figure 12. "Crevice habitat" where present in filled fractures

Figures 13 and 14. Pavement habitat where present in the middle of a dead *Selaginella densa* mat (above) and dying mat (below)

Figure 15. Frost heaves have been noted near *Boechera pusilla* habitats

The processes that keep rock outcrop unvegetated are not known, but the hard crystalline rock has virtually no water-holding capacity. The outcrops are covered by an array of crustose lichens, but the lichens do not provide a colonization surface. Well-developed frost heaves have been noted in the surrounding gravel pavement in different places and in different years that may maintain the bare pavement conditions (Figure 15).

The distribution of *Boechera pusilla* on its occupied habitat appeared to be static from year to year. This is a premise in the permanent plot monitoring design, and important to keep in mind when comparing census results between years.

Further evaluation of climate conditions was pursued incidental to monitoring. Two monitoring datasets are available near *Boechera pusilla* habitat, the NOAA meterorological data from South Pass City (488385), and the SNOTEL monitoring data above South Pass (No. 775). Marriott (1986) reported that the annual precipitation in the area averages 30.5 cm (12 in), with the majority falling as snow. Snowfall contributes significantly to cumulative precipitation available at the start of the growing season, so cumulative water-year precipitation values from the SNOTEL station (1986-2011) were graphed to evaluate available moisture to *Boechera pusilla* at key intervals early in the growing season (30 April and 31 May) (Figure 16). It is hypothesized that established plants take at least two years to flower, so that trends may reflect climate conditions of 2+ years prior. By this hypothesis, the 1988 census results could be influenced by the very high precipitation levels of 1986 when the values were 77% higher than the mean May cumulative precipitation (41.7 in compared to 23.6 in for 1986-2011). It may or may not be significant that 2001 had the lowest May cumulative precipitation over this same period, 39%

lower (14.4 in compared to 23.6 in for 1986-2011) which could have influenced 2003 census results. This climate data significantly changes the statement made in Heidel (2005) that 1988 results reflected drought if *Boechera pusilla* as short-lived early-season perennial is as strongly or primarily influenced by conditions of prior years as current year. Demographic data are needed to identify the life history stage(s) most sensitive to climate conditions.

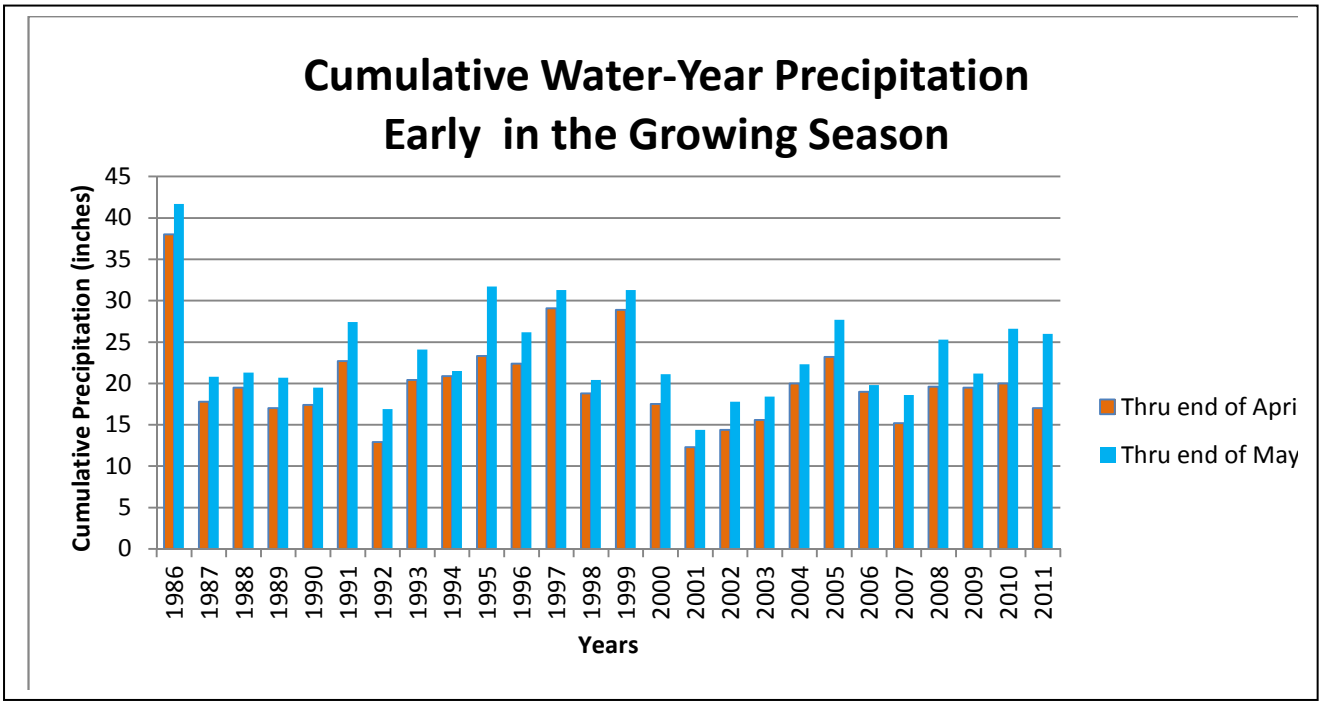



Figure 16. Cumulative water-year precipitation at South Pass – comparison of October-April and October-May (South Pass SNOWTEL Stataion, NRCS 2012).

The graph above also puts the 2011 climate conditions into context, with about 30% of accrued water-year precipitation (starting in October) arriving in May as snowfall. The high levels of late spring precipitation are represented in greater detail by SNOTEL precipitation graphs for the same period (Appendix C).

The climate conditions in South Pass City (town site) as compared to the SNOTEL station are drier, and the elevation much closer to that of *Boechera pusilla* habitat. Mean annual precipitation at this station was 13.4 in when a longer period that cited by Marriott is considered (1915-2006). There have been statements made that *B. pusilla* has a 30-day growing season (Marriott 1986). This is based on USDI NOAA meteorological data from South Pass City interpreted by Krosting and Christensen (1980). The supporting data is represented in Figure 17.

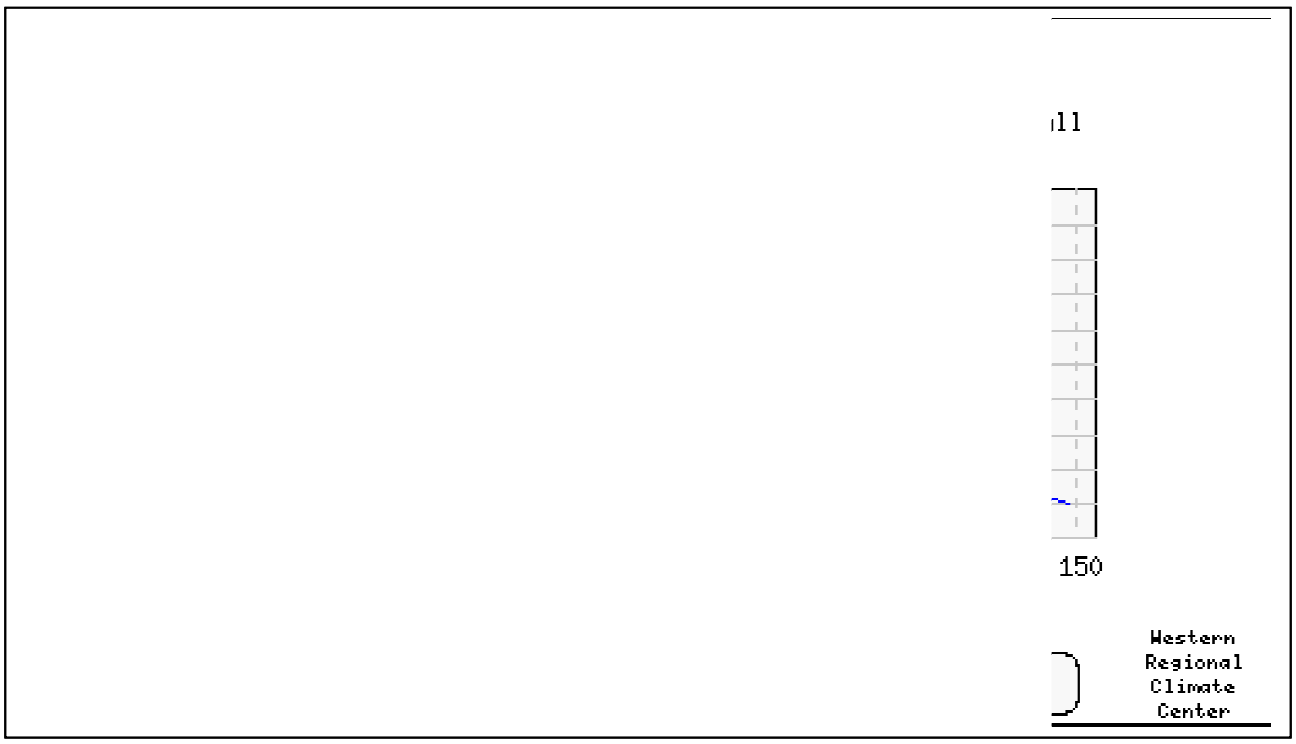



Figure 17. "Freeze Free" season probabilities at South Pass City, WY (1915-2006; from USDI NOAA 2012)

By contrast, a 30-year NOAA dataset from the same South Pass meteorological station (1961-1990; USDI NOAA 2012) showed there to be on the average, a 110-day period when the mean minimum daily temperature was above 32 ºF. The difference between these two different gauges of growing season length may be explained if an averaging of the daily minimums masks the standard deviation in daily minimum temperature. It was noted when monitoring work took place during temperatures that dipped below freezing that there were no signs of frost damage to *Boechera pusilla*. It is apt to be cold-hardy.

Microclimate conditions of *Boechera pusilla* occupied habitat have not been documented but it is hypothesized that the pegmatite outcrops retard the temperature changes of the seasons, and this dense rock is slow to heat early in the growing season, but radiating stored heat late in the growing season. It is hypothesized that *Selaginella densa* wicks the moisture that falls in light rainfall events when it is alive, and helps slow moisture loss from evaporation whether it is dead or alive.

**Distribution and Abundance**

*Boechera pusilla* is located at the southern end of the Wind River Range in southwestern Fremont County (Figure 18). It is managed by the Bureau of Land Management Rock Springs Field Office, within the High Desert District. It lies midway between the towns of Lander and Farson along State Highway 28. Its presence has been reported as part of each floristic thesis in or near the area (Fertig 1993a, b; Cramer and Hartman 1996, Massatti 2007, Welp 1997), as represented in the Rocky Mountain Herbarium online specimen database (Rocky Mountain Herbarium 2008) and the central database of Wyoming Natural Diversity Database.

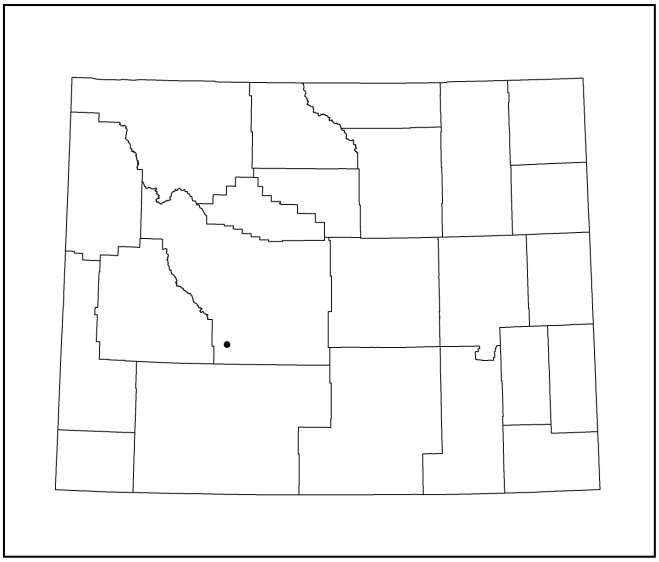


Figure 18. *Boechera pusilla* distribution in Wyoming

*Boechera pusilla* is mapped as spanning about 18.4 acres (7.45 ha), and comprised of eight subpopulations shown as discrete polygons (Figures 19 and 20). However, the largest area might be more accurately represented as a series of points rather than continuous suitable habitat and the level of mapping work has been limited. The mapping was done in 2003 using previously annotated field maps and taking GPS points while looking for outer limits. The areal extent does not represent plant density and numbers. Two of the smaller polygons contain far more plants than all the others combined. The monitoring plot lies in the easternmost subpopulation, closest to highway access, and the one that has been referred to as the biggest subpopulation in prior reports. The completeness of population mapping is discussed at the end of the occurrence record information (Appendix B), building the case for additional work to look for small outliers.

The four *Boechera pusilla* subpopulation areas that were censused in 2011 are labeled on the Figure 19 map as Subpopulations 1-4, and tallies for them are represented in the table below (Table 6). Subpopulation 1 is the monitored subpopulation, and monitoring location is detailed in Appendix A. A complete printout of population information over time, including each subpopulation, is represented in Appendix B.

Table 6. 2011 census tallies in *Boechera pusilla* subpopulations

| **Subpopulation** | **2011 tally** |
|---|---|
| 1 | 615 |
| 2 | 85 |
| 3 | 726 |
| 4 | 25 |

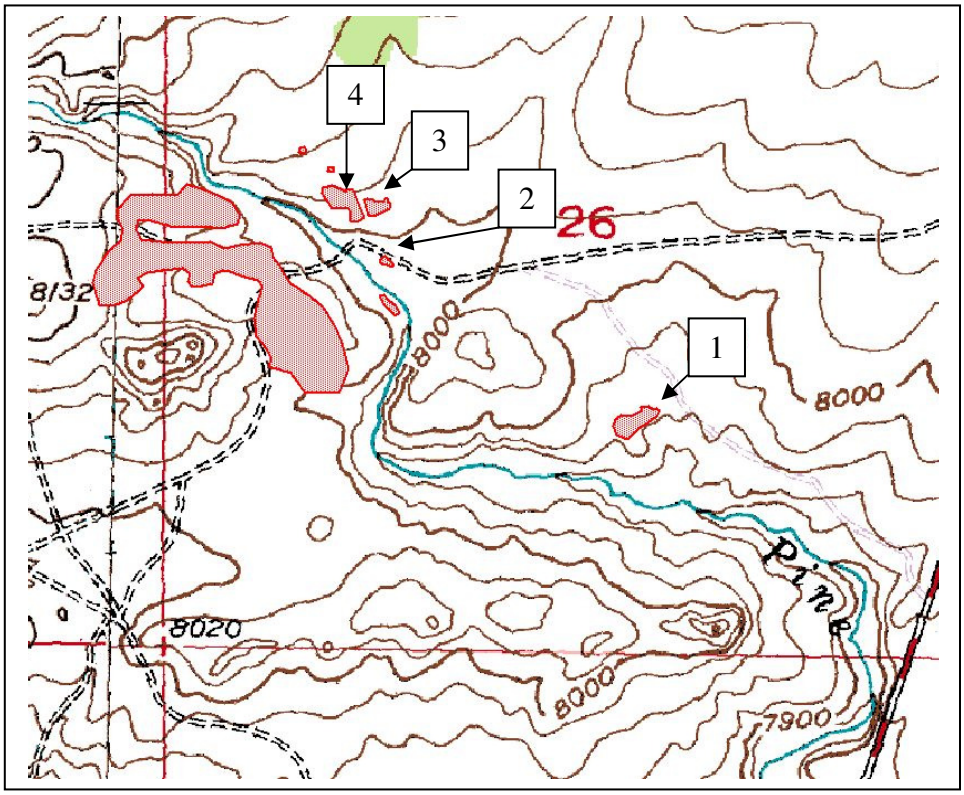



Figure 19. *Boechera pusilla* distribution in the South Pass area (South Pass and Anderson Ridge 7.5' USGS Quads)

Figure 20. *Boechera pusilla* distribution in the South Pass area (NAIP digital aerial imagery)

Most *Boechera pusilla* occupied habitat is within continuous outcrop, but not all continuous outcrop habitat is occupied. There is extensive unoccupied outcrop around Subpopulation 1 (Figure 20), much of it on sloping outcrop. The area mapped as the most extensive subpopulation (southwest of Pine Creek, Figure 20) has tiny outcrop patches, only a fraction of which are occupied.

The reason for going into this much detail about *Boechera pusilla* distribution patterns, their discontinuity, and their irregularity is to build the case that any estimates without accompanying location information have incomplete context. This is further complicated by the inconspicuousness of the plant, so that unless the investigator also recorded how estimates were made at a given locale, estimates may not be replicable, and it is difficult to compare estimates made by different people. It is inferred but not certain that the majority of estimates for the population pertain strictly to Subpopulation 1.

There has been speculation over the years whether *Boechera pusilla* has additional potential habitat. Major outcrops in the potential distribution map below were surveyed (Figure 21). Likewise, the map of pegmatite bodies in the area were also used as an alternate model for surveys (Bayley 1965, Bayley et al. 1973). One area mentioned by Marriott (1986), the Sweetwater Canyon, has not been surveyed for this species, though vegetation mapping work was conducted in this same area (Jones 2004) that typically includes collection of plant vouchers.

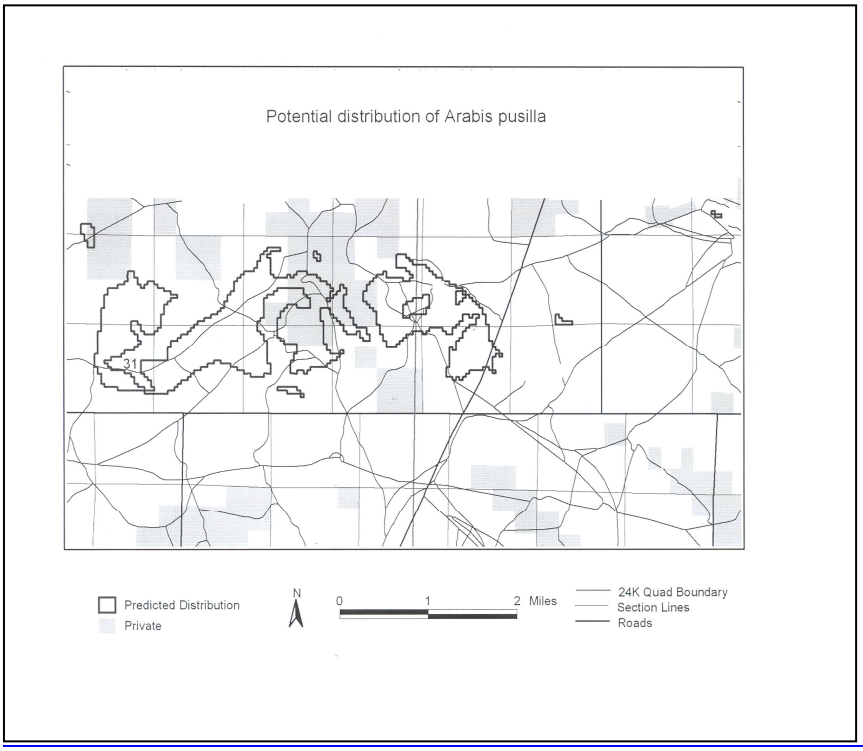



Figure 21. Potential distribution of *Boechera pusilla* in Wyoming, from Heidel (2005) based on Fertig and Thurston (2003)

Five Factor Evaluation for *Boechera pusilla*

Factor A. The present or threatened destruction, modification, or curtailment of its habitat or range

The most complete review of Factor A considerations for *Boechera pusilla* is presented by USDI Fish and Wildlife Service (2011), a synthesis of all prior information. It states that the BLM has excluded grazing from much of the habitat area, developed a habitat management plan for the species, designated the habitat area as an ACEC, incorporated this area into a SRMA, and designated *B. pusilla* a sensitive species.

At present, motorized traffic is not admitted to the exclosure and the former roadbed has been torn up and reseeded. This addresses the previous threat identified by Dorn (1990) in which off-road vehicle use was the main threat to *Boechera pusilla*. Prior to the habitat management plan, actual and potential recreational uses of the habitat included camper parking, hunting, fishing access, picknicking, unauthorized ORV use, horse boarding and feeding, plant collecting, mountain biking, and pedestrian use.

At present, the area has been withdrawn from mineral entry, all the more important with new explorations for gold taking place in the vicinity. This addresses the previous threat identified by Marriott (1986) who noted that some quarrying was done in the past on one of the granite-pegmatite outcrops near the single known occurrence. This combination of pro-active measures for sensitive plant species is unparalleled in the state.

The current *Boechera pusilla* (*Arabis pusilla*) species habitat management plan (USDI BLM 1994) was created to provide a framework for the following:

1. Protect *Boechera pusilla*, its habitat, and the ecosystem on which it depends
2. Eliminate management threats and impacts to the plant and its habitat
3. Map, monitor and inventory existing and future habitat
4. Initiate off-site studies to understand species' biology, population dynamics and habitat needs, and to provide a seedbank
5. Possible augmentation of the known population, or introduction into additional habitats.

It included provisions for a five-year review and called for compliance checks. This report is the most recent BLM report on the species since Heidel (2005). It documents major strides in monitoring and inventory, and a seed bank accession was also collected for conservation purposes.

Tasks 3-5 in the species management plan (above) are not directly related to present or threatened destruction of *Boechera pusilla* habitat but provide a platform for evaluating any potential threats. They are discussed under conclusions.

Factor B. Overutilization for commercial, recreational, scientific, or educational purposes
The only known collecting of *Boechera pusilla* specimens and seeds to date has been for documentation and seed bank conservation. A record of the seed bank collecting that was done in 2011 is presented in Appendix D, and the collection represents 1-3% of all seed produced in 2011.

Factor C. Disease or predation
There has been no sign that species trends are affected by disease or predation. No signs of browse have been seen, despite the fact that elk and mule deer occasionally use the habitat area. Very low incidence of rust were observed on flowering stems in 2011.

Factor D. Inadequacy of existing regulatory mechanisms
USDI Fish and Wildlife Service determined that there is no evidence of impacts to *Boechera pusilla* from inadequate regulatory mechanisms.

Factor E. Other natural or manmade factors affecting its continued existence
The possibility of alteration by natural disturbance has not been previously discussed. In recent years, many limber pine trees (*Pinus flexilis*) in the area have died, increasing the possibility of fire events. The sparse vegetation of occupied habitat would seem to deter fire, but the proximity of woody vegetation to its habitat makes small-scale patterns difficult to predict, and any off-road fire control practices in the area could affect it.

The possibility of alteration by natural succession has similarly been inferred to be unlikely. It is recommended that a set of photopoints be established with both horizontal landscape view and vertical view looking straight down, to be revisited at a set interval.

**Conclusion**
The U.S. Fish and Wildlife Service will prepare a 2012 Candidate Notice of Review, and this report may be pertinent to the review. The Bureau of Land Management - Resource Management Plan for this area will be updated, a planning process that provides a forum for reaffirming designations and associated management practices, and for discussing any new management questions and the most current status information.

Monitoring results show that *Boechera pusilla* numbers have not returned to 1988 levels, but expanded climate review suggests that neither the 1988 monitoring year nor any during the past decade may be typical. There are two pieces of new information that are encouraging signs of a viable population. First is the existence of another subpopulation having a comparable number of flowering plants as that in the first, monitored subpopulation, even though it is in a much smaller area. Second is that 2011 plants seemed to have responded quickly to high spring moisture levels in nearly doubling the number of flowering stems and associated reproductive outlay. The patterns of decadal decline might be explained if climate conditions of the past decade have suppressed fruit production, and there is limited or no seed bank for replenishment.

The completion of the census phase (minimum of two more years at the two largest subpopulations) is needed to evaluate trends. A final monitoring report is to be prepared, and any monitoring needs identified. If *Boechera pusilla* numbers decline in 2012-2013 in the wake

of favorable 2011 conditions, it is recommended that intense demographic monitoring be established with on-site meteorological instrumentation.

The following outline of species questions is preliminary, for further discussion with natural resource professionals and with *Boechera* experts.

1. Expand monitoring to include demographic work if there are declining trends or no trend documented at the culmination of census work.
2. Determine karyology (chromosome number) and nearest relatives to understand origin and evolutionary significance
3. Evaluate reproduction modes (apomictic or mixed-mating) and monitor for pollination activity if appropriate after pursuing the above. This would be particularly important to know as it affects minimum viable population size.

Other tasks that have been identified include searchers for small outliers using 1994 GPS points (Appendix B) and establishing photopoints at the two monitored subpopulations. Regardless of *Boechera pusilla* trends, it is recommended that the BLM develop and adopt an addendum to the species habitat management plan that spells out a monitoring framework and execution plan. This framework would spell out a compliance checklist and an abbreviated checklist of *Boechera pusilla* plant attributes for BLM staff to inspect and record at appropriate intervals, with pre-identified thresholds that would trigger census work or other responses.

**Literature Cited**

Al-Shehbaz, I. A. 2003. Transfer of most North American Species of *Arabis* to *Boechera* (Brassicaceae). Novon 13: 381-391.

Al-Shehbaz, I.A. and M.D. Windham. 2010. *Boechera*. In: Flora of North America Editorial Committee, eds. 1993+. *Flora of North America North of Mexico*. Vol. 7. Magnoliophyta: Salicaceae to Brassicaceae. Oxford University Press, New York and Oxford. pp. 348-412.

Amidon, B. 1993. *Arabis pusilla* monitoring notes. Unpublished information in BLM Rock Springs Field Office. Rocky Springs, WY.

Bayley, R.W. 1965. Geologic map of the South Pass City quadrangle, Fremont County, Wyoming: U.S. Geol. Survey Geol. Quad. Map GQ-458, scale 1:24,000.

Bayley, R.W., P.D. Proctor and K.C. Condie. 1973. Geology of the South Pass Area, Fremont County, Wyoming. U.S. Geological Survey, Includes: Geologic map of the South Pass Area, Fremont County, Wyoming, 1:48:000.

Cramer, T. and R.L. Hartman. 1996. General floristic/sensitive plant species survey of the Upper Green River Basin, Wyoming, final report. Unpublished report prepared for the Bureau of Land Management by the Rocky Mountain Herbarium, University of Wyoming.

Dobes, C., M. Koch and T.F. Sharbel. 2006. Embryology, karyology, and modes of reproduction in the North American genus *Boechera* (Brassicaceae): a compilation of seven decades of research. Annals of the Missouri Botanical Garden 93(3): 517-534.

Dorn, R.D. 1988. Vascular Plants of Wyoming. Mountain West Publ., Cheyenne.

Dorn, R.D. 1990. Report on the status of *Arabis pusilla*, a candidate Threatened species. Prepared for the US Fish and Wildlife Service by Mountain West Environmental Services. Cheyenne, WY.

Dorn, R.D. 1992. Vascular Plants of Wyoming, second edition. Mountain West Publishing, Cheyenne, WY.

Dorn, R.D. 2001. Vascular Plants of Wyoming, third edition. Mountain West Publishing, Cheyenne, WY.

Dorn, R.D. 2002. Dismemberment of *Arabis*. *Castilleja* 21(1): 3.

Fertig, W. 1992a. Checklist of the vascular plant flora of the west slope of the Wind River Range and status report on sensitive plant species occurring in the Rock Springs District, Bureau of Land Management. Rocky Mountain Herbarium.

Fertig, W. 1992b. A floristic survey of the west slope of the Wind River Range, Wyoming. Unpublished Master's Thesis, University of Wyoming, Department of Botany.

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

Fertig, W. and R. Thurston. 2003. Modeling the potential distribution of BLM sensitive and USFWS Threatened and Endangered plant species in Wyoming. Report prepared for the BLM – Wyoming State Office by the Wyoming Natural Diversity Database, Laramie, WY.

Krostin, D and T.S. Christensen. 1980. Allotment management plant prepared for Pine Creek Allotment. USDI Bureau of Land Management.

Heidel, B. 2005. Status of *Boechera pusilla* (small rockcress) in Wyoming. Prepared for the Bureau of Land Management. Wyoming Natural Diversity Database, Laramie, WY.

Heidel, B. 2007. Wyoming plant species of concern. Wyoming Natural Diversity Database, Laramie, WY.

Heidel, B. 2011. Memo – *Boechera pusilla* seed collections. Email sent 11 July 2011 to Jennifer Ramp Neale, Denver Botanic Garden, cc: BLM, USFWS.

Higgins, W. 2012. Email information about *Arabis pusilla* seed propagation. Personal communication to Bonnie Heidel.

Jones, George P. 2004. Inventory and mapping of plant communities in the Sweetwater Canyon Wilderness Study Area, Fremont County, Wyoming. Unpublished report prepared for the Bureau of Land Management by the Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY.

Marriott, H.J. 1986. A report on the status of *Arabis pusilla*, a Candidate Threatened species. Prepared for the US Fish and Wildlife Service by the Wyoming Natural Diversity Database, Laramie, WY.

Marriott, H.J. 1988a. Appendix B. TES plant species monitoring programs, Rocky Springs District, BLM, from Draft Habitat Management Plan. Prepared for the Bureau of Land Management by the Wyoming Natural Diversity Database, Laramie, WY.

Marriott, H.J. 1988b. Appendix A. Draft habitat management plan for threatened, endangered and sensitive plant species and their habitats on the Rock Springs District, Bureau of Land Management. Prepared for the Bureau of Land Management by the Wyoming Natural Diversity Database, Laramie, WY.

Massatti, R.T. 2007. A floristic inventory of the East Slope of the Wind River Mountain Range and vicinity, Wyoming. MastersThesis. University of Wyoming, Laramie, WY.

Rocky Mountain Herbarium. 2008. Specimen On-line Database. Posted electronically at: http://www.rmh.uwyo.edu/.

Rollins, R.C. 1982. Studies on *Arabis* (Cruciferae) of western North America II. Contrib. Gray Herb. 212:103-114.

Rollins, R.C. 1983. Studies in the Cruciferae of western North America. Journal of Arnold Arboretum 64: 491-510.

Rollins, R.C. 1993. *The Cruciferae of Continental North America, Systematics of the Mustard Family from the Arctic to Panama*. Stanford Univ. Press, Stanford, CA. 976 pp.

Rushworth, D.A., B. Song, C. Lee and T. Mitchell-Olds. *Boechera,* a model system for ecological genomics. Molecular Ecology 20: 4843-4857. et al. 2011

USDA Natural Resources Conservation Service. 2012. Wyoming SNOWTEL sites – NRCS National Water and Climate Center. Posted electronically at: http://www.wcc.nrcs.usda.gov/snotel/Wyoming/wyoming.html .

USDI Bureau of Land Management, 1994. *Arabis pusilla* (small rockcress) habitat management plan, HMP WY-048-WHA-P1 and environmental assessment EA WY-048-EA-93-64. Green River Resource Area of Rock Springs District, BLM.

USDI Bureau of Land Management. 1995. Notice of proposed withdrawal and opportunity for public meeting; Wyoming. Federal Register Vol. 60, No. 235:62883.

USDI Bureau of Land Management. 2001. Bureau of Land Management (Wyoming) sensitive species policy and list. Information Bulletin No. WY-2001-040. BLM Wyoming State Office, Cheyenne, WY.

USDI Bureau of Land Management. 2002. Update of Bureau of Land Management (Wyoming) sensitive species list - 2002. Information Bulletin No. WY-2003-001. BLM Wyoming State Office, Cheyenne, WY.

USDI Bureau of Land Management. 2010. Wyoming Bureau of Land Management sensitive species policy and list; Instruction Memorandum No. WY-2010-027. BLM Wyoming State Office, Cheyenne, WY.

U.S. Fish and Wildlife Service. 2011. Endangered and Threatened Wildlife and Plants; 12-month finding on a petition to list *Abronia ammophila, Agrostis rossiae, Astragalus proimanthus, Boechera* (*Arabis*) *pusilla*, and *Penstemon gibbensii* as Threatened or Endangered; Proposed Rule. Federal Register 76(111): 33924-33965 posted 9 June.

USDI National Oceanic and Atmospheric Administration. 2006. Wyoming Climate Summaries. Posted electronically at: http://www.wrcc.dri.edu/summary/climsmwy.html

USDI National Oceanic and Atmospheric Administration. 2012. Western Regional Climate Center. Posted electronically at: http://www.wrcc.dri.edu/

Welp, L.A. 1997. A floristic survey of the Great Divide Basin, Green Mountains, and Upper Sweetwater Plateau in southwest Wyoming. Unpublished Master's thesis, University of Wyoming Botany Department, Laramie WY.

Weynand, B., and B. Amidon. 1990. An illustrated field guide to the sensitive plants of the Rock Springs District. Bureau of Land Management.

Windham, M.D. 2012. Email information about prior genetics work on *Boechera pusilla*. Personal communication to Bonnie Heidel.