Performance Report
For the Period July 1, 2015 through August 31, 2016

Agreement Number: L14AC00346

Title: BLM VFO Molecular Characterization of White River Beardtongue, *Penstemon Scariosus* var. *albifluvis*

Recipient Organization: Brigham Young University

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A. Goals and Accomplishments

Abstract:
This summary report is of what we have, and are still learning regarding *Penstemon scariosus,* with a focus on the variety *albifluvis*. Using our molecular markers developed for this study we found evidence that the traditional *P. scariosus* var. *albifluvis* may need to be returned to its original species taxonomic designation of *P. albifluvis*. It also must be pointed out that the broader *Penstemon scariosus* study is still on going. During the 2015 year of analyzing our data we discovered a putative *P. scariosus* population near Tabiona, Utah which was clearly unique by both measuring its morphological characteristics and with our molecular markers. Because we were so unsure of that unusual find we deliberately withheld those samples from the remaining samples used to arrive at the study results we are reporting here. Initially, we were concerned that there was an error in with the Tabiona samples. During the 2016 field season we returned to that region and collected well over an additional dozen sample locations and also collected additional population locations of *P. gibbensii* from across Wyoming and Colorado to assist us in our understanding of the Tabiona genotype in relationship to *P. scariosus* complex. These additional samples are being molecularly and statistically analyzed now. We believe we will be able to develop a scientifically peer reviewed paper later this year or early next year which will discuss the results reported here in context with what we are discovering now. During this study we also found that *P. fremontii* var. *glabrescens* should be a distinct species which we named *P. luculentus.*

Taxonomic Clarification of two *Penstemon* Species of the Uinta Basin of Colorado and Utah

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Introduction:

Noel Holmgren and others have stated that "*P. scariosus* exhibits a complex range of variability" (Holmgren, 1984; Neese and Atwood, 2008). Although, Neese and Atwood (2008) stated that variety *albifluvis* is more distinct than the three other reported members of this species. Curiously, it was originally described as a distinct species (England, 1982); however, in 1984 Noel Holmgren listed it as a variety of *P. scariosus* (Holmgren, 1984).

Variety *albifluvis* is found almost exclusively on the oil shale ledges of the Green River Formation. In the last few years, there has been an ever increasing interest in recovering the oil found in those formations (Robinson, 2007). Because of its unique limited habit and the increasing interest to recover the hydrocarbons found in this Green River Formation it was considered a candidate species for listing as an endangered species under the Endangered Species Act of 1973 (Ashe, 2013). To illustrate the potential clash between the oil shale recovery efforts and the preservation of *P. scariosus* var. *albifluvis* one only need to drive along Dragon Road south of Bonanza, UT (see photos of the exact opposite sides of the dirt road, Fig. 1A&B).

Collecting *Penstemon* for Study:

Early summer 2013 we initiated a study of *P. scariosus* by sampling tissue of eight unique plants from multiple locations across the range of the species (see Fig. 2). Early spring 2014 we searched multiple herbarium databases where we found records suggesting that *P. scariosus* geographic range was mildly larger than we had previously thought. In the Brigham Young University S. L. Welsh Herbarium samples, we found several curious *Penstemon* specimens labeled as *P. scariosus*. These specimens were from Piceance Basin, Colorado. The specimens were unusual for a couple of reasons. First, they were somewhat outside the well-documented range of *P. scariosus*; and, second, although they keyed out to *P. scariosus* using A Utah Flora, the specimens had hirtellous stems, a trait not found in *P. scariosus*. These observations were enough to have us include the Piceance Canyon region in our planned collections. We concluded that if these plants were indeed part of the *P. scariosus* complex they needed better characterization.

In addition to the unique Piceance Canyon population we also found several other populations of *P. scariosus* in Wyoming which we were unaware of. However, one new record of a *P. scariosus* population was unusual in that it was reported to be on the Book Cliffs ridge in Grand County, Utah. These old herbarium records were about 20 miles south of all known *P. scariosus* var. *albifluvis* populations. Furthermore, there were no other records of any other *P. scariosus* in over 50 miles of this putative remote population. Late June 2014 we collected one reblooming sample from this population and it keyed out as *P. scariosus* var. *albifluvis*.

We essentially completed our *P. scariosus* complex sample collections late spring and early summer 2014. We were assisted with the collections of *P. scariosus* var.

albifluvis by individuals connected with the BLM Vernal, UT office. In total, we collected material from 17 field locations of *P. scariosus* var. *albifluvis*, 8 of *P. scariosus* var. *cyanomontanus*, 25 of var. *garrettii*, 9 of var. *scariosus*, and 11 locations of the unusual *Penstemon* found in Piceance Canyon, Colorado.

To gain an improved understanding of the extent of the Book Cliff *P. scariosus* var. *albifluvis* population(s) we returned to that location in early June 2015. Following which we continued searching, wherever legally possible, for additional remote locations of this taxon across the entire range of the Book Cliffs. We were able to conduct an extensive survey along the Utah and Colorado Book Cliffs ridge for *P. scariosus* with the assistance of four BYU undergraduates and a small grant from Uinta County, Utah and Rio Blanco County, Colorado. In our search we found that the Book Cliffs *P. scariosus* var. *albifluvis* population extended along the ridge in Grand County, Utah, mostly on southern exposures with a few plants scattered on the very top of the ridge for approximately three air miles. Thousands of plants were found in a narrow band (from a few feet wide to upwards to ~100 ft. at the widest point) along a Green River shale geological formation for that distance. This geology is very similar to where this taxon has historically been found to occur, at lower elevations closer to the White River. We did not expect the population on the Book Cliffs to be so extensive. However, that was our only discovery of new/expanded *P. scariosus* var. *albifluvis* populations. For the remaining four days we searched, with no avail, on accessible sites following the Book Cliffs to their eastern terminus north of Rifle, Colorado. The only population of *P. scariosus* var. *albifluvis* encountered remained those already described above. The results of our search does not mean that there are no new populations to be discovered in this region. There may be populations on private land or tribal land where we were unable to access or on difficult to access public lands. However, it should also be noted that we did find habitat that looked to be ideal for *P. scariosus* var. *albifluvis* in several locations but when searched there were no plants found.

Clues of a Misclassified *Penstemon*:

After studying all of our Piceance Canyon samples morphology we realized that it was indeed unique compared to *P. scarious*. Furthermore, we learned that it had already been described as *P. fremontii* var. *glabrescens* (Dorn and Lichvar, 1990). However, this clarification came as a surprise in that we found *P. fremontii* var. *fremontii* within less than 100 yards of populations of variety *glabrescens* in Piceance Canyon. We were never able to locate any identifiable hybrids between the two taxa and they were easily distinguishable by their morphological characteristics. Moreover, their overall morphology reminded us more of *P. scariosus*, which is why it is not surprising that the BYU herbarium samples were identified as *P. scariosus* by their collectors rather than a variety of *P. fremontii*. Thus, with all these discoveries in mind we concluded that this taxon needed better characterization. Consequently, we decided to utilize our molecular tools to study this taxon (*P. fremontii* var. *glabrescens*) along with our *P. scariosus* samples.

***Penstemon* DNA "Fingerprinting":**

To best explain how we approached the DNA molecular studies of our samples we will use the analogy of "fingerprinting." That is, like human fingerprints, each individual plant has its own unique DNA "fingerprint" which can be studied. However, this "fingerprinting" analogy breaks down when we learn that it is impossible to tell who the parents of person are by comparing the fingerprint of a child to that of her parents, because, a fingerprint pattern is not inheritable. There simply is not a way to identify a family relationship by comparing the parents and their child's fingerprints. On the other hand, we can readily identify genetic relationships using DNA since we inherit half of our DNA "fingerprint" from our mother and the other half from our father. Therefore, our unique DNA "fingerprint" is an exclusive combination of half of our mothers DNA "fingerprint" and half or our fathers molecular "fingerprint."

The DNA "fingerprinting" technology we choose to develop and use in our *P. scariosus* study (Anderson et al., 2016; Johnson et al., 2016) is the same methodology used by the court system which can precisely demonstrate that the person was the perpetrator of a crime. It is also the same method that can be used to determine the paternity (father) of a person. There are two names which are used for this common molecular "fingerprinting" methodology, one name is, simple sequence repeats (SSRs), and the other name is "microsatellites." Each SSR (microsatellite) is a short DNA sequence found at a reliably specific location on a chromosome. The way we identify any given microsatellite, without error, is using a molecular biology laboratory procedure called a PCR (polymerase chain reaction). When we use the PCR procedure under the correct conditions, the resulting DNA fingerprints are relatively quickly deciphered when interpreted by someone trained in the field.

The first question we addressed in our DNA fingerprinting studies was the suspicious relationship between *P. fremontii* var. *fremontii* and variety *glabrescens*. Finding these two taxa, living within yards of each other, with no apparent hybrids between the two, as well as being able to readily morphologically distinguish between them, allowed us to set up a testable scientific hypothesis.

Study of the *P. fremontii* Varieties:

We learned that there is not a close genetic relationship between *P. fremontii* var. *fremontii* and var. *glabrescens*. Or for that matter, *P. fremontii* var. *glabrescens* is not closely related to any other suspected *Penstemon* of the region. Using our SSR fingerprint data as support, as well as our morphological observations, we concluded that this taxon should be considered a species in its own right. We presented the statistical results of all of our molecular studies, as well as a map, and related background information regarding the redefinition of this interesting taxon in a recently publish paper (Johnson et al., 2016). Because the name *P. glabrescens* has already been used for a *Penstemon* in southern Colorado and northern New Mexico we cannot elevate the variety name to a species for this taxon's name (Pennell, 1920). Therefore, we renamed it *P. luculentus*. This name is derived from the Latin word for "*luculentus,*" meaning brilliant or bright. The name was chosen to reflect the brilliant blue flower color, which is particularly striking in the field in contrast to the whitish or tan shale background typically associated with this species (Fig. 3A&B).

Results of the Study of the *P. scariosus* Complex:

Once we determined that *P. fremontii* var. *glabrescens* needed to be described as a distinct species we turned our attention to understand how various populations of the *P.*

scariosus complex were related to each other. Since the majority of our funding focus was on improving our understanding of the genetic diversity of *P. scariosus* var. *albifluvis* we secured samples at more sites across a smaller geographic range than the other members of the *P. scariosus* complex. However, our study did include samples from the known perimeter of *P. scariosus* along with samples interlaced throughout its range (Table 1; Fig. 2, 4, and 5).

Once securing our tissue samples we initiated the molecular and data analysis aspects of the study. We found that there were no clear delineations between varieties *cyanomontanus*, *garrettii*, and *scariosus*. That is, using the SSRs molecular markers, we could not find distinctive genetic population alignments with the present variety definitions with any sort of statistical confidence and the recognitions of var. *cyanomontanus* is questionable. Our data clearly agree with what Holmgren (1984) specifically suggested about distinguishing a variety with *cyanomontanus* morphological characteristics as a taxon was questionable. However, the SSR marker results clearly suggest that *P. scariosus* var. *albifluvis* is statistically more distinct from the rest of the *P. scariosus* complex. Our results also suggest that its closest relative may be *P. scariosus* accessions north of Roosevelt, Utah (Fig. 2 [sample #36]). Nevertheless, it is rather distinct compared to the rest of *P. scariosus*. However, even with these finding being so clear we are collaborating with Andi Wolfe, a recognized *Penstemon* authority from Ohio State University, to evaluate these same samples with a much more comprehensive molecular marker technique to see if these new test collaborate our results. When we complete both molecular testing methods, we are working on now we will prepare one, or more, manuscript(s) for peer review and publication in reputable scientific journal(s). It should be pointed out that in 2016 we collected very compelling evidence that there may be a new taxon that has traditionally been classified as either var. *garrettii* or var. *scariosus* in the region of Tabiona, UT. We have now collected many samples from a number of populations of these unusual *Penstemon* and their data will be included in future analysis of *Penstemon scariosus* and publications of those results.

To better visualize what we learned about the *P. scariosus* complex from our SSR marker data which we collected from 2013-15 we have created a map where each *P. scariosus* collection location is represented as a pie chart of the percent of shared, or distinctive aspects of their genetic relationships (Fig. 2). When comparing all of our samples to the presently named four varieties of *P. scariosus* we can statistically identify three related “groups” with significantly different genetic “fingerprints.” We assigned a color to each of those three groups (red, green, and blue [Fig. 2]). Using this visualization method, it becomes evident when studying this map that *P. scariosus* var. *albifluvis* is distinctive (the mostly green pie charts [Fig. 2]), both with its molecular fingerprint and its geographic isolation. We again performed the same statistical method (STRUCTURE) analyzing strictly the *P. scariosus* var. *albifluvis* accessions (Fig. 4) and a separate STRUCTURE analysis of the remaining *P. scariosus* samples (Fig. 5). The results of those analysis assisted us in “teasing out” a more refined understanding of the population genetic structures of the non *P. scariosus* var. *albifluvis* samples collected in 2013-15.

The dendrogram (Fig. 6) of our preliminary analysis clearly suggest that all varieties of *P. scariosus* and *P. gibbensii* are related to each other. Using the data that we have generated and analyzed thus far suggest that var. *albifluvis* is most closely related to var. *scariosus* and the southwestern accessions of var. *garrettii.* Variety *albifluvis* is more distantly related to the more eastern accessions of var. *garrettii*, all of var. *cyanomontanus* and *P. gibbensii* (Table 1 and Fig. 5). Additionally, our data suggest that there is a lower level of genetic diversity within var. *albifluvis* than the amount of diversity found within and between the three remaining putative varieties of *P. scariosus* (Fig. 2 and 5).

We are in the midst of a study of revisiting the question of how to use morphological characteristics to see if we can accurately distinguish between the historically defined remaining three varieties of the *P. scariosus* complex. If we are successful, in finding more definitive, than the presently used morphological plant characteristics, it would allow us to recommend a revision of the descriptions of the apparent varieties within *P. scariosus*. Our objective is to find morphological characteristics that more accurately reflects the results of our molecular study.

Finally, we should report on the identification of the unusual accessions we have collected in 2016 near Tabiona, UT. These samples are identified in the field by the fact that mature plants are rather robust, both in their leaf, and flower size, compared to the var. *garrettii* of the region. Because the "unknown" does key out to be *P. scariosus* it is a prominent hypothesis of ours that it may indeed be a member of *P. scariosus*; however, if it is a *P. scariosus*, it may be independent of all presently identified members of the species. We have collected over 15 accessions of this "unknown" *Penstemon* from the Red Creek area east of Fruitland on the southwestern corner to the community of Strawberry, UT on the southeastern corner to several miles east of Tabiona on northeastern corner and up all the canyons surrounding both Tabiona and Hanna, UT on the northwestern corner. At this time, we are unclear as to the true edges of this "unknown." All of the "unknown" samples have a very similar morphological appearance and a molecular marker fingerprint. We are working on the further understanding of the uniqueness of this new "unknown" *Penstemon*. We believe that the reason for this new "unknown" being previously overlooked is twofold. First, it clearly keys taxonomically out to be *P. scariosus* and second, it appears to be a very narrow endemic of the geography described above.

Conclusion:

Using multiple herbarium records, we were able to delineate where *P. scariosus* has been found historically. We drove thousands of miles and walked for many hours collecting samples from over 70 locations for genetic comparison. The study of the herbarium records and field samples led to the discovery of an important population of *P. scariosus* var. *albifluvis*, a problem with the classification *P. fremontii* var. *glabrescens* that suggested a need to be more carefully studied, and the discovery of a potentially new "unknown" *Penstemon* taxon. For this study we developed a special set of *Penstemon* SSR markers to study *P. scariosus* and *P. fremontii* DNA fingerprints which we published in a peer reviewed journal using solely undergraduate students (Anderson et al., 2016). Using these markers we found evidence that the traditional *P. scariosus* var. *albifluvis* may need best be treated as its original taxonomic designation of *P. albifluvis* (England, 1982). We also found that *P. fremontii* var. *glabrescens* (Dorn and Lichvar, 1990) was a distinct species which we named *P. luculentus.* We accomplished that study and published that peer reviewed article with the same undergraduates (Johnson et al., 2016). We are now working to identify how *P. scariosus*, *P. albifluvis*, *P. gibbensii*, and the new "unknown" *Penstemon* are all related to each other.

References:

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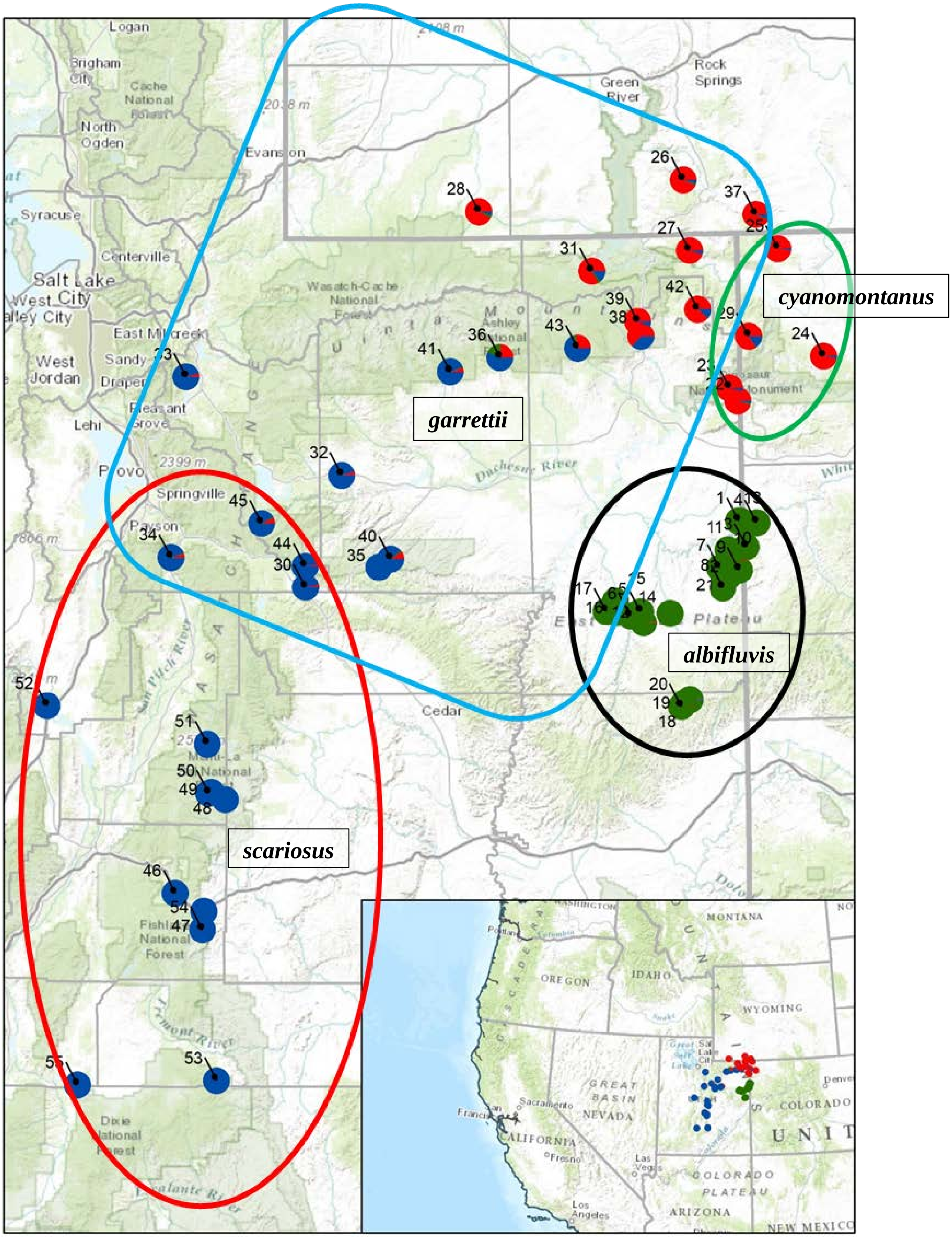
Figure 1A. *Penstemon scariosus* var. *albifluvis* is found among the brush and in the open areas on the east side of the road. Finding this plant so close to the edge of a road is unusual.

Figure 1B. Directly opposite of Fig. 1A (west side of road) is an oil shale research site. Note, that we expanded the view of the sign in the lower right of the photo so that it can be more easily read.

Figure 2. This map is of the northeastern corner of Utah and adjacent areas in Wyoming and Colorado (note the US location in lower left panel of the figure). The individual colored pie charts are where our 2013-2015 sample collections were made. These collections also represent the reported range of what has been described as *Penstemon scariosus*. The colors of the pie charts represent the percent of genetic diversity which we found in our study. The region outlined in black is considered to be where *P. scariosus* var. *albifluvis* is to be found. The region outlined in green is considered to be where *P. scariosus* var. *cyanomontanus* is to be found. The region outlined in blue is considered to be where *P. scariosus* var. *garrettii* is to be found. The region outlined in red is considered to be where *P. scariosus* var. *scariosus* is to be found. The key to each accession sample number is found in Table 1. Note that the green pie charts are essentially geographically isolated from all other *P. scariosus*.



garrettii
cyanomontanus
albifluvis
scariosus
Logan
Brigham City
North Ogden
Syracuse
Centerville
Salt Lake City
West Jordan
Draper
Lehi
Provo
Springville
Payson
Evanston
Green River
Rock Springs
Cedar
Duchesne River
Fremont River
MONTANA
OREGON
IDAHO
WYOMING
NEVADA
CALIFORNIA
COLORADO
ARIZONA
NEW MEXICO
COLORADO PLATEAU
GREAT BASIN
Sacramento
Fresno
Los Angeles
Las Vegas
Denver

Figure 3A. This photo represents a typical population of *Penstemon luculentus* (formally *P. fremontii* var. *glabrescens*) in the habitat where it is regularly found in Piceance Basin. The “brilliant” or “bright” blue blossoms against the tan shale background are normal for this species. Populations of this species can be found frequently along Highway 5 which takes off Highway 13 to enter the top of Piceance Canyon about 20 miles north of Rifle, CO.

Figure 3B. A close up photo of blossoms of *Penstemon luculentus* (formally *P. fremontii* var. *glabrescens*).

Table 1. The *Penstemon scariosus* samples and their identifications used in this study and their mapping coordinates.

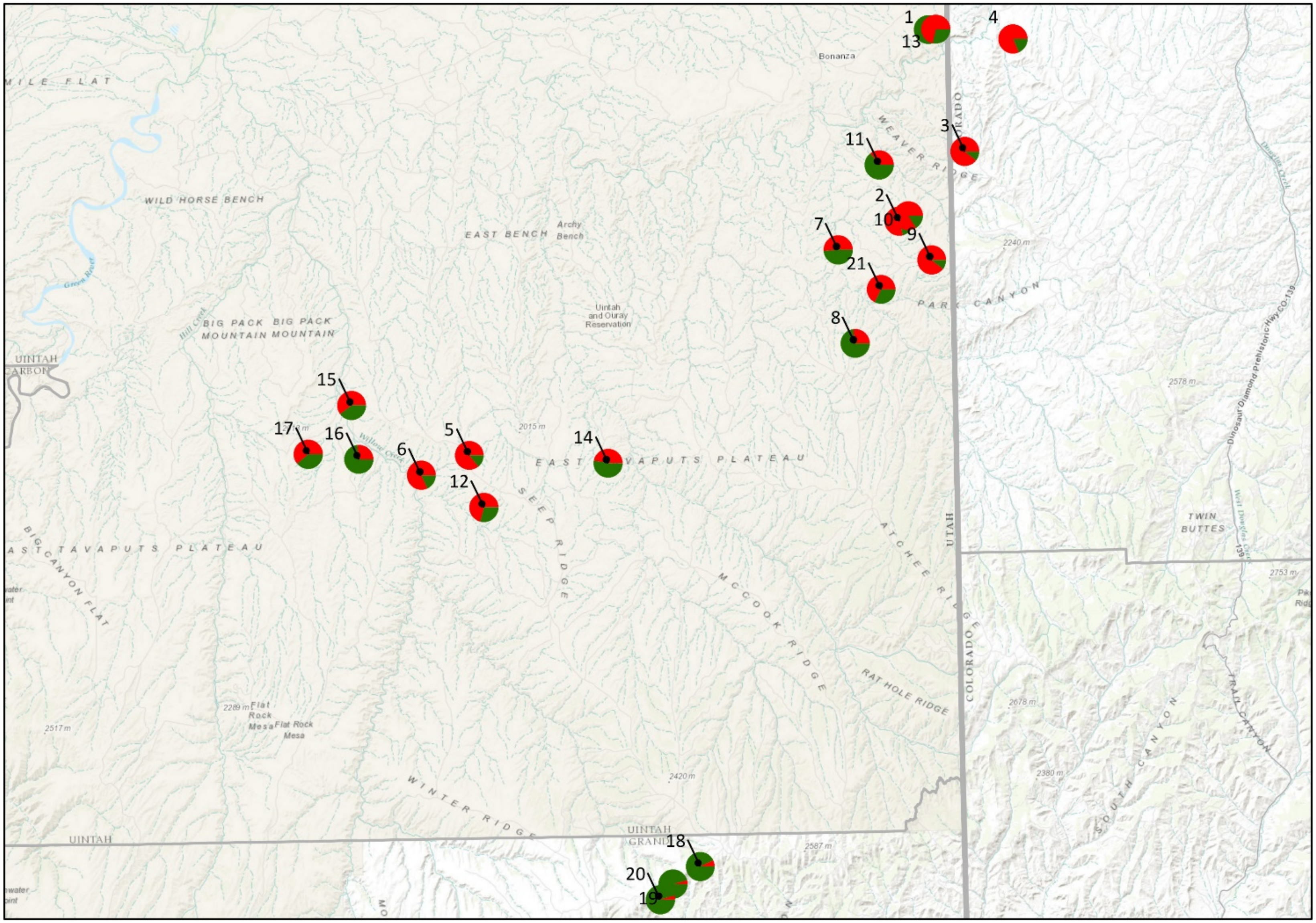
STRUCTURE ID[a]	Sample ID[b]	Location Name	Longitude	Latitude	Variety
1	Museum238757	East of Bonnanza, Uinta Co., UT, USA	-109.0685106	40.0358374	*albifluvis*
2	SCA014	Southeast of Bonnanza, Uinta Co., UT, USA	-109.0994667	39.8990500	*albifluvis*
3	CO-01	Bayless Pad Site, Uinta Co., UT, USA	-109.0370278	39.9480278	*albifluvis*
4	CO-02	(Finger Ridge) Bunte Point, Uinta Co., UT, USA	-108.9898513	40.0278961	*albifluvis*
5	UT-01	Buck Canyon, Uinta Co., UT, USA	-109.503127	39.7370932	*albifluvis*
6	UT-02	Willow Creek, Uinta Co., UT, USA	-109.547829	39.7234258	*albifluvis*
7	UT-03	Watson, Uinta Co., UT, USA	-109.1568024	39.8794561	*albifluvis*
8	UT-04	Atchees Ridge, Uinta Co., UT, USA	-109.1428611	39.8122222	*albifluvis*
9	UT-05	Rabbit Mount/Dragon RD, Uinta Co., UT, USA	-109.0700556	39.8707778	*albifluvis*
10	UT-06	No Name, Uinta Co., UT, USA	-109.0909722	39.9028611	*albifluvis*
11	UT-07	Hells Hole Road, Uinta Co., UT, USA	-109.1169167	39.9397500	*albifluvis*
12	UT-08	Sunday School, Uinta Co., UT, USA	-109.4903486	39.6996887	*albifluvis*
13	SWCA-01	White River North, Uinta Co., UT, USA	-109.0614922	40.0360149	*albifluvis*
14	SWCA-02	Bitter Creek, Uinta Co., UT, USA	-109.3742796	39.7297946	*albifluvis*
15	SWCA-03	Willow Creek, Uinta Co., UT, USA	-109.6115463	39.7742903	*albifluvis*
16	SWCA-04	Upper Agency Draw, Uintah Co., UT, USA	-109.6055909	39.7355881	*albifluvis*
17	SCA029	Along JP Man RD, Uinta Co., UT, USA	-109.65245	39.7397833	*albifluvis*
18	SCA036	Book Cliffs Ridge, Grand Co., UT, USA	-109.29595	39.4395833	*albifluvis*
19	SCA052	Book Cliffs Ridge, Grand Co., UT, USA	-109.32149	39.4273100	*albifluvis*
20	SCA053	Book Cliffs Ridge, Grand Co., UT, USA	-109.33345	39.4163200	*albifluvis*
21	SCA054	Along Dragon RD, Uinta Co., UT, USA	-109.11768	39.8505400	*albifluvis*
22	SCA009	Blue Mountain, Uinta Co., UT, USA	-109.06105	40.4383333	*cyanomontanus*
23	SCA010	Blue Mountain, Uinta Co., UT, USA	-109.09585	40.4820833	*cyanomontanus*
24	SCA011	Along Douglas MT RD, Moffat Co., CO, USA	-108.6786833	40.5811167	*cyanomontanus*
25	SCA012	Diamond Peak, Moffat Co., CO, USA	-108.86855	40.9457667	*cyanomontanus*
26	SCA040	North of Little Mountain Peak, Sweetwater Co., WY, USA	-109.2810333	41.1828833	*garrettii*

STRUCTURE ID[a]	Sample ID[b]	Location Name	Longitude	Latitude	Variety
27	SCA043	Goslin Mountain, Daggett Co., UT, USA	-109.2597667	40.9456833	*garrettii*
28	SCA044	North of Lone Tree, Uinta Co., WY, USA	-110.1887	41.0861500	*garrettii*
29	SCA047	Oilfield Reservoir area, Moffat Co., CO, USA	-109.00685	40.6541500	*garrettii*
30	SCA008	Price Canyon, Utah Co., UT, USA	-110.9577667	39.8286667	*garrettii*
31	SCA013	South of Manila, Daggett, Co., UT, USA	-109.69263	40.8822500	*garrettii*
32	SCA015	East of Fruitland, Duchesne Co., UT, USA	-110.7992	40.2043500	*garrettii*
33	SCA016	Midway, Wasatch Co., UT, USA	-111.4827	40.5342167	*garrettii*
34	SCA018	Northeast of Birdseye, Utah, Co., UT, USA	-111.5436	39.9272167	*garrettii*
35	SCA034	Argyle Canyon, Duchesne Co., UT, USA	-110.6385333	39.8956333	*garrettii*
36	SCA035	Northwest of Whiterocks, Duchesne Co., UT, USA	-110.1016833	40.5958667	*garrettii*
37	SCA039	Pine Mountain, Sweetwater Co., WY, USA	-108.9625	41.0618167	*garrettii*
38	SCA041	along HWY 191 North of Vernal, Uintah Co., UT, USA	-109.4805833	40.6615000	*garrettii*
39	SCA042	along HWY 191 North of Vernal, Uintah Co., UT, USA	-109.4939	40.7115167	*garrettii*
40	SCA045	Sowers Canyon, Duchesne Co., UT, USA	-110.5871333	39.9226333	*garrettii*
41	SCA046	Southwest of McKune Lake, Duchesne Co., UT, USA	-110.3212333	40.5501333	*garrettii*
42	SCA048	Head of Warner Draw, Uintah Co., UT, USA	-109.2282167	40.7480167	*garrettii*
43	SCA049	Red Cloud Loop, Uintah Co., UT, USA	-109.7607667	40.6246500	*garrettii*
44	SCA050	Cat Peak, Utah/Wasatch Co., UT, USA	-110.9594333	39.8991000	*garrettii*
45	SCA051	Willow Creek Guard Station area, Wasatch Co., UT, USA	-111.1497667	40.0433833	*garrettii*
46	SCA001	Along Meadow Creek, Sevier Co., UT, USA	-111.51715	38.8006667	*scariosus*
47	SCA002	Post Hollow South of Emery, Sevier Co., UT, USA	-111.3941167	38.7402333	*scariosus*
48	SCA004	West of Ferron, Sanpete Co., UT, USA	-111.3036	39.1150167	*scariosus*
49	SCA005	Further West of Ferron, Sanpete Co., UT, USA	-111.36415	39.1406667	*scariosus*
50	SCA006	Further West of Ferron, Sanpete Co., UT, USA	-111.375311	39.1368690	*scariosus*
51	SCA007	West of Orangeville, Sanpete Co., UT, USA	-111.38229	39.3021200	*scariosus*
52	SCA017	North of Scipio, Juab Co., UT, USA	-112.0759167	39.4259833	*scariosus*

STRUCTURE ID[a]	Sample ID[b]	Location Name	Longitude	Latitude	Variety
53	SCA030	South of Grover, Wayne Co., UT, USA	-111.3486667	38.1806500	*scariosus*
54	SCA031	Near Deer Peek South of Emery, Sevier Co., UT, USA	-111.4000333	38.6787833	*scariosus*
55	SCA032	Northeast of Antimony, Piute Co., UT, USA	-111.9275	38.1545833	*scariosus*
56	COM001	Near Spring Canyon, Sevier Co., UT, USA	-111.5487667	38.8608667	*comarrhenus*
57	SCA003	Geyser Peak, Sevier Co., UT, USA	-111.46215	38.5119500	*scariosus*
58	CMP001	Tony Grove, Cache Co., UT, USA	-111.6474	41.9040500	*compactus*
59	CYN001	Tony Grove, Cache Co., UT, USA	-111.6496667	41.9043167	*cyananthus*
60	GIB001	Browns Park, Daggett Co., UT, USA	-109.0498	40.8469833	*gibbensii*
61	STR001	Diamond Peak, Moffat Co., CO, USA	-108.8631333	40.9418333	*strictus*
62	STR002	Black Sulfur Creek area, Rio Blanco Co., CO, USA	-108.48805	39.7663833	*strictus*
63	SUB001	Top of Ferron Canyon, Sanpete Co., UT, USA	-111.375311	39.1368690	*subglaber*
64	SUB002	Near Francis, Summit Co., UT, USA	-111.1703333	40.5610500	*subglaber*

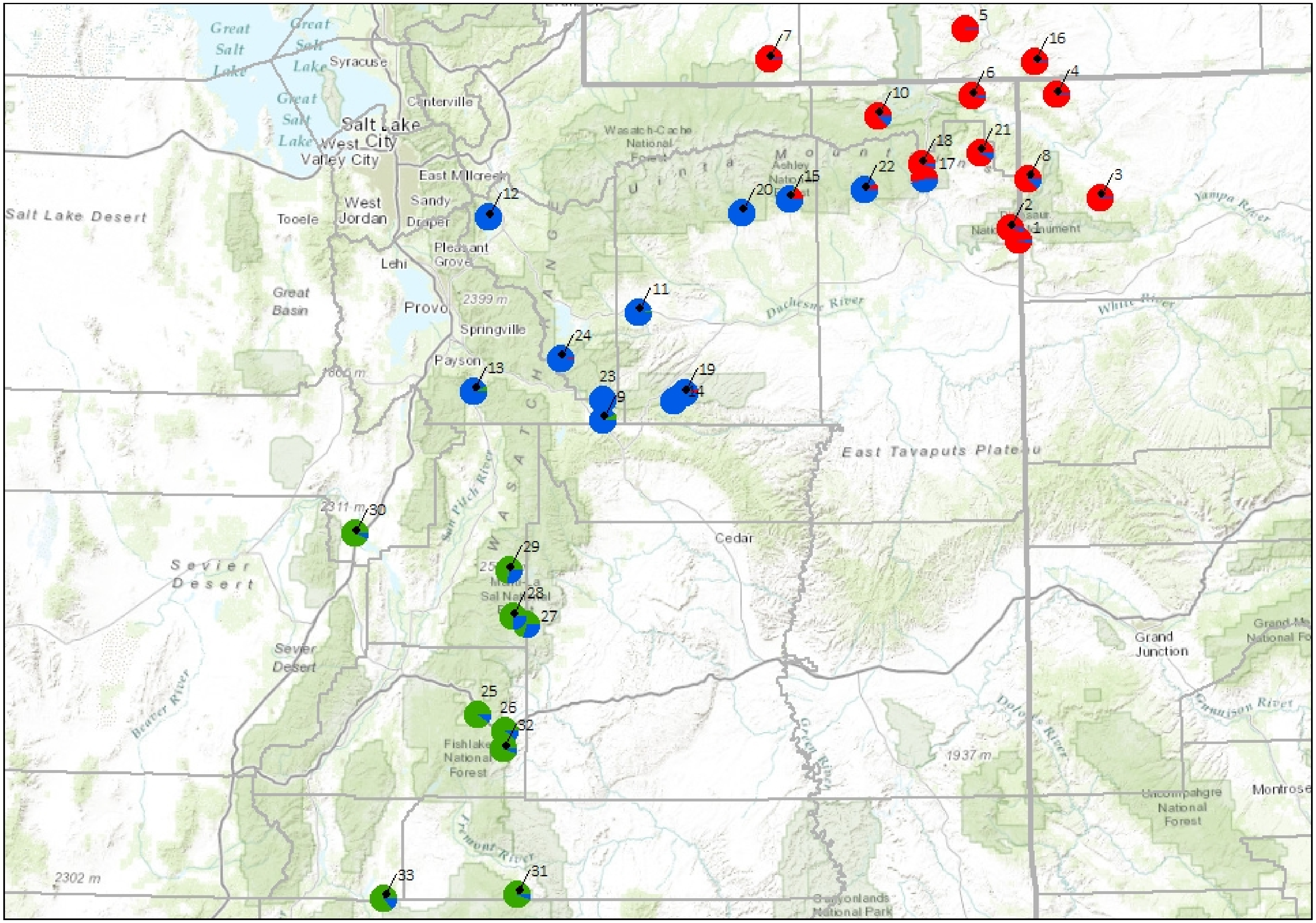
[a] The “STRUCTURE ID” is the number used to identify these samples in Figures 4 and 5.
[b]The “Sample ID” is used to identify these samples in Figure 6.

Figure 4. This map is of the region of the Uinta Basin of Utah and adjacent area of Colorado (it is the expanded area of the green pie charts found in Fig. 2). The individual colored pie charts are where the samples of *P. scariosus* var. *albifluvis* were made. These collections also represent the reported range of what has been described as *Penstemon scariosus* var. *albifluvis*. The colors of the pie charts represent the percent of genetic diversity which we found within only var. *albifluvis* in our study. Note that the green and red pie charts are essentially scattered across region. These preliminary data are suggesting that there are no real genetically unique populations of *P. scariosus* var. *albifluvis*. The key to each accession sample number is found in Table 1.



1
13
4
Bonanza
3
11
2
10
9
7
21
8
15
17
16
6
5
12
14
18
20
19
MILE FLAT
WILD HORSE BENCH
EAST BENCH
Archy Bench
Uintah and Ouray Reservation
BIG PACK MOUNTAIN
BIG PACK MOUNTAIN
UINTAH
WEAVER RIDGE
PARK CANYON
EAST TAVAPUTS PLATEAU
SEEP RIDGE
BIG CANYON FLAT
ATCHEE RIDGE
MCCOOK RIDGE
RAT HOLE RIDGE
Flat Rock Mesa
WINTER RIDGE
UINTAH
UTAH
COLORADO
TWIN BUTTES
SOUTH CANYON
TRAIL CANYON
2240 m
2578 m
2015 m
2289 m
2517 m
2420 m
2587 m
2678 m
2380 m
2753 m

Figure 5. Essentially this map is the same as Fig. 2, except it is missing the *P. scariosus* var. *albifluvis* sample accessions. This map focuses on the genetic diversity found in the accessions collected of the traditionally described as *P. scariosus* var. *cyanomontanus*, var. *garrettii* and var. *scariosus*. These collections also represent the reported range of these varieties of *Penstemon scariosus*. The colors of the pie charts represent the percent of genetic diversity which we found within and between these taxa. Note that the color distribution of these pie charts do represent more closely the traditional geographic regions of the varieties of *P. scariosus* which are reported by Holmgren (1984) and Neese and Atwood (2008). The key to each accession sample number is found in Table 1.



Great Salt Lake
Syracuse
Centerville
Salt Lake City
West Valley City
East Millcreek
West Jordan
Sandy
Draper
Tooele
Salt Lake Desert
Lehi
Pleasant Grove
Great Basin
Provo
2399 m
Springville
Payson
1860 m
Wasatch-Cache National Forest
Ashley National Forest
Uinta Mountains
Duchesne River
Yampa River
White River
Dinosaur National Monument
East Tavaputs Plateau
Cedar
Sevier Desert
2311 m
San Pitch River
Manti-La Sal National Forest
Sevier Desert
Beaver River
Fishlake National Forest
Fremont River
2302 m
Green River
1937 m
Dolores River
Gunnison River
Grand Junction
Grand Mesa National Forest
Uncompahgre National Forest
Montrose
Canyonlands National Park
1
2
3
4
5
6
7
8
9
10
11
12
13
14
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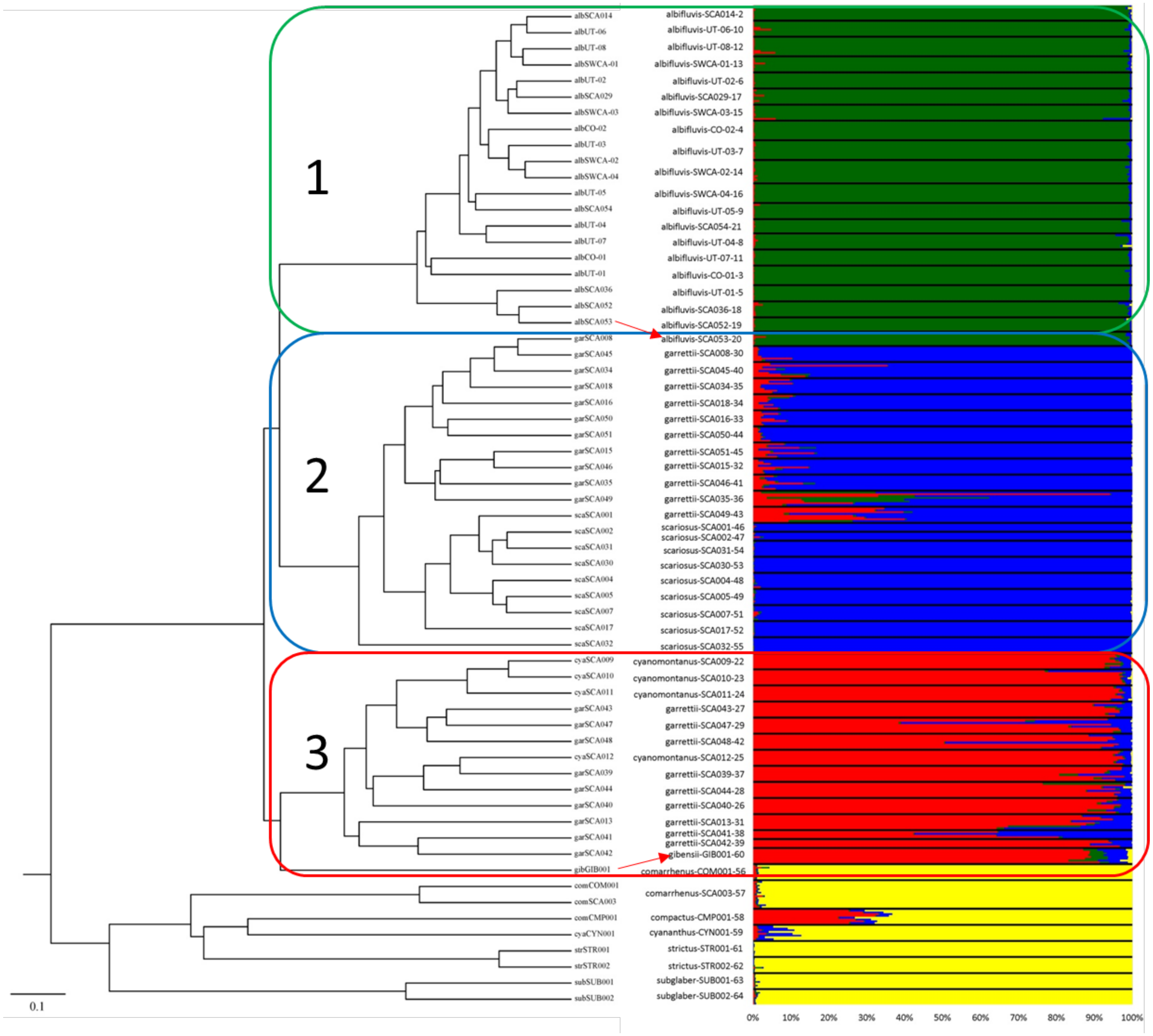
Figure 5.
The key to each *Penstemon scariosus* accession sample represented in this dendrogram is found in Table 1. There are three “boxed” sections of this dendrogram. Box 1 (the green box) represent all, and only, the accessions collected of var. *albifluvis* (see Fig. 2, and 4). Box 2 (the blue box) represents the samples of *P. scariosus* from the southern portion of the range (see Fig. 2, and 4) of this species with includes all of traditionally classified as var. *scariosus* and the southern portion of those classified as var. *garrettii*. Finally, Box 3 (the red box) includes the north eastern accessions (see Fig. 2, and 4) of the traditionally classified var. *garrettii*, all of var. *cyanomontanus* and it includes our one sample of *P. gibbensii*.


1
2
3
albSCA014
albUT-06
albUT-08
albSWCA-01
albUT-02
albSCA029
albSWCA-03
albCO-02
albUT-03
albSWCA-02
albSWCA-04
albUT-05
albSCA054
albUT-04
albUT-07
albCO-01
albUT-01
albSCA036
albSCA052
albSCA053
garSCA008
garSCA045
garSCA034
garSCA018
garSCA016
garSCA050
garSCA051
garSCA015
garSCA046
garSCA035
garSCA049
scaSCA001
scaSCA002
scaSCA031
scaSCA030
scaSCA004
scaSCA005
scaSCA007
scaSCA017
scaSCA032
cyaSCA009
cyaSCA010
cyaSCA011
garSCA043
garSCA047
garSCA048
cyaSCA012
garSCA039
garSCA044
garSCA040
garSCA013
garSCA041
garSCA042
gibGIB001
comCOM001
comSCA003
comCMP001
cyaCYN001
strSTR001
strSTR002
subSUB001
subSUB002
0.1
albifluvis-SCA014-2
albifluvis-UT-06-10
albifluvis-UT-08-12
albifluvis-SWCA-01-13
albifluvis-UT-02-6
albifluvis-SCA029-17
albifluvis-SWCA-03-15
albifluvis-CO-02-4
albifluvis-UT-03-7
albifluvis-SWCA-02-14
albifluvis-SWCA-04-16
albifluvis-UT-05-9
albifluvis-SCA054-21
albifluvis-UT-04-8
albifluvis-UT-07-11
albifluvis-CO-01-3
albifluvis-UT-01-5
albifluvis-SCA036-18
albifluvis-SCA052-19
albifluvis-SCA053-20
garrettii-SCA008-30
garrettii-SCA045-40
garrettii-SCA034-35
garrettii-SCA018-34
garrettii-SCA016-33
garrettii-SCA050-44
garrettii-SCA051-45
garrettii-SCA015-32
garrettii-SCA046-41
garrettii-SCA035-36
garrettii-SCA049-43
scariosus-SCA001-46
scariosus-SCA002-47
scariosus-SCA031-54
scariosus-SCA030-53
scariosus-SCA004-48
scariosus-SCA005-49
scariosus-SCA007-51
scariosus-SCA017-52
scariosus-SCA032-55
cyanomontanus-SCA009-22
cyanomontanus-SCA010-23
cyanomontanus-SCA011-24
garrettii-SCA043-27
garrettii-SCA047-29
garrettii-SCA048-42
cyanomontanus-SCA012-25
garrettii-SCA039-37
garrettii-SCA044-28
garrettii-SCA040-26
garrettii-SCA013-31
garrettii-SCA041-38
garrettii-SCA042-39
gibensii-GIB001-60
comarrhenus-COM001-56
comarrhenus-SCA003-57
compactus-CMP001-58
cyananthus-CYN001-59
strictus-STR001-61
strictus-STR002-62
subglaber-SUB001-63
subglaber-SUB002-64
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

B. Work Schedule

Completed.

C. Budget Information

Already reported.

D. Planned Activity for Next Reporting Period

No further reporting periods planned. We are working on expanding how we are look at the samples collected and placing them into perspective with additional samples we collected in 2016. Our objective is to prepare one or more peer reviewed publications on the data reported here in combination with the additional data we have collected.