2008 Status Report
Demographic Monitoring and Pollination Biology
for
Penstemon scariosus var. *albifluvis* and *Penstemon grahamii*
in Uintah County, Utah

Prepared for:
Ron Bolander
Bureau of Land Management
Utah State Office
P.O. Box 45155
Salt Lake City, UT 84145-0155


Penstemon scariosus var. *albifluvis*


Penstemon grahamii

Prepared by:
Rita Dodge, Conservation Director
Wendy Yates, Botanist
Red Butte Garden and Arboretum
285 Connor Rd.
Salt Lake City, UT 84113

This annual report summarizes research conducted on *Penstemon scariosus* var. *albifluvis* (White River Penstemon) and *Penstemon grahamii* (Graham's Penstemon). This is the fifth consecutive year that this study has been conducted by Red Butte Garden and results are presented for all five years. Research was conducted during the peak flowering season of both species, typically from the middle of May through mid June. This research project includes 3 studies: 1) demographic study for both species; 2) pollination study for *P. grahamii*; and 3) survey for *P. grahamii.* Additionally, Dr. Vincent Tepedino conducted pollinator observations for *P. grahamii*, and his original report is included as Appendix C.

Demographic Study

Penstemon scariosus var. *albifluvis* (White River Penstemon)

The study area included two populations, called the White River site located on Bureau of Land Management property, and the Watson site located on private property. A detailed description of methodology can be found in the 2004 annual report. Tagged individuals were relocated using a metal detector and data recorded per individual plant. Data collected included the woody base diameter, number of flowering individuals, height of tallest inflorescence, number of flowers per inflorescence, number of fruit per inflorescence, number of fruiting individuals, and herbivory. We measured the diameter of the woody base of *P. scariosus var. albifluvis* to the nearest 0.5 cm. Table 1 summarizes demographic characteristics of the White River site over a five year monitoring period. Table 2 summarizes demographic characteristics of the Watson site for 2004 and 2008. The Watson site was not accessible each year, therefore only the results of the first and present years are presented.

In the 2004 to 2007 annual reports, we recorded a category named "tag no plant" (TNP), which referred to tags found within the plot where there was no longer a plant. This category was created because it was unknown if these plants could remain dormant for a period of time or if they had died. After 5 years, data suggest the plants originally reported as TNP are in fact dead, and are henceforth categorized as dead. This change is reflected in the current report; however, the 2004 - 2007 reports still have the TNP category. In order to provide an accurate comparison across years, the summaries in Tables 1 and 2 show the previous TNP results recalculated as the number of individual's dead for all years at the White River and Watson sites.

At the White River site, total number of live individuals found within our plots has declined by 36%, from 135 individuals in 2004 to 86 in 2008. Annual survivorship of *P. scariosus* var. *albifluvis* at the White River site was found to be the lowest in 2007 with 78.4% and the highest in 2006 with 94.6%. Of the original 135 plants located in 2004, only 56.3% individuals remain alive in 2008. This year a high number of individuals were not relocated due to the loss of tags. Tags have been lost annually due to the unstable substrate, soil movement, and possible animal activity. Some of the loose tags were found near the river, while others may have fallen into the river. Both the inflorescence height and the average woody caudex diameter, an indicator of age and size class, have increased steadily each year. This indicates that those individuals which are surviving are also continuing to grow.

In 2006, 48.2% of the plants reported herbivory, while in 2008 only 18.6% of the plants were affected. It appears that herbivory was caused by both insects and animals. At the White River site insects seem to be more prevalent.   While at the Watson site there is indication of heavy grazing by animals. However, the animals eating the plants have not been identified. It is possible that rabbits and small rodents are responsible for herbivory. Only 10 new recruitments have been added to the study at this site over the past 4 years. However, 96.5% individuals flowered this year and 95.3% individuals produced fruit. The amount of fruit developed this year was much greater than results of the past four years. Hopefully, this will lead to an increase in the number of seedlings allowing new individuals to be added to the study.

This year we were able to continue monitoring at the Watson site. As noted in the 2006 report we did not have permission from the private land owners to collect data in 2006 and 2007. Between the years 2004 and 2008 the Watson population records a survivor rate of 32.2%, and 33 new individuals have been added to the study. Herbivory was 72.5% in 2008, which is much higher than the White River site. In 2008, 71.4% flowered and 68% produced fruit. Both of these results are lower percents than what was found at the White River location. The cause of this is unknown, however, the Watson location may be dealing with more environmental impacts related to energy development, which may decrease the possibility for pollinators to pollinate and increase the opportunity for herbivory.

Table 1. Summary of *P. scariosus* var. *albifluvis*, status over 5-year monitoring period at White River population.

White River Site	2004	2005	2006	2007	2008
Total # of Individuals Alive (includes new tags)	135	111	116	91	86
New Individuals Tagged	135	0	10	0	0
# of Individuals not relocated	n/a	11	8	24	26
# of Individuals Dead	n/a	13	9	10	2
Percent Mortality	n/a	9.6	8.1	8.6	2.2
Percent Survivorship	n/a	82.2	95.6	78.4	94.5
Percent Herbivory	37	32.4	48.2	38.4	18.6
% of Individuals with Flowers	42	87.3	81.8	96.7	96.5
% of Individuals with Fruit	17	75.6	69	57	95.3
Average Fruit per Inflorescence	0.8	9.5	n/a	6.5	11.3
Average Inflorescence Height	18.1cm	25.2cm	20.0cm	28.3cm	31.6cm
Average Woody Caudex Diameter	4.0cm	4.0cm	4.2cm	4.7cm	7.5cm

Table 2. Summary of *P. scariosus* var. *albifluvis*, status for 2004 and 2008 monitoring years at Watson population.

Watson Site	2004	2008
Total # of Individuals Alive (includes new tags)	180	91
New Individuals Tagged	180	33
# of Individuals not relocated	n/a	104
# of Individuals Dead	n/a	18
Percent Mortality	n/a	10
Percent Survivorship	n/a	32.2
Percent Herbivory	n/a	72.5
% of Individuals with Flowers	25	71.4
% of Individuals with Fruit	18.8	68
Average Fruit per inflorescence	n/a	6.6
Average Inflorescence Height	10.5cm	19cm
Average Woody Caudex Diameter	3.2cm	6cm

Growth rates, as measured the diameter of the woody caudex, were monitored and results include 155 plants surviving between 2004 and 2008, from the White River and

Watson sites combined. 67% increased in size class. Only 8% decreased to a smaller size class, and 25% remained the same size class (Table 3). The majority of plants range in size from 0.5-4.5cm diameter of woody caudex. Combined results indicate that the majority of the surviving plants are also continuing to grow.

Table 3. Movement between basal size classes from 2005 to 2007 comparing *P.scariosus* populations as measured by diameter of woody caudex. Size classes: small = 0-2.5cm, medium = 3.0 -4.5cm, large = 5.0-6.5cm, xlarge=7.0cm+

size class	White River (cm)	Watson (cm)
small to small	0	5
small to medium	6	14
small to large	3	5
small to xlarge	9	13
medium to small	1	5
medium to medium	3	10
medium to large	12	1
medium to xlarge	21	8
large to small	0	0
large to medium	1	1
large to large	3	5
large to xlarge	7	5
xlarge to small	0	0
xlarge to medium	2	1
xlarge to large	0	1
xlarge to xlarge	9	4
Total increases	**58 (75%)**	**46 (59%)**
Total decreases	**4 (5%)**	**8 (10%)**
Total no change	**15 (19%)**	**24 (31%)**

***Penstemon grahamii* (Graham's Penstemon)**

The *P. grahamii* populations included two sites called the Buck Canyon site and the Blue Knoll/Seep Ridge site, both located on BLM land. A detailed description of methodology can be found in the 2004 annual report. Tagged individuals were relocated using a metal detector and data recorded per individual plant. Data collected included the rosette diameter, number of inflorescences, height of inflorescence, number of flowers per inflorescence, number of fruiting individuals, and herbivory. If there was more than one rosette per tag, diameters were summed for the total rosette diameter.

Table 4 summarizes demography of the Buck Canyon population, and Table 5 summarizes demography of Blue Knoll/Seep Ridge population.

In the 2004 to 2007 annual reports, we recorded a category named "tag no plant" (TNP), which referred to tags found within the plot where there was no longer a plant. This category was created because it was unknown if these plants could remain dormant for a period of time or if they had died. After 5 years, data suggest the plants originally reported as TNP are in fact dead, and are henceforth categorized as dead. This change is reflected in the current report; however, the 2004 - 2007 reports still have the TNP category. In order to provide an accurate comparison across years, the summaries in Tables 4 and 5 show the previous TNP results recalculated as the number of individual's dead for all years at the Buck Canyon and Blue Knoll/Seep Ridge sites.

Survivorship at the Buck Canyon site was the highest recorded to date at 90.9%, while mortality was the lowest at 6% in 2008. Herbivory was relatively low at 11%, compared to a previous high of 31% in 2006. The low herbivory for this year was influenced by the number of flowering individuals protected with mesh and wire cages used in the pollination study. This year 30.5% individuals produced flowers and 25% individuals produced fruit. This is the highest fruit and flower production reported over the past five years.

The Blue Knoll/Seep Ridge site recoded 82.6% survivorship in 2008, while in 2007 the survivorship rate was 47.4%. Herbivory in 2008 at 19.6%, compared to the highest in 2004 at 50.7%. Herbivory for this year was influenced by the number of flowering individuals protected with mesh and wire cages used in the pollination study. 30.7% of individuals produced flowers, the highest since 2004, and 27.3% developed fruit, the highest observed over the past five years. Data for both sites can fluctuate greatly from year to year, though trends remain similar between the two sites. As shown in Figure 1, survivorship trends follow the same patterns of increases and decreases annually, and are likely influenced by the same factors.

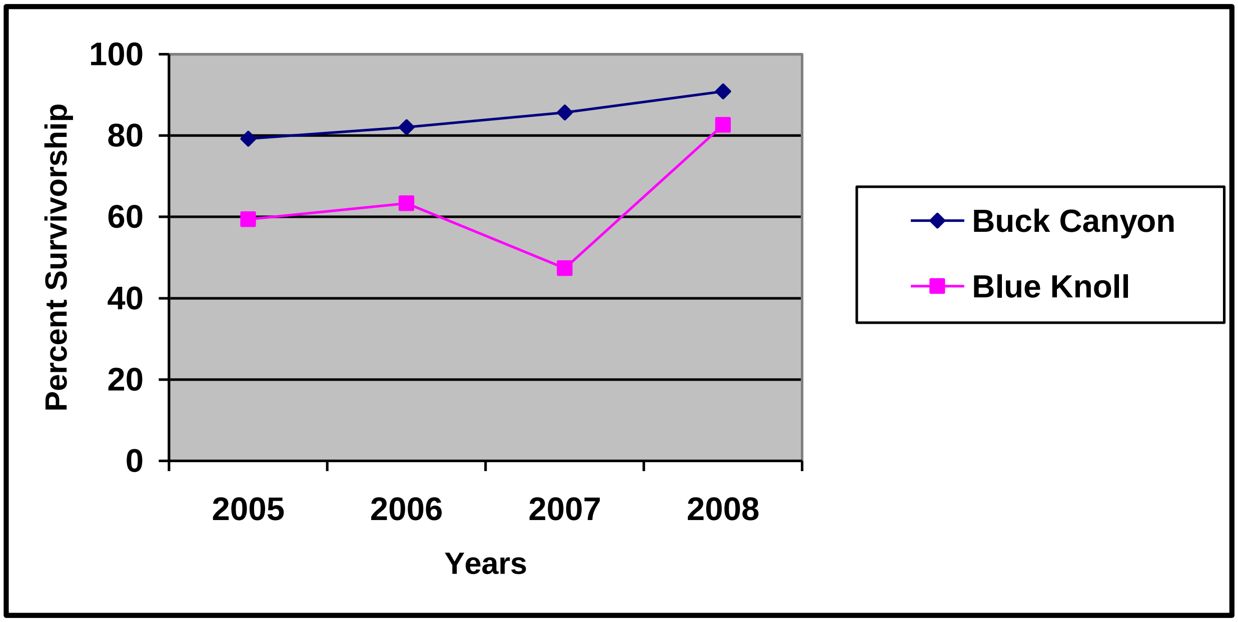
Table 4. Summary of *P. grahamii* status over 5-year monitoring period at Buck Canyon population.

Buck Canyon	2004	2005	2006	2007	2008
Total # of Individuals Alive (includes new tags)	77	84	77	66	72
New Individuals Tagged	77	23	8	0	12
# of Individuals not relocated	n/a	1	5	8	9
# of Individuals Dead	n/a	8	13	16	4
Percent Mortality	n/a	10.3	17.8	20.7	6
Percent Survivorship	n/a	79.2	82.1	85.7	90.9
Percent Herbivory	35	4.7	31	13.6	11
% of Individuals with Flowers	27	4.7	0	15.2	30.5
% of Individuals with Fruit	6.5	0	0	4.5	25
Average Fruit per Inflorescence	2	0	0	2.7	5.3
Average Inflorescence Height	3.7cm	2.5cm	n/a	5.6cm	6cm
Average Rosette Diameter	n/a	4.6cm	3.8cm	4.3cm	4.1cm

Table 5. Summary of *P. grahamii* plant status over 5-year monitoring period at Blue Knoll population.

Blue Knoll	2004	2005	2006	2007	2008
Total # of Individuals Alive (includes new tags)	69	71	59	52	66
New Individuals Tagged	69	30	12	24	23
# of Individuals not relocated	n/a	3	12	31	26
# of Individuals Dead	n/a	25	18	24	15
Percent Mortality	n/a	36.2	25.3	32.2	30.7
Percent Survivorship	n/a	59.4	66.2	47.4	82.6
Percent Herbivory	50.7	18.3	40.6	11.5	19.6
% of Individuals with Flowers	44	18	0	15	30.7
% of Individuals with Fruit	4.3	5.7	0	9.6	27.3
Average Fruit per Inflorescence	2.1	1.1	0	3.8	6.6
Average Inflorescence Height	6.1cm	2.3cm	n/a	7.9cm	6.8cm
Average Rosette Diameter	n/a	6.8cm	4.8cm	4.6cm	5cm

Figure 1. Survivorship trends of *P. grahamii* at Buck Canyon and Blue Knoll populations.



Starting in 2005 and continuing through 2008 we measured the diameter of individual rosettes to the nearest 0.5cm in addition to recording the number of rosettes. Diameters were summed when there was more than one rosette. The size-frequency distributions should not be used to draw conclusions on a size-reproduction correlation because we continue to have too little flowering data in either plot at this time. The majority of *P. grahamii* individuals range in size from 0.5-4.5cm in basal rosette diameter. Combined data from both sites shows that 29% of the individuals declined in plant size class from 2005 to 2008. 35% increased size class and 36% remained the same size class. The details of movement between size classes for both populations are presented in Table 6.

Table 6. Movement between basal size classes from 2005 to 2007 comparing *P. grahamii* populations as measured by diameter of basal rosette(s). Size classes: small = 0-2.5cm, medium = 3.0 -4.5cm, large = 5.0-6.5cm, xlarge=7.0cm+

size class	Buck Canyon (cm)	Blue Knoll (cm)
small to small	4	0
small to medium	4	1
small to large	5	1
small to xlarge	1	1
medium to small	4	0
medium to medium	8	4
medium to large	7	0
medium to xlarge	1	0
large to small	0	1
large to medium	2	2
large to large	3	3
large to xlarge	0	0
xlarge to small	2	0
xlarge to medium	7	2
xlarge to large	2	1
xlarge to xlarge	1	2
Total increases	**20 (39%)**	**4 (22%)**
Total decreases	**15 (29%)**	**5 (28%)**
Total no change	**16 (31%)**	**9 (50%)**

Pollination Study

Two breeding system studies were conducted on *P. grahamii*. The studies included: 1) The mesh bag study and 2) the mesh wire cage study. Both studies focus on determining the pollination biology of *P. grahamii.* Initially, the mesh bag study was the only one being conducted. However, environmental factors, such as, wind and herbivory, created the necessity to modify our methodology and develop the mesh cage study. Since the mesh bag methodology was already being used, the cage study data was analyzed separately. In future pollination studies, only the mesh cage study would be recommended.

Mesh Bag Study

We monitored the breeding system of *P. grahamii* using three treatments: autogamy, geitogamy and xenogamy, with vector pollination as a control group. The study included 48 individuals. Autogamy treatment was done by selecting a flower that was almost ready to open but still unable to accept pollinators. To ensure that pollinators could not enter for the duration of the pollination period we placed a mesh bag over the flower. Xenogamy treatment was done by selecting two plants that were approximately 10-15 ft apart. A cotton swab was used to extract pollen from one flower and deposited on the target flower. After the pollen was transferred a mesh bag was securely placed over the flower to prevent further pollination by insects. Geitogamy treatment was conducted by randomly selecting two flowers from the same plant and transferring pollen from one flower to the other using a cotton swab. Vector pollination was done by selecting and marking a flower that is presumably cross pollinated by bees/insects and served as control for "normal" pollination. It is known that in some plant species that the position of the flower along the inflorescence can influence the seed production of that fruit. This has not been studied specifically in *P. grahamii*. To account for this variable, the position of the flower chosen for each pollination treatment was rotated at each individual.

Data is presented in Table 5 indicates with an X mark the number of plants producing fruit for each treatment. The control group recorded the highest percent of developed fruits with 50%. Autogamy treatment was found to be the lowest number with only 0.02% fruit. The second highest recorded treatment was xenogamy with 22.9% germinated flowers. 14.6% fruits resulted in the geitogamy treatment.

Table 5. The Mesh Bag Study: The number of developed fruit capsules produced per pollination treatment.

Sample	Autogamy	Xenogamy	Geitongamy	Vector (Control)
1				
2				
3				
4				X
5		X		X
6		X	X	
7		X		
8				X
9				
10				
11				
12		X		
13				
14		X		X
15			X	X
16			X	X
17		X	X	X
18		X		X
19	X			X
20				X
21				
22			X	X
23				X
24				X
25				
26		X		X
27				
28				X
29		X		X
30				X
31				X
32				
33				
34				
35				
36				
37		X		X
38		X	X	X
39				
40				
41			X	X
42				X
43				
44				
45				
46				X
47				
48				X
TOTAL	**1 (0.02%)**	**11 (22.9%)**	**7 (14.6%)**	**24 (50%)**

Mesh Cage Study

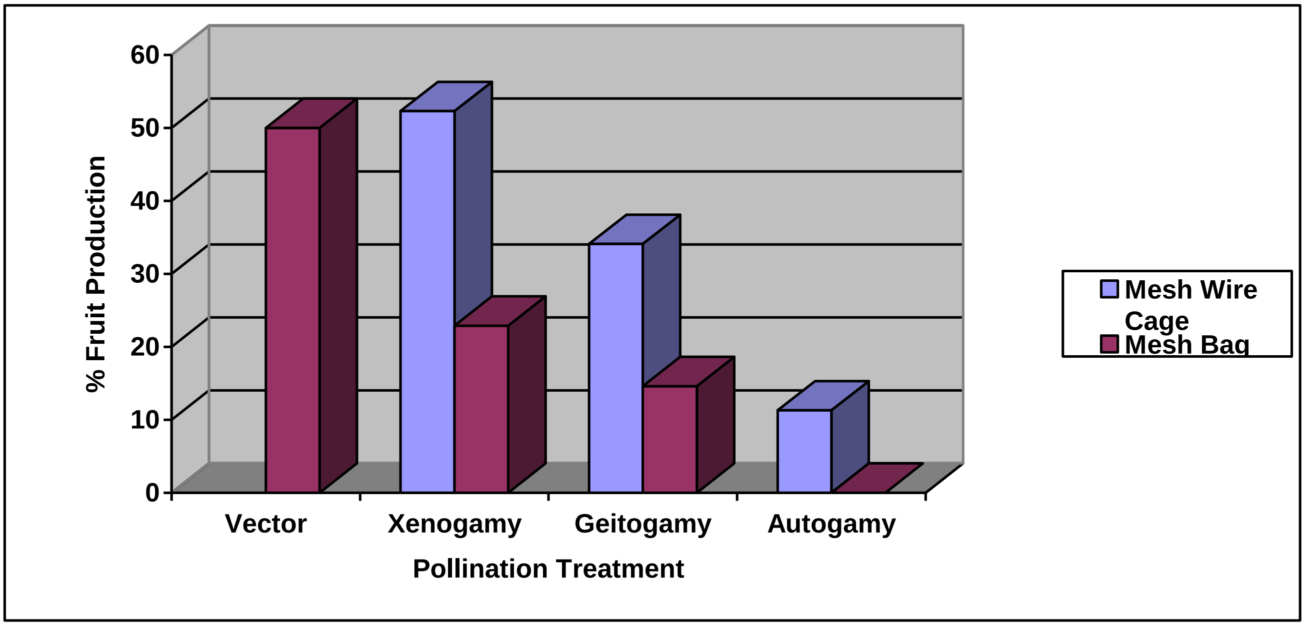
In this study we used the same three pollination treatments described in the mesh bag study. A wire cage covered with mesh netting was placed over the entire plant of all individuals included in the study. This study included 44 individuals; however, because the wire cage covered the entire plant and due to the limited number of flowering plants at the site we were unable to include a control group in this study. The mesh cage also artificially reduced the rate of herbivory in the earlier demographic results section. Xenogamy treatment resulted in the highest amount of developed fruit with 52.3% of the flowers producing fruit. Geitongamy treatment produced 34.1%, and the autogamy treatment produced the least with 11.3% developed fruit. Table 6 summarizes the number of plants producing fruits and the treatment used. An X under each treatment indicates that fruit was produced.

The two pollination studies show that xenogamy treatment produced the highest percent of fruit. Both studies also showed that self pollination (autogamy) can result in fruit; however, it does not appear to be a favorable method. Figure 2 compares the results from both pollination studies. Although the studies differ in the percent fruit produced, the pollination treatments seem to follow a consistent pattern of best to least favorable first xenogamy, second geitonogamy, and last autogamy. These results are consistent with most pollination studies, and with what we expected to find.

Table 6. The Mesh Wire Cage Study: The number of developed fruit capsules produced per pollination treatment.

Sample	Autogamy	Xenogamy	Geitongamy
1		X	X
2		X	
3			X
4	X		
5	X	X	X
6		X	
7			X
8			
9			X
10		X	
11		X	
12			X
13		X	
14			
15		X	X
16			
17	X		X
18		X	
19			X
20		X	
21		X	
22			
23		X	X
24		X	X
25			
26		X	
27		X	
28			
29			
30		X	
31		X	
32			
33		X	
34	X		X
35		X	X
36		X	X
37			
38		X	
39			
40	X		
41		X	X
42			
43		X	
44			
TOTAL	**5 (11.3%)**	**23 (52.3%)**	**15 (34.1%)**

Figure 2. A comparison between the two studies used for pollination biology of *P. grahamii.*



Survey for *Penstemon grahamii*

Surveys for *P. grahamii* were conducted by revisiting historically recorded Element Occurrences and surveying habitat nearby those locations. Specific populations (element occurrences) for survey were identified by the Utah State Heritage Program with input from Ron Bolander. Most locations surveyed were previously identified in the 2002 *Penstemon grahamii* ESA listing petition. Researchers stood approximately 10 ft. apart and walked in parallel lines while handheld GPS devises were used to mark locations of individual plants. All GPS data was recorded as standard UTM coordinates using datum NAD 83. When a plant of interest was found, the area was surveyed in detail and the data recorded on data sheets. Plants were recorded as either flowering or non-flowering rosettes. Table 7 found in Appendix A includes a list of all *P. grahamii* locations and the number of individuals found at each location. A total of 1,307 flowering individuals were recorded and 3,487 non-flowering rosettes were recorded. Maps of the areas surveyed are found in Appendix B. In Appendix B, the number associated with each GPS point (red dot) on the map represents the number of individuals found at that location, not the location number. Appendix C contains copies of the field survey data forms.

Discussion

A point of concern is the extremely rare recruitment events observed for *P. scariousus* var. *albifluvis*; only 10 new individuals over 5 years at the White River site. The causes for this low recruitment are undetermined, and several variables may be involved. Poor seed viability could be one possibility. The plot is located on a steep slope and it is possible that the seeds are migrating and germinating south along the White River at the base of the slope where plants already occur (outside of the plot boundaries). Observations by field staff have been made that more recruitment events seem to be occurring at the base of the slope and in a strip along the river. We do not know if this is due to water availability or topography differences. In future years we would like to track the demography of this portion of the population.

The percentage of *P. scariosus* var. *albifluvis* individuals producing fruit has increased steadily over time, as has the inflorescence height and woody caudex diameter. It is possible these variables are related and a statistical analysis of the data should be considered in order to determine their correlation, if any. We hope to be able to conduct this analysis in 2009.

The herbivory data presented included all herbivory either mammalian or insect occurring anywhere on the plant. General observation noted that most herbivory occurring on rosettes of *P. grahamii* was related to insects; and in previous years herbivory of flowering parts was due to mammals. Herbivory occurring on *P. scariosus* var. *albifluvis* was related to insects at the White River site and mammalian at the Watson site. Plant mortality due to mammalian herbivory could be playing a significant role in the survival of *P. scariosus* var. *albifluvis* plants at the Watson site.

P. grahamii experienced its most productive year over the duration of the study with the highest recorded rates for flowering and fruiting. The increase in flowering and fruiting could be due to the increased precipitation received during winter and spring, coupled with a slow spring and suitable growing temperatures throughout the season. Herbivory rates were artificially reduced due to the use of the mesh cages. However, he reduced insect herbivory, particularly capsule borers, certainly benefited the plants ability to produce seed.

For *P. grahamii*, the Buck Canyon site has had consistently lower mortality rates and higher survivorship the Blue Knoll/Seep Ridge site. This may be due to a slightly harsher and less protected environment at the Blue Knoll site. However, both sites exhibit the same trend in population survivorship over the past 5 years (Fig. 1), indicating that environmental factors effecting both sites are impacting the overall population success.

The pollination study produced results consistent with what was expected. The vector pollination was the most successful at producing fruit, followed in order by xenogamy, geitogamy, and autogamy. These results underscore the importance of maintaining large enough populations in the wild to maintain genetic integrity and prevent in-breeding depression. The pollination study did not count the number of fruits produced per capsule, and should be added to any future pollination study.

Fluctuations within a population are unpredictable from year to year. The five years of data resulting from this study represents only a short-term trend in the population demography of these two species. A continued long-term study will assist in obtaining accurate long-term trends for these species. The potential for several more studies related to each species exist. A few of these studies could be 1) questions on pollinator abundance and impacts on reproduction, 2) impacts on reproduction resulting from development disturbances, 3) and fluctuations in population size and reproduction related to climate. Answers to these and other questions would assist in the development of an action oriented management plan. Since, the BLM manages a large portion of the habitat which is crucial for survival; we suggest continued study of these species which will provide valuable information for the management of *Penstemon scariosus* var. *albifluvis* and *Penstemon grahamii*.

Appendix A

Table 7: Survey locations for *P. grahamii* 2008

Location #	EASTING	NORTHING	FLOWERING	ROSETTES
1	652755	4402471	35	50
2	652647	4401942	13	43
3	652853	4401821	11	25
4	653013	4402042	7	30
5	652670	4401737	12	20
6	652632	4401735	20	50
7	652610	4401784	16	50
8	659106	4403228	16	213
9	658952	4403339	9	82
10	658846	4403250	21	220
11	656868	4404857	148	220
12	657251	4405231	3	10
13	657061	4405358	5	4
14	657300	4405204	0	15
15	652888	4400145	45	170
16	652972	4400124	54	138
17	654268	4399794	53	193
18	652443	4401973	10	24
19	652390	4402006	11	15
20	652711	4402090	2	44
21	652558	4401953	8	32
22	652547	4401912	36	77
23	652492	4401902	5	18
24	652458	4401905	0	57
25	652443	4401926	6	6
26	652314	4402154	41	50
27	652344	4402160	12	27
28	652488	4402225	9	15
29	652462	4402247	5	7
30	652284	4402355	0	80
31	652440	4402367	5	30
32	652202	4402348	15	2
33	652175	4402473	3	15
34	652145	4402458	13	43
35	652211	4402448	0	17
36	652071	4402524	4	47
37	652025	4402541	1	36
38	651969	4402551	1	0
39	653442	4401946	2	8
40	654321	4400900	10	100
41	654378	4400894	0	25
42	653951	4402996	34	30
43	653938	4403075	5	34
44	653894	4403126	13	21

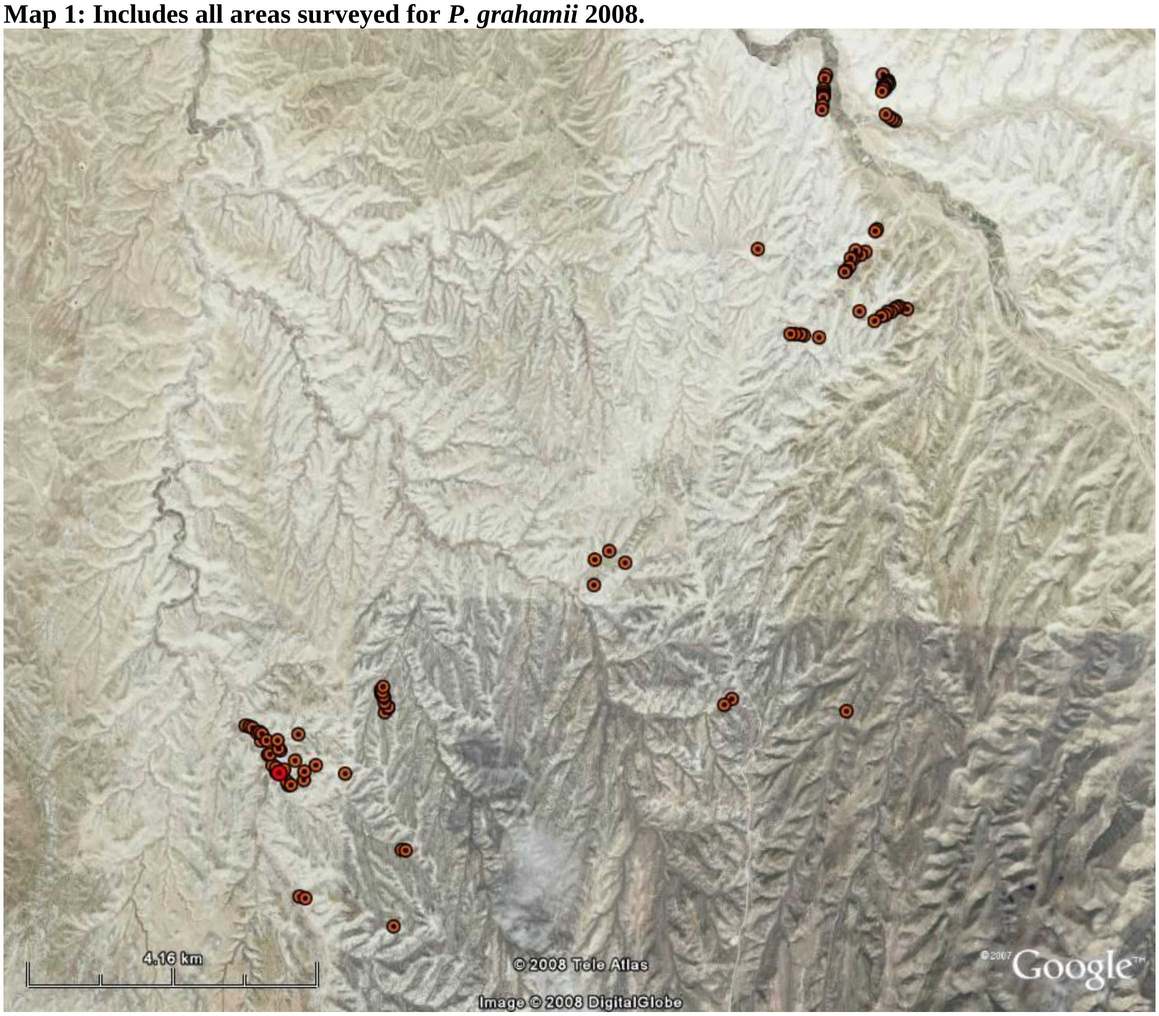
45	653887	4403177	6	7
46	653917	4403222	7	30
47	653912	4403148	3	6
48	653928	4403091	13	18
49	654010	4402936	5	15
50	653962	4402860	8	29
51	654009	4402929	7	26
52	659786	4412368	20	30
53	659771	4412315	24	15
54	659762	4412169	22	18
55	659769	4412121	8	13
56	659772	4412084	10	4
57	659768	4412061	17	20
58	659765	4412036	9	2
59	659759	4411926	18	31
60	659757	4411867	5	16
61	661149	4409077	0	2
62	661030	4409108	5	10
63	660998	4409092	6	15
64	660962	4409066	10	12
65	660922	4409022	4	8
66	660868	4409020	6	18
67	660840	4408973	13	25
68	660787	4408952	16	28
69	660691	4408879	11	6
70	660626	4410167	12	8
71	660648	4410196	3	5
72	660502	4409863	7	15
73	660490	4409845	3	25
74	660465	4409005	8	10
75	660437	4409817	16	65
76	660358	4409875	11	18
77	660334	4409753	32	43
78	660296	4409761	2	15
79	660282	4409637	0	18
80	660264	4409606	2	14
81	660234	4409572	10	12
82	660218	4409556	29	49
83	660609	4412179	3	1
84	660646	4412213	5	30
85	660610	4412203	6	20
86	660624	4412220	12	23
87	660641	4412228	8	18
88	660628	4412237	3	6
89	660626	4412271	0	1
90	660667	4412297	5	17
91	660683	4412338	0	8
92	660691	4412321	0	9

93	660700	4412289	0	10
94	660651	4412237	4	11
95	660821	4411769	30	75
96	660781	4411789	6	6
97	660733	4411817	62	40
98	660681	4411853	8	5
99	659905	4408597	10	8
100	659682	4408615	0	15
101	659639	4408623	15	30
102	659557	4408623	8	10
103	659490	4408628	15	50

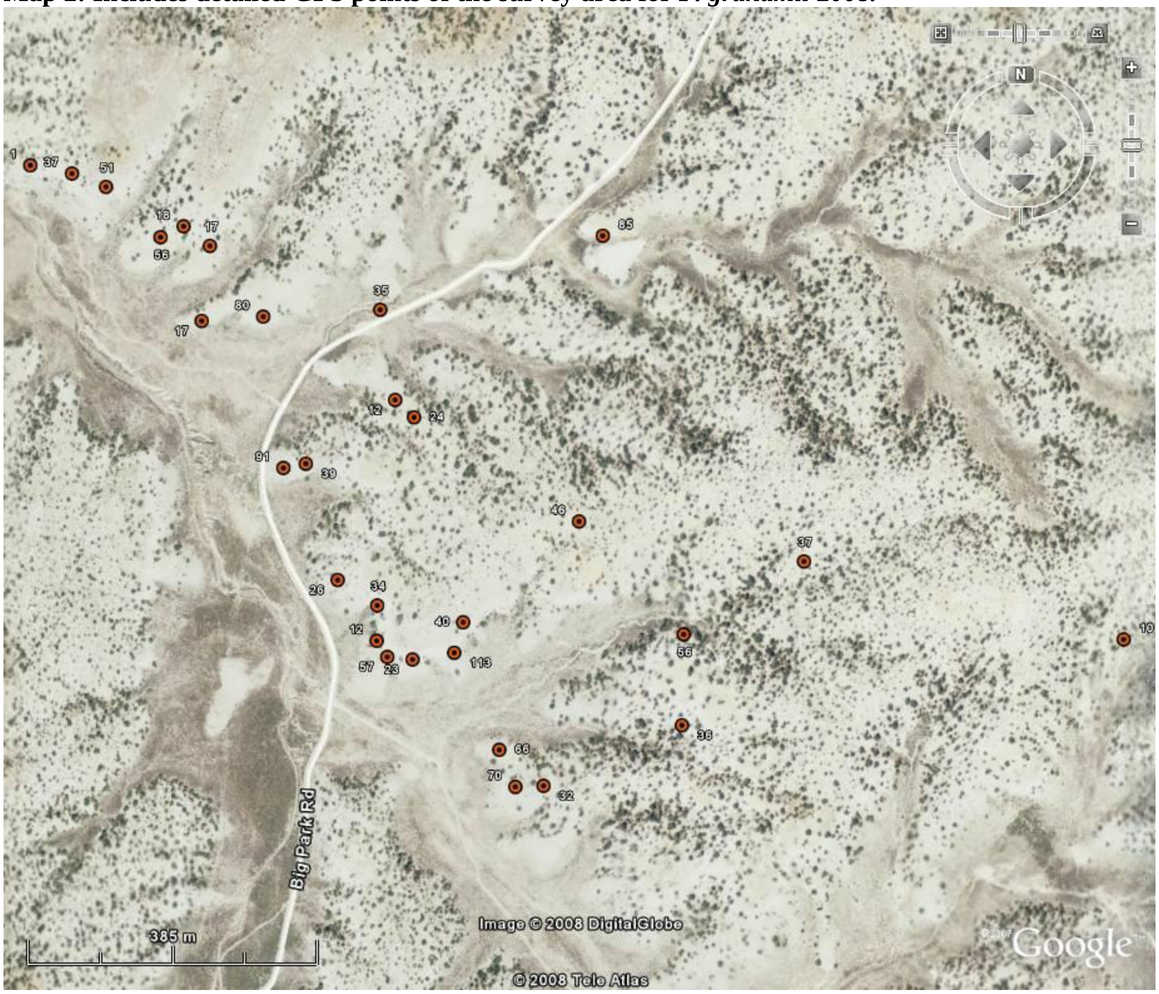
Appendix B

Maps produced with Google Earth, http://earth.google.com/.
Each GPS location is indicated by a red dot on the map.
The number associated with each GPS point on the map represents the number of individuals found at that location, not the location number in Table 7.

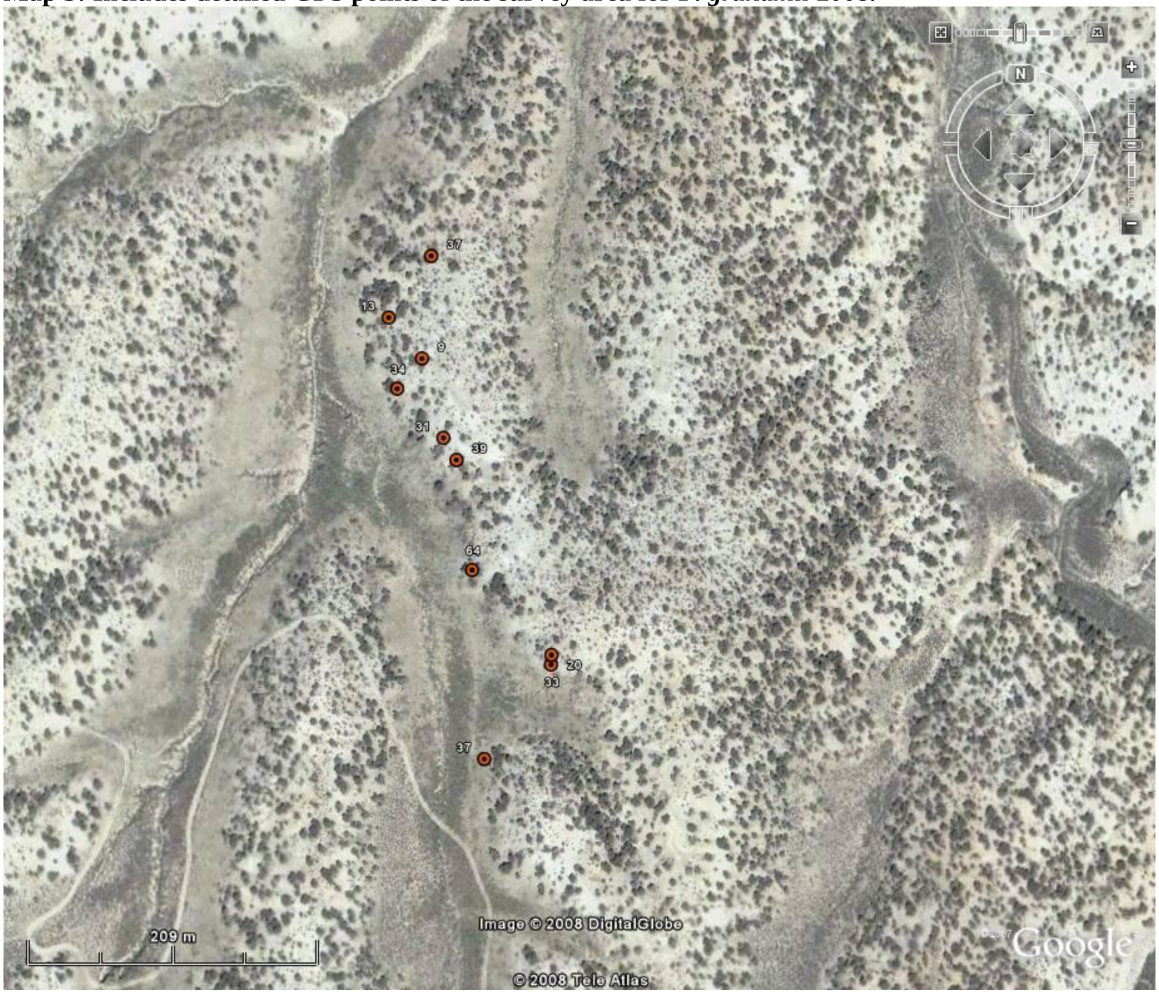
Map 1: Includes all areas surveyed for *P. grahamii* 2008.



Map 2: Includes detailed GPS points of the survey area for *P. grahamii* 2008.



Map 3: Includes detailed GPS points of the survey area for *P. grahamii* 2008.



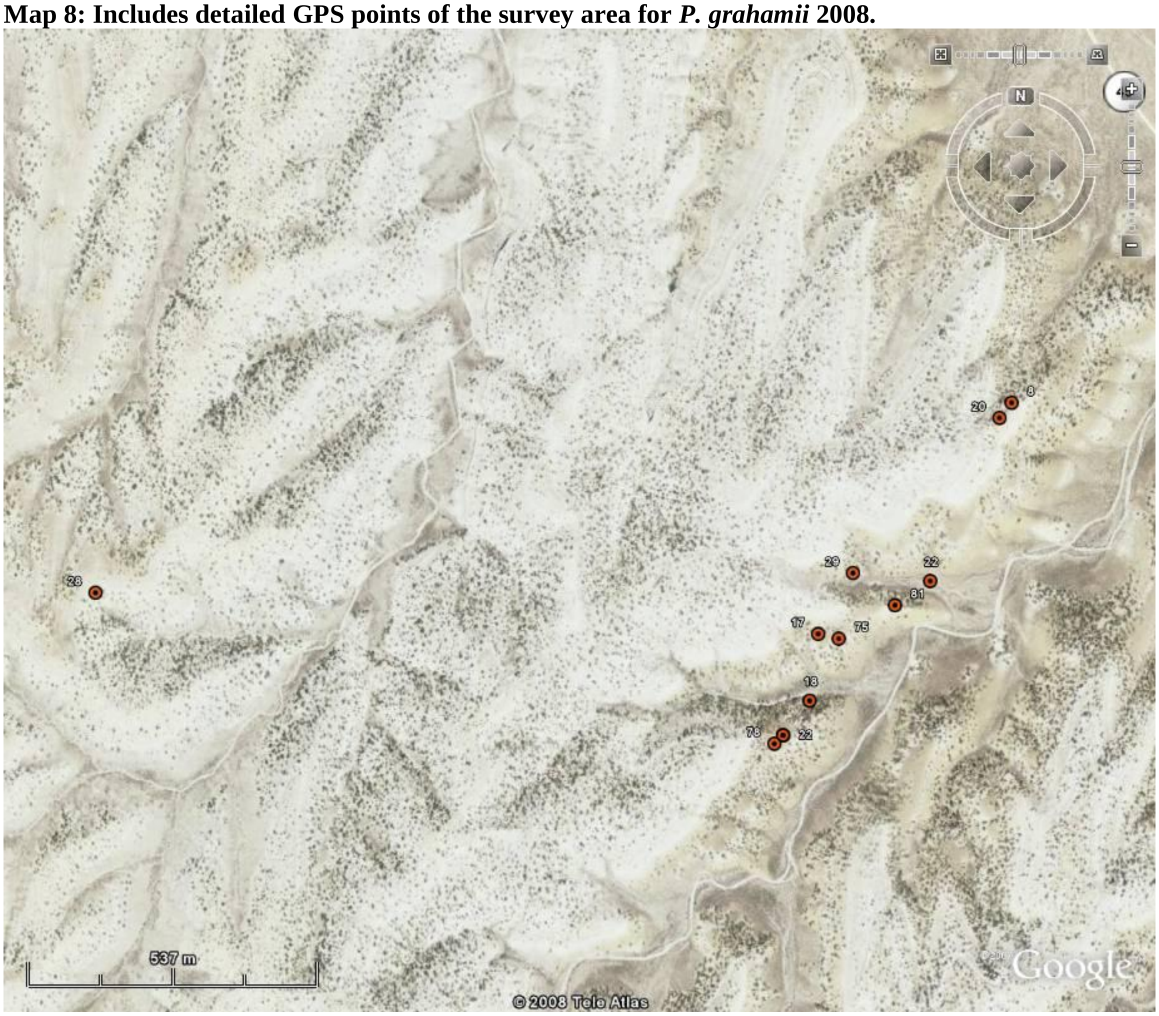
Map 4: Includes detailed GPS points of the survey area for *P. grahamii* 2008.

Map 5: Includes detailed GPS points of the survey area for *P. grahamii* 2008.

Map 6: Includes detailed GPS points of the survey area for *P. grahamii* 2008.

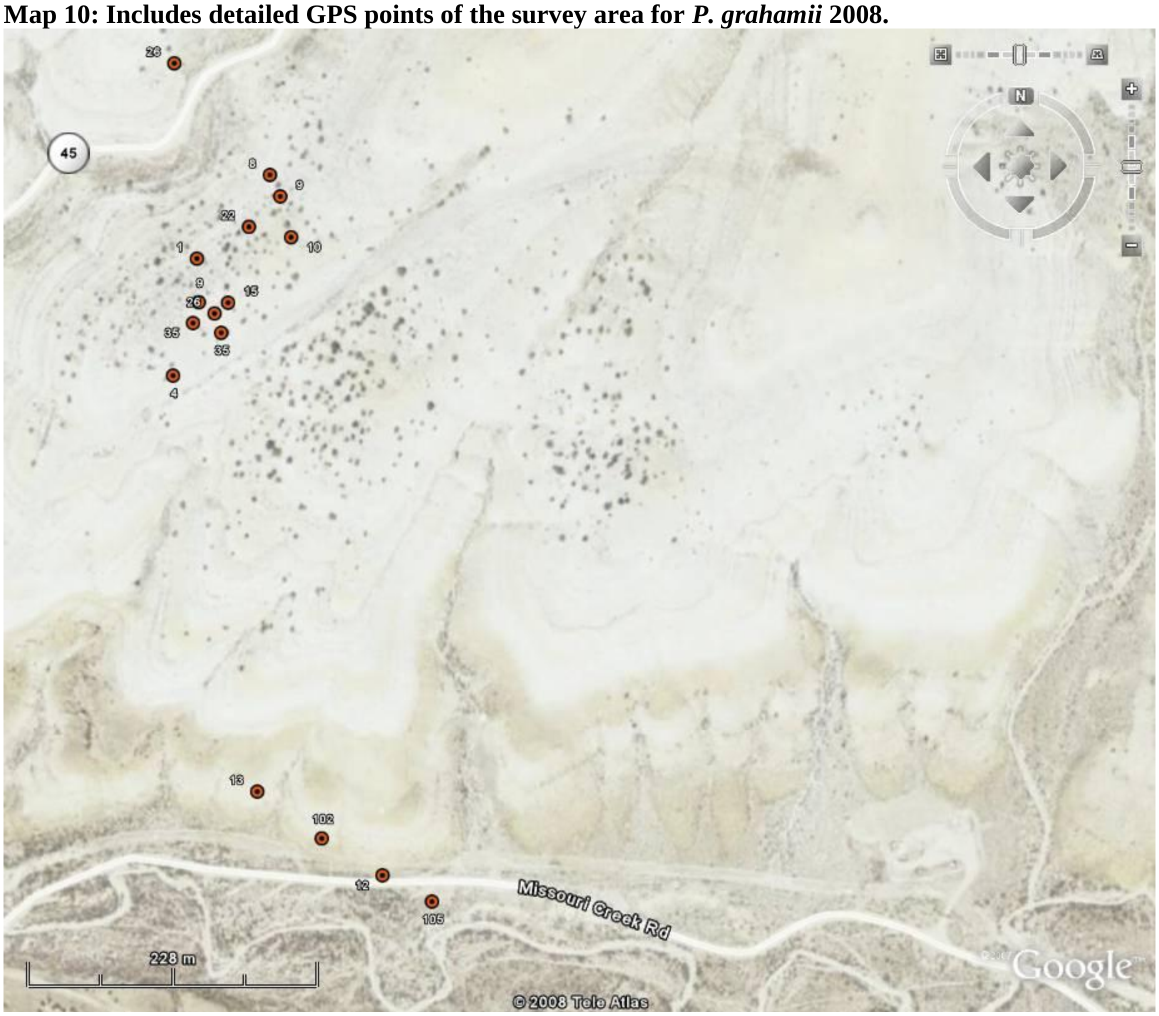
Map 7: Includes detailed GPS points of the survey area for *P. grahamii* 2008.

Map 8: Includes detailed GPS points of the survey area for *P. grahamii* 2008.



Map 9: Includes detailed GPS points of the survey area for *P. grahamii* 2008.

Map 10: Includes detailed GPS points of the survey area for *P. grahamii* 2008.



Appendix C

Report on Flower-visitors to *Penstemon grahamii* and *P. pachyphyllus* (2008)

From May 28 to 30, 2008, I collected and observed insect visitors to the flowers of the rare endemic beardtongue, *Penstemon grahamii*, and its common congener, *P. pachyphyllus*, in the Uintah Basin of eastern Utah. My purpose was to supplement information that I had gathered on *P. grahamii* in previous years, and to gauge the similarity in flower-visitors between these two contemporaneously blooming penstemons. In contrast to previous years when flowering had been sparse, this trip was particularly promising because we anticipated a large population of blooming plants due to above-average winter and spring moisture. I was not disappointed: there were more *P. grahamii* plants in bloom than I have seen in my previous three years of attending to this species.

I visited several *P. grahamii* sites over the three-day period: Blue Knoll (5/30: blooming here was all but completed – only a few plants had open flowers); an unnamed site which had been surveyed the previous weekend, diagonally southwest of the meeting of roads 4190 (Seep Ridge Road) and 2810 – bloom here was good (5/28, 5/30); "Wendy's site", discovered by Wendy Yeates (WY) of Red Butte Gardens in 2007, along a two-track running north from road 4190, east of Blue Knoll (see WY for exact location) – this was the best site for open flowers (5/29 with Beth Chester); a new site I discovered during the course of this investigation, about one mile northeast along road 2810 after it leaves road 4190 – also many flowers (5/30). I did not visit the Buck Canyon population as I was advised by WY that flowering had ceased. I also collected/observed plants in the very large population of *P. pachyphyllus* that begins just east of the meeting of roads 4190 and 2810 (four miles east of Blue Knoll), and proceeds for several miles, mostly on the south side of 4190 (5/28, 5/30). The two congeners, rare and common, abut at the meeting of 4190 and 2810.

My rationale for collecting/observing flower visitors of *P. pachyphyllus* is as follows: In my experience, blooming by *P. grahamii* is much less predictable than is blooming by *P. pachyphyllus*, whose flowers seem to be abundant every year. I believe that flowering by *P. grahamii* is so unreliable from year-to-year that flower visitors, especially specialists, must frequently be supported by other plant species. Thus *P. grahamii* may be "parasitizing" other plant species for pollinators. The most likely "other" species to support pollinators of *P. grahamii* is its congener, *P. pachyphyllus.* This is particularly the case because several of the species recorded visiting *P. grahamii* in past years, i.e., the masarid wasp *Pseudomasaris vespoides*, and some species of *Anthophora* and *Osmia* bees, are either specialized visitors of penstemon species, or are strongly partial to penstemon flowers.

I found the flowers of the two *Penstemon* species rather different in size, color (*P. pachyphyllus* flowers are smaller and are mostly blue sometimes shading to pinkish while *P. grahamii* tend to large, flaring lavender flowers) and morphology (the staminode of *P. pachyphyllus* is relatively short and straight, is inserted in the corolla and bears a short segment of burnt-orange, brownish hairs on the upper surface, while that of *P. grahamii* is much longer, is covered with short, thick orange hair and has a strong hairpin hook at the end). The outer anthers of *P. pachyphyllus* combine with the staminode to make entrance to the narrow corolla tube more restricted; this is not the case with *P. grahamii*, whose corolla tube is more accessible.

Collections and observations at the flowers of both *Penstemon* species yielded a disappointingly low number of flower visitors. In about three hours on two days and at several different spots, I recorded eight species of insects visiting *P. pachyphyllus* flowers: the bees *Osmia gaudiosa* (a small, metallic blue-green twig-nesting species), *Lasioglossum sisymbrii* (a nondescript, ground-nesting, species of sweat bee that forages from many plant groups); *Dialictus* spp. (a small, nondescript, ground-nesting, species of sweat bee that forages from many plant groups), and *Anthophora* spp. (a large, long-tongued ground-nesting species that is commonly encountered visiting *Penstemon* species). Only the *Lasioglossum sisymbrii* and *Dialictus* females were collecting beardtongue pollen.

Other than native bees, on *P. pachyphyllus* I also collected one species of syrphid fly (Syrphidae) and three genera of eumenid wasps: *Pterocheilus*, *Euodynerus*, *Ancistrocerus*, all of which were visiting the flowers for nectar and which are predators of caterpillars. I observed many more of these wasps visiting the flowers. Indeed, they were by far the most common insects thereon. It is important to realize that these wasps are NOT the pollen-collecting specialist *Pseudomasaris vespoides*, that is normally associated with *Penstemon* species and which has been captured visiting numerous species including *P. grahamii* in previous years. Strangely, that species was not seen.

Visitors to the flowers of *P. grahamii* were even more uncommon. At the unnamed site diagonally southwest of the meeting of roads 4190 and 2810 I observed a few individuals of species of *Osmia*, *Dialictus*, and *Anthophora* on the flowers. I observed no flower visitors during 90 minutes at Blue Knoll. At Wendy's site, Beth Chester and I (and Wendy's field technician) collected only four insects, all bees, during several hours of cumulative collecting: *Anthophora*, *Agapostemon* (a very common bright metallic green sweat bee that is a flower generalist), *Lasioglossum sisymbrii* and *Osmia rawlinsi*, a fairly uncommon species. Again, only the *Lasioglossum sisymbrii* female was collecting beardtongue pollen.

These results, so disappointing in numbers of pollinators, invite interpretation: What is going on here? There are many possible explanations, all untestable in the present case. I will offer only my favorite, one that I erected many years ago: in the western United States, where the vast majority of bees and wasps have but a single adult generation per year and that generation is relatively short-lived (perhaps four weeks), flower-visiting bees and flowers are out of phase. Immature bees are produced by the current flower crop but they do not emerge as adults until the following year. In general, a good year for flowers will result in an increased population of bees ***in the following year***! A year of few flowers (last year for *P. grahamii*) will support the production of few flying adult bees this year. In addition, when there are relatively few adults scattered across a large number of flowers, those adults are harder to encounter; they're diluted by the large number of resources. Thus, next year may be a better year for bees. At least that's the hypothesis.