Population assessment of *Pyrrocoma radiata* (Snake River goldenweed)

2016

Progress Report to the USDI, Bureau of Land Management, Vale District

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PREFACE

This report is the result of an agreement between the Institute for Applied Ecology (IAE) and a federal agency. IAE is a non-profit organization whose mission is conservation of native ecosystems through restoration, research and education. Our aim is to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems, species, and effective management strategies and by conducting research, monitoring, and experiments. IAE offers educational opportunities through 3-4 month internships. Our current activities are concentrated on rare and endangered plants and invasive species.

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Cover photograph: IAE crew monitoring a Snake River goldenweed long-term study plot at Lookout Mountain.

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EXECUTIVE SUMMARY

The Institute for Applied Ecology monitored populations of *Pyrrocoma radiata* (Snake River goldenweed) on land managed by the BLM Vale District in 2015 and 2016.

- We monitored 26 sites occurring on Vale BLM lands in 2015, including 1 previously undocumented site.
    - Identified 1 previously undocumented population.
    - Counted/estimated 16,368 plants, with sites ranging from 12 to 3109.
    - 3 sites were found to have no plants in 2015.
- We monitored 50 sites occurring on Vale BLM lands in 2016, including 3 sites that had been monitored in 2015. In addition, 2 new populations of *P. radiata* were documented by Roger Ferriel, Vale District BLM Fire Botanist, in 2016.
    - Counted/estimated 74,290 plants, with sites ranging from 2 to 35,000.
    - 10 sites were found to have no plants in 2016.
    - 3 sites re-monitored from 2015 had higher plant counts in 2016.
- We revisited 5 paired (fenced and unfenced) long-term study plots in 2015 that had been established in 1991.
    - In 2015, the Upper Lime site had the highest total number of plants (586 plants) compared to the 4 other long-term monitoring sites (279 plants total), with the lowest being the Lower Lime site, which only had a single vegetative plant.
    - In 2015 the average plant height was greater in the "OUT" plots at all sites, except for Upper Lookout Mountain.
        - Upper Lookout Mtn "IN" had the largest plants with the highest proportion of seed/flower heads per plant of any of the sites in 2015.
    - In 2015, overall *P. radiata* cover in several long-term study plots (Upper Lime "IN", Lower Lime "IN", and Upper Lookout Mtn "OUT") had decreased from 2009.
    - Cover of exotic graminoids increased in all long-term study plots from 1991 to 2015.

Exotic annual grasses and ungulate grazing are the major threats to *P. radiata* populations occurring on Vale BLM lands recorded during our monitoring. We noted sharp declines for multiple populations and recommend management efforts to limit further decline. We also documented 3 new populations, including the largest recorded (35,000 plants). Although management efforts are needed to ensure conservation of *P. radiata*, we also noted that it responded positively to wildfire and associated management activities, and Vale BLM is considering it as a component for future post-wildfire seeding efforts.

Population assessment of *Pyrrocoma radiata* (Snake River goldenweed)

REPORT TO THE USDI, BUREAU OF LAND MANAGEMENT, VALE DISTRICT

INTRODUCTION

Pyrrocoma radiata [synonym: *Haplopappus radiatus* (Nutt.) Cronquist] (Snake River goldenweed) is a woody, tap-rooted perennial. Mature plants have one to several flowering stems growing 30 cm, up to 100 cm tall (Figure 1). The plants are nearly always glabrous, occasionally with a few scattered hairs on the upper stems and onto the involucres. The broadly elliptical basal leaves are 15-50 cm long (including the petiole) and 5-20 cm wide. The cauline leaves are numerous, sharply toothed and reduced, becoming sessile and clasping above, the lower leaves obovate, and the upper ovate (ODA 2010).

FIGURE 1. *PYRROCOMA RADIATA* (SNAKE RIVER GOLDENWEED) IN FLOWER.

P. radiata typically flowers late in the season in June or July, or sometimes as late as September. Flower heads are 2.5-4 cm wide and range from 1-12 flowers per stem, usually in an open corymbiform arrangement. The involucres are approximately 2.5 cm high, with ovate-oblong, pale-margined loose bracts. The 17-50 ray florets are yellow and 0.6-1.2 cm long, and the 80-100 disk corollas are yellow and approximately 1.5 cm long. The achenes are elongate with 40-60 rigid, unequal brownish pappus bristles (ODA 2010).

It is most closely related to *Pyrrocoma carthamoides* (Columbia goldenweed), which also occurs in the Snake River canyon. Both subspecies of the more common *P. carthamoides* have much narrower basal leaves (0.5-4 cm) and pubescent stems, becoming more densely pubescent near the inflorescences (ODA 2010).

P. radiata is a member of the Asteraceae family. It inhabits dry, rocky, open soil associated with predominately annual vegetation (ODA 2010). This is typically a sagebrush grassland community, often in areas managed for livestock grazing. *P. radiata* is green and flowers later in the season than most other species in the habitats where it typically occurs, and is therefore quite easy to spot surrounded by the brown, dormant vegetation (Moseley 1994).

It is classified as endangered by the Oregon Department of Agriculture (ODA), a Sensitive Species by the Bureau of Land Management and a Species of Concern with the U.S. Fish and Wildlife Service (ORBIC 2016). Potential threats to the species are grazing or trampling from livestock, herbivory by grasshoppers, seed predation by insects, drought and exotic plants (ODA 2010, Figure 2).

FIGURE 2. *PYRROCOMA RADIATA* SURROUNDED BY DENSE, EXOTIC, ANNUAL GRASSES NEAR LIME, OR.

P. radiata occurs in the Blue Mountains and Snake River Plain ecoregions. It is restricted to the lower Snake River Canyon in Baker and Malheur Counties in Oregon and Washington County in Idaho. The species is narrowly endemic; all known populations are distributed in a small geographic area of less than 30 x 40 miles (ODA 2010).

This report documents two years of monitoring for *P. radiata* populations to determine the extent and population status. This species has been recorded at 95 sites listed in the GeoBOB database and managed by the Vale District of the Bureau of Land Management (BLM). Continued monitoring of these sites will provide the BLM with information on population status, long-term trends and supply baseline data to help understand and predict the response of the populations to habitat changes caused by natural forces, human-induced threats and prescribed management actions. Additionally, this report analyzes population and community data collected from 5 paired (fenced and unfenced) long-term study plots established in 1991 and periodically monitored thereafter.

Objectives

The objectives of this project were to:

1) Document population trends of *Pyrrocoma radiata* at known sites on Vale BLM lands.
2) Document new populations, if encountered.
3) Assess impacts of threats (i.e. herbivory, trampling, etc.).

METHODS

Population Monitoring

Site locations were obtained from the Vale District BLM (Roger Ferriel, Fire Botanist). Twenty-five of these sites were located and surveyed by IAE in late July and early August 2015. In addition, 1 new population of *P. radiata* was located and counted during 2015 monitoring. Fifty sites were monitored by IAE in late July 2016, which included 3 sites that had also been monitored in 2015. In addition, 2 new populations of *P. radiata* were documented by Roger Ferriel, Vale District BLM Fire Botanist, in 2016. In total, 75 sites were monitored in 2015 and 2016 (Appendix A). *P. radiata* populations were inventoried

by total count and/or estimated dependent on site accessibility and population size. Sighting report forms were completed for each occurrence noting potential causes of disturbance, geology, plant community composition, presence of exotic species, and physical characteristics of the site.

Long-term Plots

In addition to the known sites occurring on Vale BLM lands, there were 5 long-term study sites with paired plots, one unfenced plot and one fenced to keep livestock out, in the Burnt River valley which were surveyed by IAE staff in 2015. These permanent plots were established in 1991 when the Vale District BLM entered into a cooperative monitoring project with the Plant Conservation Biology Program of ODA to monitor *P. radiata* (Kaye 1992). The study design, setup, and sampling methods follow Kaye (2002), with notation for 2015 specific sampling.

Study Design

All plots were established in 1991, and fencing was completed prior to the 1992 growing season. All fencing remained intact throughout 2015 sampling. Fenced areas are approximately 0.015 hectare, or 12 m on a side. A total of 5 paired plots were established at 4 locations in the vicinity of Lime and Lookout Mountain Road in Baker County, Oregon. Plots are numbered 1-IN, 1-OUT, 2-IN, 2-OUT, and so on, with "IN" indicating the plot is inside the exclosure, and "OUT" indicating the plot is outside the exclosure (Kaye 2002). Directions to the long-term plots are included in Appendix C.

Plots were 10 x 10 m, whether inside or outside of an exclosure. Each plot was composed of 5 1-m wide belt transects (labeled A through E) alternating with 1-m wide walk-ways; each transect had subplots labeled 1 through 10 (i.e. “A-1”, “A-2”, etc) (Figure 3). The belt transects were monumented with rebar posts anchored at each end. There were 5 transects of 10 subplots each, for a total of 50 subplots per plot. To locate the plots for sampling, a meter tape was run from the left to the right post (facing up-hill), and each 1-m segment of meter tape formed the lower edge of each subplot. A 1 x 1 m quadrat frame was then placed on the ground (with one edge along the meter tape) to delineate the subplot (Kaye 2002).

Sampling

Data was collected from long-term study plots to assess the vigor and fecundity of *P. radiata* and assess plant community composition. Original sampling was conducted twice, once in mid-May and once in late-July or early August. The spring sampling was conducted primarily to maintain the plots and to locate and map seedlings, and was not included in 2015 sampling efforts. In 2015, plots were surveyed once during the growing season in early August. Data on plant height (cm), length of longest leaf (cm), number of leaves, number of healthy and aborted flower heads (capitula), number of grazed stems, and percentage herbivory (by insects unless otherwise noted), were recorded following procedures established in Kaye (2002). Plant community data was collected at each plot by visual estimation of percent cover of individual species within the entire 10 x 10 m square (Kaye 2002). Mid-point values for cover classes were used to calculate averages and for analysis.

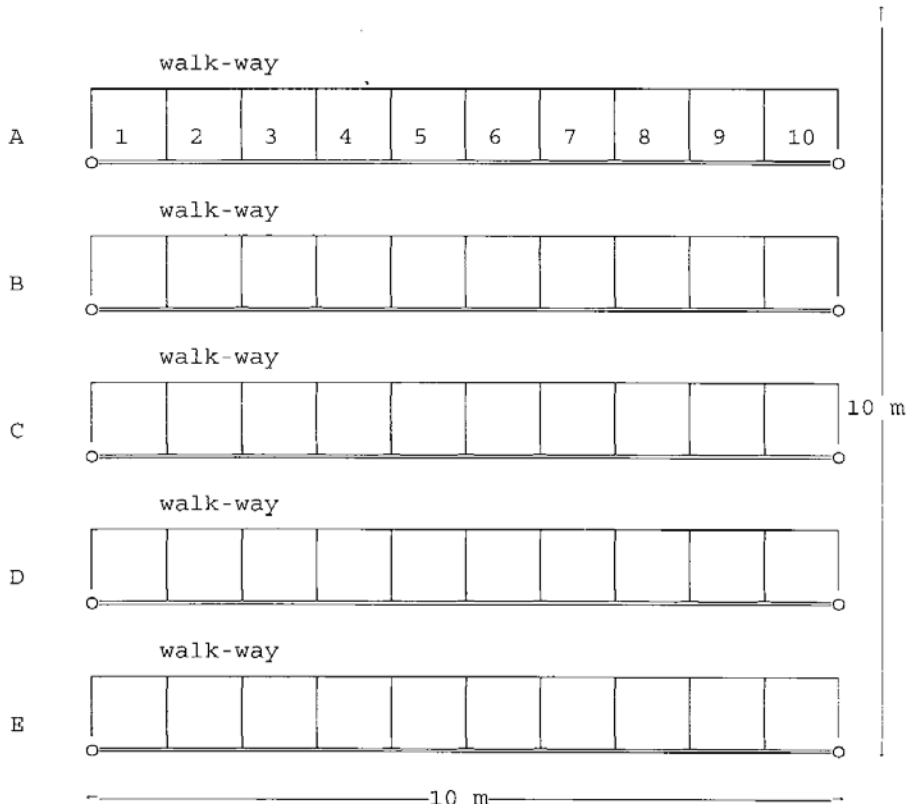

FIGURE 3. LAYOUT OF PERMANENT PLOTS FOR MONITORING *PYRROCOMA RADIATA*, FROM KAYE (2002).

RESULTS

2015 Population Monitoring

We monitored 26 sites occurring on Vale BLM lands in 2015, including 1 new record (Table 1). We counted/estimated 16,368 plants, with sites ranging from 12 to 3109, including 3 sites with no plants recorded in 2015. Of the total count, 8938 were reproductive and 7430 were vegetative (Table 1).

Fourteen sites had >200 plants, with 9 of those having >500 plants during 2015 surveys (Table 1). OR035_415 had the greatest number of *P. radiata* with 3109. A portion of the population at OR035_1109 was located on private land and counted separately; however, those 120 plants (100 reproductive and 20 vegetative) are included in the total counts for that site (Table 1).

Threats to *P. radiata* observed during 2015 monitoring included exotic annual grasses (i.e. *Bromus tectorum*, *Poa bulbosa*, and *Taeniatherum caput-medusae*), which were present at every site visited, as well as ungulate grazing and human disturbance (Table 1).

TABLE 1. NUMBER OF PYRROCOMA RADIATA PLANTS (REPRODUCTIVE AND VEGETATIVE) AND ASSOCIATED THREATS AT SITES MONITORED ON VALE BLM LANDS IN 2015.

Site #	Reproductive	Vegetative	Total	Threats
OR035_386	385	205	590	Exotic annual grasses
OR035_387	50	206	256	Exotic annual grasses
OR035_389	22	48	70	Exotic annual grasses
OR035_394	125	120	245	Exotic annual grasses
OR035_397	31	458	489	Exotic annual grasses
OR035_398	0	0	0	Exotic annual grasses
OR035_403	0	0	0	Exotic annual grasses
OR035_404	82	37	119	Exotic annual grasses, human disturbance
OR035_414	75	95	170	Exotic annual grasses
OR035_415	1861	1248	3109	Exotic annual grasses
OR035_418	259	523	782	Exotic annual grasses
OR035_419	1750	250	2000	Exotic annual grasses
OR035_422	725	1420	2145	Exotic annual grasses
OR035_845	0	0	0	Exotic annual grasses
OR035_905	26	66	92	Exotic annual grasses
OR035_960	1044	764	1808	Exotic annual grasses
OR035_991	200	50	250	Exotic annual grasses
OR035_1102	630	582	1212	Exotic annual grasses
OR035_1104	5	37	42	Exotic annual grasses, ungulate grazing
OR035_1105	4	8	12	Exotic annual grasses
OR035_1108	131	193	324	Exotic annual grasses

OR035_1109	900	870	1770	Exotic annual grasses
OR035_1116	17	7	24	Exotic annual grasses
OR035_1117	80	37	117	Exotic annual grasses
OR035_1118	36	6	42	Exotic annual grasses
OR035_1636*	500	200	700	Exotic annual grasses
TOTAL:	**8938**	**7430**	**16,368**	

*New population mapped in 2015.

2016 Population Monitoring

We monitored 52 sites occurring on Vale BLM lands in 2016, including 3 sites that had been monitored in 2015 and 2 new records (Table 2). We counted/estimated 74,290 plants, with sites ranging from 2 to 35,000, including 10 sites with no plants recorded in 2016. Of the plants counted, 61,439 were reproductive and 12,851 were vegetative (Table 2).

Twenty sites had >200 plants, with 16 of those having >500 plants during 2016 surveys (Table 2). Sites OR035_991, OR035_419, and OR035_1636 were monitored in both 2015 and 2016. All 3 sites increased in 2016 as compared to 2015. We re-monitored two sites that had burned in the Lime Fire; OR035_991 had 1016 total plants and OR035_419 had 6240 in 2016, which was over 3x the number of plants counted at those sites in 2015 (Appendix A).

Threats to *P. radiata* observed during 2016 monitoring included exotic annual grasses (i.e. *Bromus tectorum*, *Poa bulbosa*, and *Taeniatherum caput-medusae*; Figure 4), exotic forb species (i.e. *Onopordum acanthium* and *Salsola tragus*), grazing, insect herbivory, soil erosion, and proximity to wind turbine development (Table 2). Heavy grazing poses a threat to *P. radiata* because it can lead to soil disturbance and erosion on the steep slopes where it grows; additionally, we observed many *P. radiata* plants that had their flower/seed heads grazed by ungulates (Figure 5) and some that were trampled.

FIGURE 4. AREA OF DENSE THATCH FROM *TAENIATHERUM CAPUT-MEDUSAE* AT SITE OR035_409 WITH *PYRROCOMA RADIATA* PRESENT.

Wind turbine development (Figure 6) is expanding in the area, in close proximity to OR035_416, OR035_421, and OR035_972, and roads are being widened to accommodate construction vehicles, which could cause soil disturbance and reduce habitat. OR035_421 was the closest site to wind turbine development, with a wind turbine going up right across the road from the polygon.

Exotic annual grasses are a threat to *P. radiata* and other native species because they can outcompete native species for space and resources as well as limit seedling establishment (Johnson and Davies 2012, Young 1992). *T. caput-medusae* (medusahead), an exotic winter annual, is a successful competitor because it experiences rapid root growth over winter, and produces copious amounts of seed in the spring, at a time when many native species are just beginning to germinate. Where it invades, *T. caput-medusae* can limit seedling establishment through competition, suppression, and alteration of fire cycles (Johnson and Davies 2012). *T. caput-medusae* forms a dense layer of litter that decomposes slower than other plants because of its high silica content; the resulting highly persistent thatch layer suppresses native plant growth, while promoting the germination of medusahead seed (Young 1992).

FIGURE 5. PYRROCOMA RADIATA PLANT WITH FLOWER/SEED HEAD GRAZED OFF BY UNGULATE AT SITE OR035_413.

FIGURE 6. WIND TURBINE DEVELOPMENT NEAR SITES OR035_416, OR035_421, AND OR035_972.

TABLE 2. NUMBER OF *PYRROCOMA RADIATA* PLANTS (REPRODUCTIVE AND VEGETATIVE) AND ASSOCIATED THREATS AT SITES MONITORED ON VALE BLM LANDS IN 2016.

Site #	Repro	Veg	Total	Threats
OR035_382	0	0	0	Exotic annual grasses
OR035_383	24	10	34	Exotic plant species
OR035_384	52	16	68	Exotic annual grasses
OR035_388	37	5	42	Exotic annual grasses
OR035_390	228	116	344	Exotic annual grasses
OR035_391	135	54	189	Exotic plant species
OR035_392	1935	1935	3870	Exotic annual grasses
OR035_393	41	83	124	Exotic annual grasses
OR035_395	515	192	707	Exotic annual grasses
OR035_396	463	537	1000	Exotic annual grasses, ungulate grazing
OR035_399	76	7	83	Exotic annual grasses
OR035_402	38	6	44	Exotic annual grasses
OR035_406	63	54	117	Exotic plant species
OR035_408	890	559	1449	Exotic plant species
OR035_409	2932	1080	4012	Exotic annual grasses
OR035_412	1774	524	2298	Exotic annual grasses, heavy insect herbivory
OR035_413	705	667	1372	Exotic annual grasses, ungulate grazing
OR035_416	36	62	98	Exotic annual grasses, ungulate grazing, wind turbine development
OR035_419	4399	1841	6240	Exotic annual grasses
OR035_421	8	3	11	Exotic annual grasses, proximity to wind turbine development
846	982	1720	2702	Exotic annual grasses, ungulate grazing
OR035_906	160	35	195	Exotic annual grasses
OR035_971	132	240	372	Exotic annual grasses
OR035_972	179	255	434	Exotic annual grasses, proximity to wind turbine development
OR035_973	0	0	0	Exotic annual grasses
OR035_976	0	0	0	Exotic annual grasses
OR035_978	85	30	115	Exotic annual grasses
OR035_979	6	7	13	Exotic plant species
OR035_980	0	0	0	Exotic plant species
OR035_981	0	0	0	Exotic annual grasses
OR035_986	0	0	0	Exotic annual grasses
OR035_987	0	0	0	Exotic annual grasses
OR035_988	32	6	38	Exotic plant species
OR035_989	5	1	6	Exotic plant species
OR035_991	528	488	1016	Exotic annual grasses
OR035_1101	3	4	7	Exotic annual grasses
OR035_1106	0	0	0	Exotic annual grasses, degraded rangeland
OR035_1107	139	150	289	Exotic annual grasses
OR035_1111	438	310	748	Exotic annual grasses, ungulate grazing

OR035_1115	142	47	189	Exotic annual grasses
OR035_1119	670	228	898	Exotic plant species
OR035_1120	2	0	2	None observed
OR035_1121	66	28	94	Exotic plant species
OR035_1122	0	0	0	None observed
OR035_1451	604	755	1359	Exotic annual grasses
OR035_1456	8	0	8	Exotic annual grasses
OR035_1457	54	35	89	Exotic annual grasses
OR035_1458	0	0	0	None observed
OR035_1459	31	112	143	Exotic annual grasses, ungulate grazing, erosion
OR035_1629*	7425	75	7500	Exotic annual grasses
OR035_1630*	34,650	350	35,000	Exotic annual grasses
OR035_1636	747	224	971	Exotic annual grasses
TOTAL:	**61,439**	**12,851**	**74,290**	

*New populations mapped in 2016.

Long-term Plots

Plant Counts

In 2015, the Upper Lime site had the highest total number of plants (586 plants) compared to the 4 other long-term monitoring sites (279 plants total) (Table 3). The Lower Lime site had the lowest total number of plants with only a single vegetative plant, which was observed in the "OUT" plot. Of the total plants recorded at all the plots in 2015, 516 plants were in the "IN" plots and 349 were in the "OUT" plots (Table 3).

During the 1991-2000 monitoring of the long-term plots, the population at the Upper Lime site varied from a low of 341 in 1992 to a high of 1498 in 1999 (Kaye 2001). The 2015 population of 516 for Upper Lime (Table 3) was within the range of the historical population monitoring data of that site.

In 2015, Lower Lime and Upper Lookout Mountain plots had the lowest population counts recorded since monitoring was initiated. In 2015 Lower Lime only had 1 plant (Table 3), while from 1991-2000 the population ranged from a low of 127 in 2000 to a high of 490 in 1998 (Kaye 2001). Upper Lookout Mountain had 22 total plants in 2015 (Table 3), which was below the previous population range of 216 (2000) to 422 (1994) recorded from 1991-2000 (Kaye 2001).

The count at Lower Lookout Mountain 4 in 2015 was 124 (Table 3), which was within the range of 84 (2000) to 228 (1991) recorded from 1991-2000 (Kaye 2001). The Lower Lookout Mountain 5 population in 2015 (132 plants; Table 3) was higher than any of the total population counts from 1991-2000 which ranged from a low of 44 in 1996 to a high of 98 in 1999 (Kaye 2001).

Vigor, Fecundity and Herbivory

Vigor, fecundity and herbivory data on *P. radiata* was collected and analyzed for the long-term plots from 1991 to 1999 (Kaye 2001) and we followed those protocols to collect data in 2015.

In 2015 the average plant height was greater in the "OUT" plots at all the sites, except for Upper Lookout Mountain (Table 3). Upper Lookout Mountain "IN" had the largest plants with the highest proportion of seed/flower heads per plant of any of the sites in 2015 (Table 3). This was the most vigorous population of *P. radiata* surveyed in 2015 with an average plant height at least 9 cm taller, 4 more leaves per plant, and average leaf length at least 2 cm longer than plants at all other sites (Table 3).

At the time of the survey the total seed heads for "IN" plots was 190 and "OUT" plots was 111 (Table 3). This difference was mostly due to the 97 total seed heads in the Upper Lookout Mountain "IN" plot (Table 3). Upper Lookout Mountain "IN" was the most fecund population of *P. radiata* surveyed in 2015, with an average of over 5 flower heads per plant compared to less than 1 flower head per plant in all the other populations (Table 3). The percentage of aborted to fertile flower heads was highest at Upper Lime "IN" (29%) and Lower Lookout Mountain 5 "OUT" (23%) (Table 3).

Herbivory was highest at the enclosed plots for all of the sites, except for Lower Lime, which had no plants to measure in the "IN" plot, and at the Lower Lookout plot, which had an equal herbivory rate inside and outside the exclosure (Table 3). The site with the highest herbivory rate was Upper Lookout Mountain. It was highest (around 80%) at the "IN" plot, and the Upper Lookout Mountain "OUT" plot was the second highest (near 25%) in 2015 (Table 3). Nearly all of the herbivory observed in 2015 was due to insects.

TABLE 3. SUMMARY OF PLANT VIGOR, FLOWER/SEED HEAD COUNT AND HERBIVORY DATA AT LONG-TERM MONITORING PLOTS IN 2015.

Plot Name	2015 Total Plants	Ave. plant height (cm)	Ave. # leaves per plant	Ave. of longest leaf (cm)	Total flower heads	# Seed/ Flower heads per plant	Total # aborted heads	Ave. *Graze Class
Upper Lime IN	379	15.2	5.7	18.4	34	0.1	10	4
Upper Lime OUT	207	17.0	10.7	18.6	33	0.2	1	3
Lower Lime IN	0	0.0	0.0	0.0	0	0.0	0	N/A
Lower Lime OUT	1	10.0	2.0	10.0	0	0.0	0	3
Upper Lookout Mtn IN	19	32.7	14.9	23.3	97	5.1	10	6
Upper Lookout Mtn OUT	3	14.3	4.0	14.7	0	0.0	0	4
Lower Lookout Mtn 4 IN	39	16.2	6.0	19.9	17	0.4	0	3
Lower Lookout Mtn 4 OUT	85	21.4	8.1	17.8	48	0.6	3	3
Lower Lookout Mtn 5 IN	79	18.7	5.7	21.0	42	0.5	3	2
Lower Lookout Mtn 5 OUT	53	23.6	5.6	20.5	30	0.6	7	2

*Graze Classes: 1 = <1%; 2 = 1-5%; 3 = 5.1-25%; 4 = 25.1-50%; 5 = 50.1-75%; 6 = 75.1-95%; 7 = 95.1-100%

Plant Community

Plant community data for the long-term study plots was collected in 1991, 2000, 2009 and 2015 (Appendix B).

UPPER LIME

In 2015, *P. radiata* cover had decreased from 37.5% in 2009 to 15% in the "IN" plot; the "OUT" plot had the same percent cover in 2009 and 2015 (37.5%) (Appendix B). Exotic graminoid cover at the site

has increased over the monitoring period (Figure 7). In 1991, both "IN" and "OUT" plots had 15% total exotic graminoid cover, which has increased to over 100% in both "IN" and "OUT" plots in 2015 (Appendix B). *B. tectorum* increased from 15% in the "IN" and 37.5% in the "OUT" plot in 2009 to 62.5% in both plots in 2015. *P. bulbosa* cover increased in the "IN" plot from 0.5% in 2009 to 37.5% in 2015, and in the "OUT" plot from 15% in 2009 to 62.5% in 2015. Over the years this site has transitioned from being native-dominated to now being exotic-dominated (Figure 7).

Balsamorhiza sagittata cover increased from 0.5% in 2009 to 15.5% in the "OUT" plot in 2015, while 7 minor component species (0.5% to 3% cover in 2009) disappeared from the plots in 2015 (Appendix B). Four of these were native species and 3 were exotic. In 2015, 2 new species were observed for the first time at the Upper Lime plots, both of which were exotic species (*Bromus hordeaceus* ssp. *hordeaceus* and *C. draba*). A total of 4 native species were observed in 2015, which is a decrease from the high of 11 observed in 2000, the 8 observed in 1991, and the 7 observed in 2009 (Appendix B).

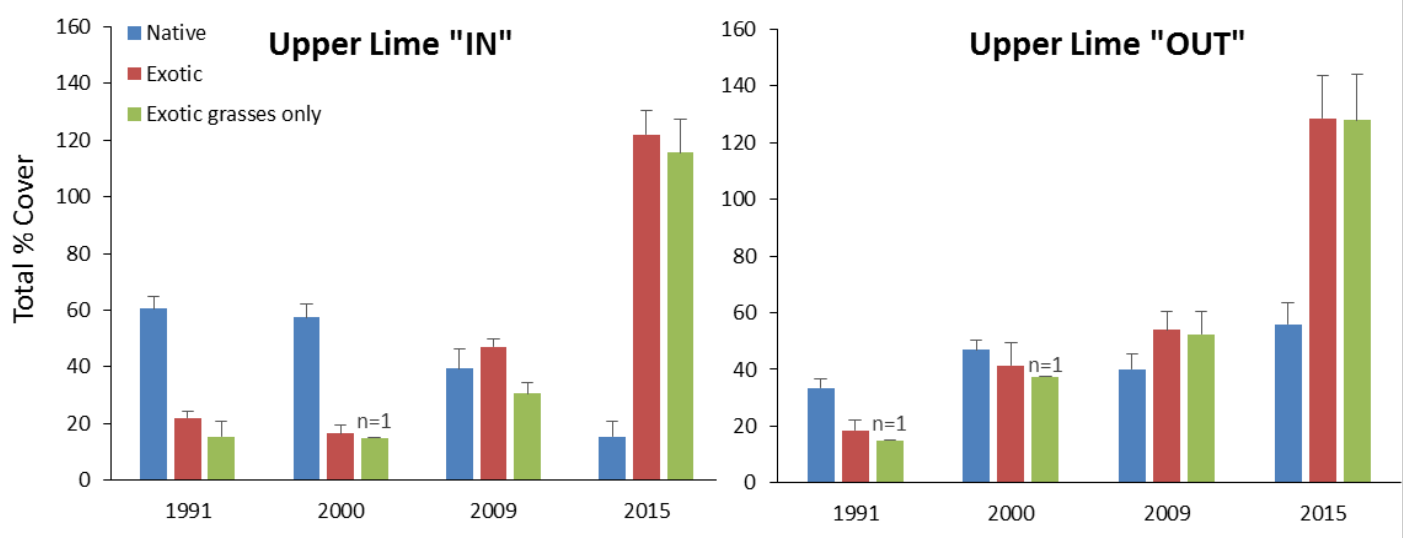

FIGURE 7. TOTAL % COVER OF NATIVE PLANT SPECIES, EXOTIC PLANT SPECIES, AND EXOTIC GRASSES ONLY FOR UPPER LIME "IN" AND UPPER LIME "OUT" IN 1991, 2000, 2009, AND 2015.

LOWER LIME

In 2015, overall *P. radiata* cover had decreased from 2009 (Appendix B). The "IN" plot decreased from 15% in 2009 to 0.5% in 2015. The "OUT" plot stayed the same from 2009 to 2015 at 0.5%, but this is a decrease from a high of 15% in 1991 (Appendix B). *Artemisia tridentata* cover was the same in both the "IN" and "OUT" plots in 2015 as in 2009. The "IN" plot has had 15% cover since 1991, but the "OUT" plot has increased from 3% in 1991 to 37.5% in 2009 and 2015 (Appendix B). *Poa secunda* in 1991 was at 37.5% cover at the "OUT" plot, but this decreased to 3% in 2015 (Appendix B).

Exotic species cover, especially exotic graminoids, at the site has increased over the monitoring period (Figure 8). *B. tectorum* increased from 3% cover in 2009 (both "IN" and "OUT" plots) to 62.5% in "OUT" and 87.5% in "IN" plots in 2015. The noxious weed, *Lepidium draba* (formerly known as *Cardaria draba*), had 37.5% cover in the "IN" plot in 1991, but was no longer found in the plot in 2015. *P. bulbosa* cover decreased since 2000 in both the "IN" and "OUT" plots (Appendix B). *T. caput-medusae* decreased from 2009 to 2015 in the "OUT" plot (from 15% to 3%), but increased in the "IN" plot (15% in 2015) where it had not been recorded since 1991 (0.5%) (Appendix B). Overall exotic graminoid

cover increased from 38% in both "IN" and "OUT" plots in 1991 to over 100% at the "IN" plot and 80% in the "OUT" plot in 2015 (Figure 8). Lower Lime "IN" has remained exotic-dominated from 1991-2015, while Lower Lime "OUT" has transitioned from being native-dominated to now being exotic-dominated (Figure 8).

The total species richness at the site decreased from 2009 to 2015 (from 13 to 11 at the "IN" plot and from 14 to 12 at the "OUT" plot). A total of 8 native species were observed in 2015, which is a decrease from the high of 10 observed in 1991. Native species that had been recorded previously (1991, 2000, and/or 2009) but were no longer present in 2015 were all native forbs that had been minor components (0.5% cover); these species included *Achillea millefolium*, *Amsinckia tessellata*, *Crepis occidentalis*, *Lomatium triternatum*, *Phlox* sp., and *Lupinus arbustus* ssp. *calcaratus* (Appendix B).

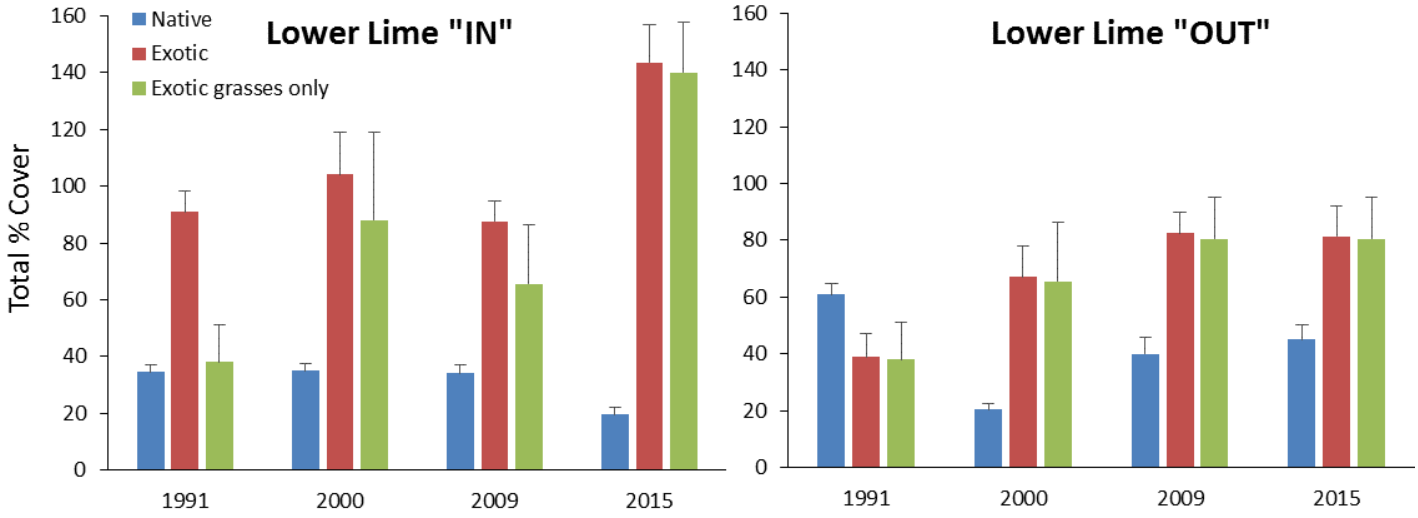

FIGURE 8. TOTAL % COVER OF NATIVE PLANT SPECIES, EXOTIC PLANT SPECIES, AND EXOTIC GRASSES ONLY FOR LOWER LIME "IN" AND LOWER LIME "OUT" IN 1991, 2000, 2009, AND 2015.

UPPER LOOKOUT MOUNTAIN

In 2015, *P. radiata* cover increased from 3% in 2009 to 15% in the "IN" plot; however, it was absent from the "OUT" plot entirely (Appendix B). *A. tridentata* appeared in the plots for the first time in 2015, but was not a large component of the plant community, having only 3% total cover. Total cover of *B. sagittata* increased in the "IN" plot from 3% in 2009 to 15% in 2015 (Appendix B). The native graminoids *P. secunda* and *Elymus elymoides* were in the plots in 2000 and 2009, but were absent from the plots in 2015 (Appendix B).

B. tectorum increased in both the "IN" and "OUT" plots in 2015. *B. tectorum* increased from 15% to 87.5% in the "IN" plot and from 0.5% to 37.5% in the "OUT" plot from 2009 to 2015 (Appendix B). *B. tectorum* has been observed at the site since 1991 as a dominant component of the plant community. *C. draba* was first recorded in the plots in 2009 and has increased cover in 2015 (from 0.5% to 3% in the "IN" plot). The cover of *P. bulbosa* increased in the "OUT" plot from 15% in 2009 to 37.5% in 2015. In 2015, *T. caput-medusae* cover increased from 2009 in the "OUT" plot, from 3% up to 37.5%, which was the same percent cover first measured in 1991 (Appendix B).

The total species richness at the site decreased from 2009 to 2015 (from 19 to 14 at the "IN" plot and from 24 to 12 at the "OUT" plot). Overall, the cover of exotic graminoids increased from 2009 to 2015. In 2015, the total exotic graminoid cover was the highest recorded from 1991-2015 (Figure 9, Appendix B). Both Upper Lookout Mountain "IN" and "OUT" have remained exotic-dominated over the course of the study (Figure 9).

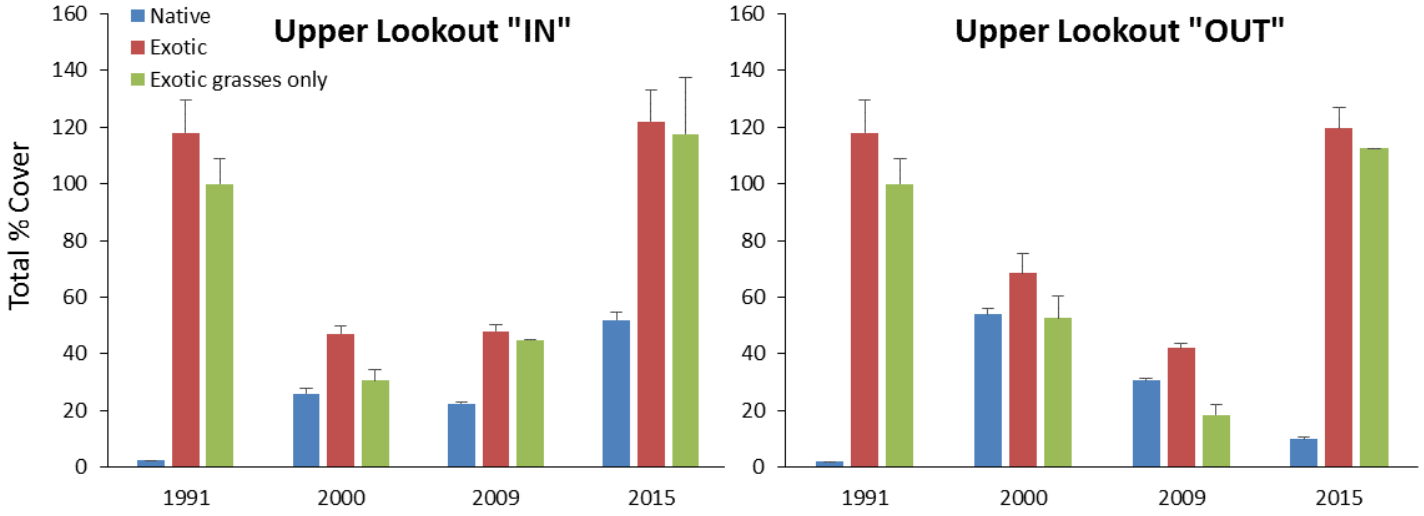

FIGURE 9. TOTAL % COVER OF NATIVE PLANT SPECIES, EXOTIC PLANT SPECIES, AND EXOTIC GRASSES ONLY FOR UPPER LOOKOUT MTN "IN" AND UPPER LOOKOUT MTN "OUT" IN 1991, 2000, 2009, AND 2015.

LOWER LOOKOUT MOUNTAIN #4

In 2015, *P. radiata* cover remained the same as in 2009 (3%) for both the "IN" and "OUT" plot (Appendix B). *A. tridentata* cover was stable in the "OUT" plot and increased in the "IN" plot. Total *A. tridentata* cover has increased at the site from a low in 1991 of 0.5% at each plot to 37.5% at each plot. *Eriogonum strictum* is one of the substantial native components at this site; it has increased over the years monitored from a total of 3.5% in 1991 to 30% in 2015. Total *P. secunda* cover increased from 2009 to 2015, but is still lower than cover recorded in 1991 and 2000. *E. elymoides* decreased to just a trace presence in the plots in 2015. Lower Lookout Mountain 4 has the highest native species cover of all the sites, with half of the total comprised of *A. tridentata* and *P. secunda* comprising the second largest component (Appendix B).

B. tectorum cover increased in both the "IN" and "OUT" plots in 2015, but is still lower than cover in 1991 and 2000. In 2015, *P. bulbosa* increased from 0.5% in both plots in 2009 to 37.5% in "IN" and 15% in "OUT". *T. caput-medusae* was present at the site but was not a major component in either of the plots. Lower Lookout Mountain 4 had the lowest exotic graminoid cover of all the sites in 2015 (Appendix B).

The total species richness declined at the site from 2009 to 2015, from 16 to 14 at the "IN" plot and from 20 to 13 at the "OUT" plot. Since monitoring began in 1991, the native species have outnumbered exotic species in the plots. However, 2015 had the lowest native species count. Four native species that were minor components in 2009 were not found in the plots in 2015 (Appendix B). However, in terms of percent cover, native species cover actually increased from 2009 to 2015 (Figure 10). Lower Lookout 4 is the only site that was exotic-dominated when monitoring began in 1991 and is now native-dominated in both the "IN" and "OUT" plots (Figure 10).

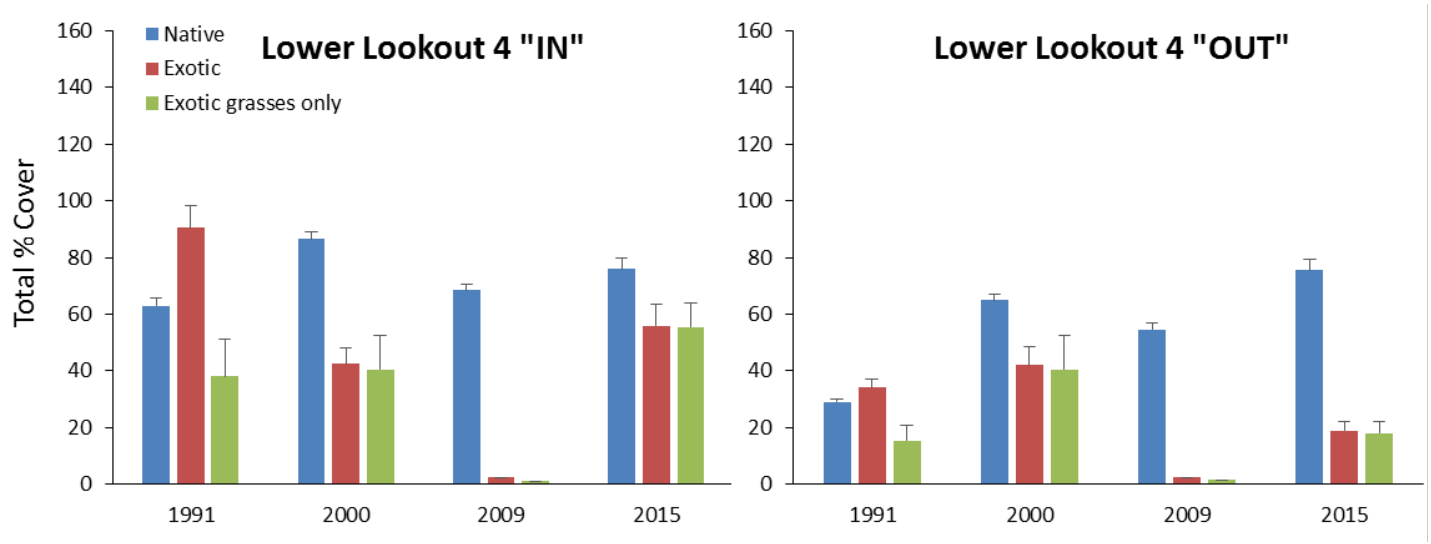

FIGURE 10. TOTAL % COVER OF NATIVE PLANT SPECIES, EXOTIC PLANT SPECIES, AND EXOTIC GRASSES ONLY FOR LOWER LOOKOUT 4 "IN" AND LOWER LOOKOUT 4 "OUT" IN 1991, 2000, 2009, AND 2015.

LOWER LOOKOUT MOUNTAIN #5

In 2015, *P. radiata* cover remained at 3% in both plots as it was in 2009, which is an increase from the cover recorded in 1991 (0.5% at each plot) (Appendix B). *A. tridentata* cover increased to 15% in 2015 from 3% in 2009 in both plots. *E. strictum* and *P. secunda* both decreased from 15% in 2009 to 3% in 2015 in the "IN" plot and stayed at 15% in the "OUT" plot. *E. elymoides* was absent from the plots in 2015, decreasing from 18% in 2009.

B. tectorum cover has fluctuated at the site over the years monitored, but has not greatly increased over time. *P. bulbosa* cover increased the most of all the exotic graminoid species from 2009 to 2015, from 0.5% to 37.5% in the "IN" plots and from 3% to 37.5% in the "OUT" plots (Appendix B). *T. caput-medusae* was recorded for the first time in the "IN" plot in 2015 (15%); it had been recorded in the "OUT" plot in 1991 (0.5%) and was found again in 2015 at 3%. In 2015, the total exotic graminoid cover was the highest recorded from 1991-2015 (Figure 11).

The total species richness at the site decreased from 2009 to 2015, from 19 to 14 at the "IN" plot and from 17 to 12 at the "OUT" plot. The native species count at the site decreased from 15 to 9 at the "IN" plot and from 12 to 8 at the "OUT" plot. Five native species (*E. elymoides, Chaenactis douglasii, Crepis occidentalis, Epilobium* sp., and *Lomatium macrocarpum*) that were present in 2009 were absent from the plots in 2015. In 2009, 4 other native species previously present at the plots were not observed. The native species count in 2015 was the lowest of all the years monitored (Appendix B). Even with these declines, the Lower Lookout Mountain 5 plots have more native species than exotic species, and these plots have the highest number of native species than any of the other sites. The total percent cover of native species remains relatively high compared to other sites (Appendix B). Along with Lower Lookout 4 "IN" and "OUT", Lower Lookout 5 "OUT" was the only other plot that was native-dominated in 2015 (Figure 10, Figure 11).

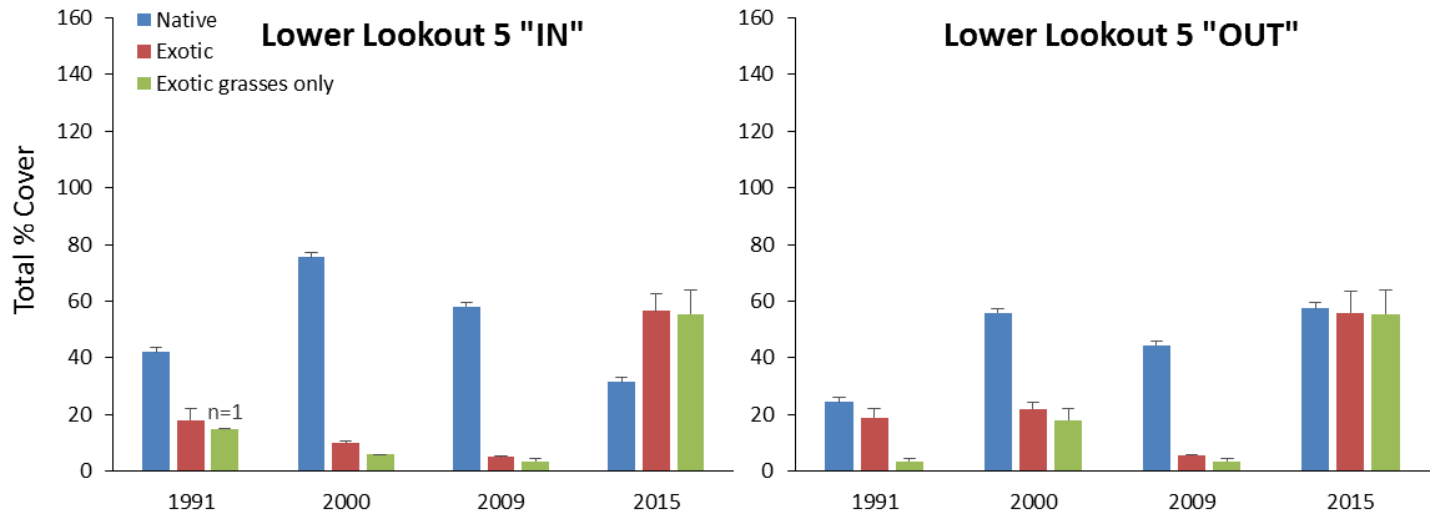

FIGURE 11. TOTAL % COVER OF NATIVE PLANT SPECIES, EXOTIC PLANT SPECIES, AND EXOTIC GRASSES ONLY FOR LOWER LOOKOUT 5 "IN" AND LOWER LOOKOUT 5 "OUT" IN 1991, 2000, 2009, AND 2015.

CONCLUSIONS

Population Monitoring

In 2015 and 2016, 75 unique sites were monitored for *P. radiata*. In 2015, a total of 16,368 *P. radiata* plants were counted across 26 sites, including 1 new record. In 2016, a total of 74,290 *P. radiata* plants were counted across 52 sites, including 3 sites that were also monitored in 2015 and 2 new records. After accounting for the 3 sites that were monitored in both 2015 and 2016 (OR035_419, OR035_991, and OR035_1636), the combined total was 87,708 plants. In 2015, 3 sites were found to contain no *P. radiata* and in 2016, 10 sites were found to contain no *P. radiata*. This total count represents the most current estimate of the extent of this species on Vale BLM lands.

The 3 sites that were monitored in both 2015 and 2016 all had higher counts of *P. radiata* in 2016 (Appendix A). Although we could not directly compare other sites, the substantial increases observed at the 3 sites re-monitored in 2016 are promising. The 2 sites that had been burned in the Lime Fire in 2015 had more than 3x the number of plants in 2016 (Appendix A). In addition, across all sites, there was a greater percentage of reproductive plants in 2016 (61%) than in 2015 (55%) (Table 1, Table 2).

Long-term Plots

In 2015, the Upper Lime study plots had the highest total number of plants compared to the four other long-term monitoring sites, with the lowest numbers at the Lower Lime site, which only had a single vegetative plant (Table 3). The unfenced ("OUT") and fenced ("IN") plots varied in their number of plants, plant height, length of longest leaf, number of leaves, number of healthy and aborted flower heads, number of grazed stems, and percentage herbivory, but these differences were not consistent across sites.

In 2015, overall *P. radiata* cover in several long-term study plots (Upper Lime "IN", Lower Lime "IN", and Upper Lookout Mountain "OUT") had decreased from 2009 (Appendix B). Kaye (2001) calculated the mean extinction probability (risk of 90% decline in 25 years) for the *P. radiata* populations at the long-term study sites. Three plots (Upper Lime "IN" and "OUT" and Upper Lookout "OUT") had less than a 20% chance of 90% decline in 25 years, while the remaining plots had a high risk of catastrophic decline (range: 62 – 100%) (Kaye 2001). In just 15 years (2000-2015) we observed 3 plots having declines greater than 90%, one of which was Upper Lookout "OUT", one of the plots that had a low extinction probability. Another plot, Lower Lime "IN", had a 100% decline from 2000 to 2015. However, the low number of *P. radiata* within long-term study plots in 2015 was not necessarily reflective of population characteristics across the entire site. Surveys conducted at the sites where these study plots were located revealed large numbers of *P. radiata* in 2016. In some cases, it appears that *P. radiata* has shifted away from areas where study plots had been established. Thus, the long-term study plots may not currently reflect the population characteristics at these sites.

Cover of exotic graminoids increased in all long-term study plots from 1991 to 2015 (Appendix B). In 2015, all but 3 plots (Lower Lookout 4 "IN" and "OUT" and Lower Lookout 5 "OUT") were exotic-dominated. Many of the dominant exotic species in study plots, including *B. tectorum*, *P. bulbosa*, and *T. caput-medusae*, were commonly observed throughout 2015 and 2016 surveys as well. Exotic annual grasses are a threat to *P. radiata* and other native species because they can outcompete native species for space and resources as well as limit seedling establishment (Johnson and Davies 2012, Young 1992). In addition to exotic annual grasses, other threats to *P. radiata* include heavy ungulate grazing, insect herbivory, soil erosion, wind turbine development, and other exotic plant species.

Conservation Status

Habitat at most *P. radiata* sites monitored has been disturbed. In Idaho, Mancuso and Moseley (1993) found that *P. radiata* sites supporting the highest quality habitat typically contained the most plants, covered the largest areas, and also seemed to have a wider range of age classes represented. They found plants were fewer in number or entirely absent, lower in density, and with little evidence of younger individuals in sites that were more degraded. Because of these patterns, they regarded the loss of high quality habitat as the most serious threat to the long-term persistence of *P. radiata* (Mancuso and Moseley 1993).

One of the main contributors to *P. radiata* habitat degradation is the spread of exotic plant species. Exotic species, especially annual grasses such as cheatgrass (*B. tectorum*) and medusahead (*T. caput-medusae*), now dominate much of the range of *P. radiata* and were encountered at nearly every site we monitored. Besides their ability to outcompete native species for space and resources and limit seedling establishment, exotic annual grasses can also alter the fire regime in areas where they are introduced (Brooks et al. 2004, Zouhar et al. 2008). Invasion of exotic annual grasses increases fire frequency by increasing the fuel surface-to-volume ratio, increasing horizontal fuel continuity, and creating a fuel packing ratio that facilitates ignition (Brooks et al. 2004). In the Snake River Plains, the sagebrush-steppe evolved with fire-return intervals of 35-100 years, but now the fire-return intervals have decreased to 2-4 years in many areas due to the invasion of cheatgrass (Whisenant 1990). A reduced fire-return interval can prevent normal vegetation replacement sequences considered essential to secondary succession (Whisenant 1990).

Although we observed successful germination and survival of *P. radiata* after fire (2015 Lime Hill Fire), it is unknown how *P. radiata* would respond to a regime of frequent, high intensity fires. Looking at over 30 years of fire records from the BLM in Shoshone, Idaho, Whisenant (1990) found that as fire frequency (fires/year) increased, perennial plants were lost from the plant community. It is likely that there is a threshold for *P. radiata* to be able to persist after successive intense wildfires and as exotic annual grasses decrease fire-return intervals, those thresholds could be met.

Although 2015 and 2016 surveys revealed many large populations of *P. radiata* (9 sites had >500 plants during 2015 surveys and 16 sites had >500 plants during 2016 surveys), many of these populations have much lower population counts/estimates than previous surveys. For example, OR035_412 had 2298 *P. radiata* plants in 2016, which seems like a sizeable population, but only 3 years before (2013) it was estimated to have 10,000 plants (Appendix A). OR035_412 had heavy insect herbivory as well as a high cover of exotic annual grasses, which could have contributed to the decrease in *P. radiata*; we observed large patches of *P. radiata* that had been heavily grazed ("skeletonized") by grasshoppers and there were several areas where *T. caput-medusae* (medusahead) was very dense and starting to thatch.

Of the 75 total sites surveyed in 2015 and 2016, 24 of these had lower population counts/estimates than historic records; since we do not have historic data for all sites that were surveyed, the number of sites that had fewer *P. radiata* than previous years could be even higher. Eighteen sites had declines > 50%, with 11 of those experiencing extreme declines (> 90% decrease). Every site that had a reduced number of *P. radiata* than previous surveys had exotic annual grasses (*B. tectorum*, *P. bulbosa*, and/or *T. caput-medusae*) present, often with > 50% cover. In addition to exotic annual grasses, human activity likely led to finding no plants in 2015 compared to 1250 plants in 2013 at OR035_403. The site is heavily used as an ORV area and also as an authorized dumpsite. Many sites had evidence of ungulate grazing, including patches of *P. radiata* with grazed flower heads and patches that had been trampled. Some sites, such as OR035_396, had a majority of *P. radiata* plants grazed by ungulates. With exotic annual grasses and heavy ungulate grazing threatening *P. radiata* populations, management should focus on reducing their impact. Exotic annual grasses should be treated using appropriate methods and timing. Currently, all *P. radiata* sites on the Vale BLM District are permitted for livestock grazing. Impacts of ungulate grazing may be reduced if cattle were fenced out of *P. radiata* populations or stocking rates are lower, and/or timing of grazing occurred at times of the year when *P. radiata* is not reproductive. Although native ungulates (deer and elk), and potentially feral horses, also could be grazing *P. radiata*, cattle grazing has more opportunity for altering rates to try to reduce the amount of grazing at the current time.

Though there were more sites surveyed with less *P. radiata* than historic records (24 sites), there were also sites that had a greater number of *P. radiata* than in previous years (12 sites) (Appendix A). Nine of these sites had > 50% more *P. radiata* than in previous years. In addition, 3 new records of *P. radiata* were observed in 2015 and 2016, one of which (OR035_1630) had the greatest number of *P. radiata* recorded at a single site with 35,000 plants (Appendix A). This site represents nearly 40% of the current known total for *P. radiata*, but only 20-25% of the plants occur on BLM lands (7000-8750) and could potentially be prioritized for management/conservation action(s). Population counts from the 3 new records combined (2016 data) revealed 43,471 plants, which greatly increased the estimate of the current population size of this species. As this area is comprised of difficult terrain in areas where plants

are often growing, further survey efforts could potentially reveal even more undocumented populations of *P. radiata*.

Despite evidence of some population growth and new populations being recorded, there are still many conservation concerns for *P. radiata*. In 2015, there were 9 sites surveyed that had population counts less than 100 plants, and in 2016, there were 15 sites with less than 100 plants (Table 1, Table 2). Sites with very low population counts have an increased risk of suffering from the deleterious effects of inbreeding and demographic stochasticity (Soulé 1987). From the historic data we have, we observed 2 sites that had population counts < 30 in previous surveys that now did not have any *P. radiata* in 2016 (Appendix A). Current populations (surveyed in 2016) range from 2 to 35,000 individuals and likely have varying abilities to withstand current and future threats.

Another major threat facing all *P. radiata* populations is climate change. Taking climate change into account, Pfingsten (2012) found that all population models projected slight *P. radiata* population decreases by 2050 under two different emission scenarios ("optimistic" and "pessimistic"). Kaye (2002) found that population growth rate (λ) was correlated with climate, with population growth rate being positively correlated with fall (October through December) precipitation. In addition, flower head production was positively correlated with winter (January through March) precipitation (Kaye 2002). Thus, changes in amount of precipitation, especially in the fall and winter, could have detrimental effects on the population growth rate and flower head production of *P. radiata*. With a changing landscape and a changing climate, *P. radiata* could be at risk for population declines.

Despite the different factors threatening *P. radiata* populations, *P. radiata* has proven to be a fairly robust plant. *P. radiata* has a substantial root stock that allows it to survive after grazing and/or fire. After the Lime Fire in 2015, not only were the burned populations more robust in 2016, but we also observed *P. radiata* growing in the bulldozed fire-line. Due to its resiliency, it is being considered for selection by the Vale BLM to be used in future fire restoration efforts. Collection of *P. radiata* seed will allow it to be included among a suite of native species seeded in areas that have been burned by wildfire throughout the range of the species. In addition to these seeding efforts, *P. radiata* could spread naturally since there are multiple large source populations across the region. Many of these populations are healthy with a large percentage of reproductive individuals. With targeted management actions and restoration efforts, *P. radiata* populations can become a model for successful conservation.

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APPENDIX A. LIST OF *PYRROCOMA RADIATA* POPULATIONS SAMPLED IN 2015 AND 2016 OCCURRING ON VALE BLM LANDS. INCLUDES HISTORICAL DATA FROM GEOBOB WHERE AVAILABLE.

SITE ID	YEAR	COUNT*
846	2016	2702
	1997	5000
OR035_1636**	2016	971
	2015	700
OR035_1629**	2016	7500
OR035_1630**	2016	35,000
OR035_1101	2016	7
OR035_1102	2015	1212
OR035_1104	2015	42
OR035_1105	2015	12
OR035_1106	2016	0
OR035_1107	2016	289
OR035_1108	2015	324
OR035_1109	2015	1770
	1997	4
OR035_1111	2016	748
	2013	10,000
OR035_1115	2016	189
	2013	119
OR035_1116	2015	24
OR035_1117	2015	117
OR035_1118	2015	42
OR035_1119	2016	898
OR035_1120	2016	2
OR035_1121	2016	94
	2013	6
OR035_1122	2016	0
	2013	27
OR035_1451	2016	1359
	2007	100
OR035_1456	2016	8
	1996	1
OR035_1457	2016	89
OR035_1458	2016	0
	1997	4
OR035_1459	2016	143
	2003	500
OR035_382	2016	0
OR035_383	2016	34
OR035_384	2016	68

	2013	400
	1996	1
OR035_386	2015	590
	2013	4000
OR035_387	2015	256
OR035_388	2016	42
	2013	27
OR035_389	2015	70
	2013	105
OR035_390	2016	344
OR035_391	2016	189
	2013	197
OR035_392	2016	3870
	2013	1000
OR035_393	2016	124
OR035_394	2015	245
OR035_395	2016	707
OR035_396	2016	1000
	1997	21,245
	1989	550
OR035_397	2015	489
OR035_398	2015	0
OR035_399	2016	83
	2011	150
	1997	3000
	1989	75
OR035_402	2016	44
	2013	2500
OR035_403	2015	0
	2013	1250
OR035_404	2015	119
OR035_406	2016	117
	2013	1200
OR035_408	2016	1449
OR035_409	2016	4012
	2013	4000
OR035_412	2016	2298
	2013	10,000
OR035_413	2016	1372
OR035_414	2015	170
OR035_415	2015	3109
	2013	1200
OR035_416	2016	98
	2013	550
OR035_418	2015	782

	2013	2500
OR035_419	2016	6240
	2015	2000
OR035_421	2016	11
OR035_422	2015	2145
	2013	325
	1997	2700
	1990	500
OR035_845	2015	0
OR035_905	2015	92
OR035_906	2016	195
	2013	1065
	1997	2700
OR035_960	2015	1808
OR035_971	2016	372
OR035_972	2016	434
OR035_973	2016	0
OR035_976	2016	0
OR035_978	2016	115
	2013	105
OR035_979	2016	13
	2013	1150
OR035_980	2016	0
OR035_981	2016	0
OR035_986	2016	0
OR035_987	2016	0
	2013	550
OR035_988	2016	38
	2013	1065
OR035_989	2016	6
	2013	197
	2003	500
OR035_991	2016	1016
	2015	250
	2013	325
	2007	63
	1997	2700

*Only includes records with specific counts/estimates, including verified records of no plants at a site.
**Populations first mapped in 2015 or 2016.

APPENDIX B. PLANT COMMUNITY DATA FROM LONG-TERM PLOTS FROM 1991-2015 BY SITE.

The cover codes follow Kaye (2001): 1= >1%, 2= 1-5%, 3= 5-25%, 4= 25-50%, 5= 50-75%, 6= 75-100%. Mid-points of each cover class were assigned to individual species and used to calculate averages: 1 = 0.5%, 2 = 3%, 3 = 15%, 4 = 37.5%, 5 = 62.5%, 6 = 87.5%. *Pyrrocoma radiata) [Snake River goldenweed (syn. *Haplopappus radiatus*)] in bold.

Upper Lime

		Upper Lime "IN"				Upper Lime "OUT"			
Species	**Native/Intro**	**1991**	**2000**	**2009**	**2015**	**1991**	**2000**	**2009**	**2015**
Alyssum alyssoides	Introduced	0.5	0.5	0.5	-	3	3	0.5	-
Balsamorhiza sagittata	Native	3	0.5	-	0.5	15	3	0.5	15
Brodiaea howellii	Native	-	0.5	-	-	-	-	-	-
Bromus hordeaceus ssp. *hordeaceus*	Introduced	-	-	-	0.5	-	-	-	-
Bromus tectorum	Introduced	15	15	15	62.5	15	37.5	37.5	62.5
Lepidium draba	Introduced	-	-	-	3	-	-	-	-
Collinsia parviflora	Native	-	0.5	-	-	-	0.5	-	-
Collomia grandiflora	Native	0.5	-	-	-	-	-	-	-
Crepis occidentalis	Native	3	3	-	-	0.5	3	-	-
Epilobium sp.	Native	-	-	0.5	-	-	0.5	-	0.5
Erodium cicutarium	Introduced	3	0.5	0.5	-	0.5	0.5	-	-
Helianthus cusickii	Native	-	-	-	-	-	0.5	0.5	-
Lactuca serriola	Introduced	-	-	15	3	-	-	0.5	0.5
Lomatium macrocarpum	Native	-	-	0.5	-	-	-	-	-
Lomatium triternatum	Native	15	15	0.5	-	3	0.5	-	-
Lupinus arbustus ssp. *calcaratus*	Native	-	-	-	-	-	0.5	-	-
Melilotus officinalis	Introduced	-	-	-	-	-	0.5	-	-
Phacelia hastata	Native	0.5	0.5	-	-	-	0.5	0.5	-
Phlox sp.	Native	0.5	-	-	-	-	-	-	-
Poa bulbosa	Introduced	0.5	-	0.5	37.5	-	-	15	62.5
Poa secunda	Native	0.5	-	0.5	-	-	-	0.5	3
Pseudoroegneria spicata	Native	-	-	-	-	-	0.5	0.5	-
Pyrrocoma radiata	Native	37.5	37.5	37.5	15	15	37.5	37.5	37.5
Ranunculus testiculatus	Introduced	3	0.5	-	-	-	-	-	-
Sisymbrium sp.	Introduced	-	-	-	0.5	-	-	-	-
Taeniatherum caput-medusae	Introduced	-	-	15	15	-	-	-	3
Tragopogon dubius	Introduced	-	-	0.5	-	-	-	0.5	-
Total species richness	27	13	11	12	9	7	14	11	8
Native species richness	15	8	7	5	2	4	10	6	4
Introduced species richness	12	5	4	7	7	3	4	5	4
Total % cover native species		61	58	40	16	34	47	40	56
Total % cover exotic species		22	17	47	122	19	42	54	129
Total % cover exotic graminoids		16	15	31	116	15	38	53	128

Lower Lime

		Lower Lime "IN"				Lower Lime "OUT"			
Species	**Native/Intro**	**1991**	**2000**	**2009**	**2015**	**1991**	**2000**	**2009**	**2015**
Achillea millefolium	Native	-	-	-	-	0.5	-	-	-
Amsinckia tesselata	Native	-	0.5	-	-	-	0.5	-	-
Artemisia tridentata	Native	15	15	15	15	3	15	37.5	37.5
Balsamorhiza sagittata	Native	15	3	3	3	3	0.5	0.5	3
Bromus tectorum	Introduced	37.5	0.5	3	87.5	37.5	3	3	62.5
Lepidium draba	Introduced	37.5	-	15	-	-	-	-	-
Carduus nutans	Introduced	-	-	0.5	-	-	-	0.5	-
Chorispora tenella	Introduced	0.5	0.5	-	-	0.5	0.5	-	-
Crepis occidentalis	Native	0.5	0.5	-	-	0.5	0.5	-	-
Epilobium sp.	Native	-	-	-	-	-	-	-	0.5
Erodium cicutarium	Native	-	-	0.5	-	-	-	0.5	-
Helianthus annuus	Native	-	-	0.5	-	-	-	0.5	-
Helianthus cusickii	Native	-	-	-	0.5	-	-	-	0.5
Lactuca serriola	Introduced	-	15	3	0.5	-	0.5	0.5	0.5
Leymus cinereus	Native	-	-	-	0.5	-	-	-	-
Lomatium triternatum	Native	-	-	-	-	0.5	-	-	-
Lupinus arbustus ssp. *calcaratus*	Native	0.5	0.5	-	-	0.5	0.5	-	-
Phlox sp.	Native	0.5	-	-	-	0.5	-	-	-
Poa bulbosa	Introduced	-	87.5	62.5	37.5		62.5	62.5	15
Poa secunda	Native	-	-	-	-	37.5	0.5	0.5	3
Pseudoroegneria spicata	Native	0.5	0.5	0.5	-	0.5	-	0.5	0.5
Pyrrocoma radiata	Native	**3**	**15**	**15**	**0.5**	**15**	**3**	**0.5**	**0.5**
Ranunculus testiculatus	Introduced	15	0.5	-	-	0.5	0.5	-	-
Sisymbrium sp.	Introduced	-	-	3	0.5	-	-	0.5	-
Taeniatherum caput-medusae	Introduced	0.5	-	-	15	0.5	-	15	3
Tragopogon dubius	Introduced	-	-	3	3	-	-	0.5	0.5
Total species richness	26	12	12	13	11	14	12	14	12
Native species richness	15	7	7	5	5	10	7	6	7
Introduced species richness	11	5	5	8	6	4	5	8	5
Total % cover native species		35	35	34	20	61	21	40	45
Total % cover exotic species		91	104	88	144	39	67	83	82
Total % exotic graminoid species		38	88	66	140	38	66	81	81

Upper Lookout Mountain

		Upper Lookout Mtn "IN"				Upper Lookout Mtn "OUT"			
Species	**Native/Intro**	**1991**	**2000**	**2009**	**2015**	**1991**	**2000**	**2009**	**2015**
Achillea millefolium	Native	0.5	0.5	0.5	-	0.5	0.5	3	3
Alyssum alyssoides	Introduced	-	-	0.5	-	-	0.5	0.5	0.5
Amaranthus sp.	Native	-	-	-	-	-	-	-	0.5
Amsinckia tesselata	Native	-	0.5	0.5	-	-	-	0.5	-
Artemisia tridentata	Native	-	-	-	3	-	-	-	-
Balsamorhiza sagittata	Native	0.5	3	3	15	0.5	3	3	3
Bromus hordeaceus ssp. *hordeaceus*	Introduced	-	15	-	-	-	15	0.5	-
Bromus tectorum	Introduced	37.5	15	15	87.5	62.5	37.5	0.5	37.5
Lepidium draba	Introduced	-	-	0.5	3	-	-	3	3
Carduus nutans	Introduced	-	-	-	-	-	-	0.5	-
Chorispora tenella	Introduced	-	0.5	-	-	-	-	-	-
Cirsium sp.	Unassigned	-	-	-	-	-	-	0.5	-
Crepis occidentalis	Native	0.5	3	-	-	0.5	15	-	-
Elymus elymoides	Native	-	-	3	-	-	3	3	-
Epilobium sp.	Native	-	-	3	0.5	-	-	0.5	-
Eriogonum strictum	Native	-	-	-	-	-	-	-	3
Erodium cicutarium	Introduced	15	0.5	0.5	-	15	0.5	15	-
Grindelia nana	Native	-	-	-	-	-	-	0.5	-
Helianthus annuus	Native	-	-	-	-	-	-	0.5	-
Helianthus cusickii	Native	-	0.5	3	15	-	0.5	0.5	0.5
Lactuca serriola	Introduced	-	-	0.5	0.5	-	-	0.5	0.5
Lagophylla ramossisima	Native	-	-	0.5	-	-	-	0.5	-
Lepidium sp.	Introduced	-	-	-	0.5	-	-	-	-
Lithophragma glabrum	Native	-	-	-	-	-	0.5	-	-
Lomatium macrocarpum	Native	-	-	-	-	-	0.5	-	-
Lupinus arbustus ssp. *calcaratus*	Native	-	-	-	-	-	-	0.5	-
Madia sp.	Native	-	-	-	3	-	-	-	-
Phlox sp.	Native	0.5	0.5	-	-	-	0.5	-	-
Poa bulbosa	Introduced	-	15	15	15	-	15	15	37.5
Poa secunda	Native	-	3	3	-	-	15	15	-
Pseudoroegneria spicata	Native	-	-	3	0.5	-	0.5	-	-
Pyrrocoma radiata	Native	**0.5**	**15**	**3**	**15**	**0.5**	**15**	**3**	**-**
Ranunculus testiculatus	Introduced	3	0.5	-	-	3	-	-	-
Sisymbrium sp.	Introduced	-	-	0.5	-	-	-	3	3
Taeniatherum caput-medusae	Introduced	62.5	0.5	15	15	37.5	-	3	37.5
Tragopogon dubius	Introduced	-	-	0.5	0.5	-	-	0.5	-
Total species richness	35	9	15	19	14	8	16	24	12
Native species richness	21	5	8	10	7	4	12	14	6
Introduced species richness	14	4	7	9	7	4	4	10	6
Total % cover native species		3	26	23	52	2	54	31	10
Total % cover exotic species		118	47	48	122	118	69	42	120
Total % cover exotic graminoids		100	31	45	118	100	53	19	113

Lower Lookout Mountain #4

		Lower Lookout Mtn. 4 "IN"				Lower Lookout Mtn. 4 "OUT"			
Species	**Native/Intro**	**1991**	**2000**	**2009**	**2015**	**1991**	**2000**	**2009**	**2015**
Alyssum alyssoides	Introduced	-	0.5	0.5	-	0.5	0.5	0.5	0.5
Amsinckia tesselata	Native	-	0.5	-	-	-	0.5	-	-
Artemisia tridentata	Native	0.5	15	15	37.5	0.5	37.5	37.5	37.5
Astragalus purshii	Native	0.5	0.5	-	-	0.5	0.5	0.5	-
Astragalus vallaris	Native	0.5	0.5	0.5	-	0.5	-	0.5	-
Balsamorhiza sagittata	Native	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Bromus tectorum	Introduced	37.5	37.5	0.5	15	15	3	0.5	3
Chrysothamnus viscidiflorus	Native	0.5	3	0.5	0.5	3	3	3	0.5
Collomia grandiflora	Native	-	0.5	-	-	-	0.5	-	-
Crepis occidentalis	Native	15	3	-	0.5	3	0.5	0.5	-
Elymus elymoides	Native	-	3	15	0.5	-	0.5	0.5	-
Epilobium sp.	Native	-	-	-	-	-	-	0.5	-
Ericameria nauseosus	Native	0.5	3	3	3	3	15	3	3
Eriogonum strictum	Native	3	15	15	15	0.5	0.5	0.5	15
Erodium cicutarium	Introduced	15	0.5	0.5	-	3	0.5	-	-
Helianthus cusickii	Native	-	-	0.5	0.5	-	-	-	0.5
Leymus cinereus	Native	-	-	-	-	0.5	0.5	0.5	0.5
Lomatium macrocarpum	Native	0.5	0.5	-	-	0.5	0.5	-	-
Lomatium triternatum	Native	0.5	0.5	-	-	0.5	0.5	-	-
Lupinus arbustus ssp. *calcaratus*	Native	-	-	-	-	-	0.5	0.5	-
Penstemon speciosus	Native	-	-	0.5	-	-	-	0.5	-
Phlox sp.	Native	0.5	0.5	-	-	0.5	0.5	-	-
Poa bulbosa	Introduced	-	3	0.5	37.5	-	37.5	0.5	15
Poa secunda	Native	37.5	37.5	15	15	15	3	3	15
Pyrrocoma radiata	Native	**3**	**3**	**3**	**3**	**0.5**	**0.5**	**3**	**3**
Ranunculus testiculatus	Introduced	37.5	0.5	-	-	15	0.5	-	-
Taeniatherum caput-medusae	Introduced	0.5	-	-	3	0.5	-	0.5	-
Tragopogon dubius	Introduced	-	0.5	0.5	0.5	-	-	0.5	0.5
Total species richness	28	17	22	16	14	19	22	20	13
Native species richness	21	13	16	11	10	14	17	15	9
Introduced species richness	7	4	6	5	4	5	5	5	4
Total % cover native species		63	87	69	76	29	65	55	76
Total % cover exotic species		91	43	3	56	34	42	3	19
Total % cover exotic graminoids		38	41	1	56	16	41	2	18

Lower Lookout Mountain #5

		Lower Lookout Mtn. 5 "IN"				Lower Lookout Mtn. 5 "OUT"			
Species	**Native/Intro**	**1991**	**2000**	**2009**	**2015**	**1991**	**2000**	**2009**	**2015**
Achillea millefolium	Native	0.5	0.5	0.5	0.5	-	0.5	0.5	3
Alyssum alyssoides	Introduced	-	0.5	0.5	0.5	0.5	0.5	0.5	-
Amsinckia tesselata	Native	-	0.5	-	-	-	0.5	-	-
Antennaria dimorpha	Native	0.5	-	-	-	-	-	-	-
Artemisia tridentata	Native	-	3	3	15	0.5	3	3	15
Astragalus purshii	Native	0.5	0.5	-	-	0.5	0.5	-	-
Astragalus vallaris	Native	-	0.5	0.5	3	-	-	-	-
Balsamorhiza sagittata	Native	-	-	-	-	-	-	0.5	0.5
Bromus tectorum	Introduced	15	3	3	3	3	15	0.5	15
Cheanactis douglasii	Native	-	-	0.5	-	-	-	-	-
Chrysothamnus viscidiflorus	Native	-	-	0.5	0.5	0.5	0.5	0.5	3
Crepis occidentalis	Native	3	3	0.5	-	3	0.5	-	-
Draba verna	Introduced	-	3	-	-	-	3	-	-
Elymus elymoides	Native	0.5	15	15	-	-	0.5	3	-
Epilobium sp.	Native	-	-	0.5	-	-	-	0.5	-
Ericameria nauseosus	Native	3	15	3	0.5	-	15	3	3
Eriogonum strictum	Native	15	15	15	3	3	15	15	15
Erodium cicutarium	Introduced	-	-	-	-	-	-	0.5	-
Grindelia nana	Native	-	-	-	-	-	3	-	-
Lactuca serriola	Introduced	-	-	0.5	-	-	-	0.5	-
Lomatium macrocarpum	Native	3	3	0.5	-	0.5	0.5	-	-
Lomatium triternatum	Native	-	0.5	-	-	0.5	0.5	-	-
Phlox sp.	Native	-	0.5	-	-	0.5	0.5	-	-
Poa bulbosa	Introduced	-	3	0.5	37.5	-	3	3	37.5
Poa secunda	Native	15	15	15	3	15	15	15	15
Pseudoroegneria spicata	Native	0.5	0.5	0.5	3	-	-	0.5	-
Pyrrocoma radiata	Native	**0.5**	**3**	**3**	**3**	**0.5**	**0.5**	**3**	**3**
Ranunculus testiculatus	Introduced	3	0.5	-	-	15	0.5	-	-
Taeniatherum caput-medusae	Introduced	-	-	-	15	0.5	-	-	3
Tragopogon dubius	Introduced	-	-	0.5	0.5	-	-	0.5	0.5
Total species count	30	13	20	19	14	14	20	17	12
Native species count	21	12	16	15	9	10	16	12	8
Introduced species count	9	2	5	5	5	4	5	6	4
Total % cover native species		42	76	58	32	25	56	45	55
Total % cover exotic species		18	10	5	57	19	22	6	56
Total % cover exotic graminoids		15	6	4	56	4	18	4	56

APPENDIX C. DESCRIPTION OF *PYRROCOMA RADIATA* LONG-TERM PLOT LOCATIONS FROM KAYE (2002).

Upper Lime (site 1): This site is located on a south-facing slope at 2000 feet elevation in an unnamed tributary drainage of the Burnt River, about ¾ air mile northwest of Lime, T13S R44E S27 SW1/4 NW1/4. The site is best reached by taking the Lime exit off Highway 84 south-bound, and turning right (west) across the railroad tracks and through a gate (north of the over-pass). This dirt road doubles back north for about ½ mile then climbs west in the direction of Table Rock. Where the road begins to climb it may be impassable in wet weather, and the plot must be reached by foot. In either case, continue to follow the road up-hill for about ½ mile, then drop down (southeast) to the site. Two plots (1-in & 1-out), one inside and one outside of an exclosure, are located at this site. The fenced plot is below the unfenced plot. The Lower Lime site can be reached by continuing downhill from this site about ½ mile.

Lower Lime (site 2): This site is located on an east-facing, gentle slope at 2480 feet elevation with high shrub cover (*Artemisia tridentata*), about ½ air mile north of Lime, T13S R44E S27 SW1/4 NE1/4. It is about ½ mile below (east) of the Upper Lime site. To reach the site, take the Lime exit of Highway 84 south-bound and turn right (west) across the railroad tracks and through a gate (before the over-pass). This site can be reached either by driving on to the Upper Lime site and dropping down (east), or by parking among the trees just after crossing the railroad track, and walking uphill (southwest) to the site. Two plots (2-in & 2-out), one inside and one outside of an exclosure, are located at this site. The fenced plot is located southeast (and downhill) from the unfenced plot.

Upper Lookout Mountain (site 3): This site is located about ½ air mile northeast of the Lower Lookout site (see below) on a gentle, west-facing slope below the Lookout Mountain Road, T12S R44E S33 NE1/4 SE1/4. Elevation here is 2960 feet. The site is reached by following the directions to the Lower Lookout site, continuing past this site about ¾ mile along the Lookout Mountain Road, and parking at a pullout by the next cattle guard. There are two plots at this site (3-in & 3-out), one inside the exclosure, and one outside. Plot 3-out is located west (downhill) from plot 3-in.

Lower Lookout Mtn. (sites 4-5): This site is located about 2 road miles south of Weatherby off Highway 84 along the Lookout Mountain Road, on a west-facing slope at 2720 feet elevation, T12S R44E S33 SW1/4 SE1/4. To reach the site, take the Lookout Mountain Road exit off Highway 84, and drive east on this road approximately ½ mile to a pullout at a cattle guard. The site is up-hill (north) of the road. Four plots (4-in, 4-out, 5-in, & 5-out), two inside and two outside of exclosures, are located at this site. Plot 4-in (with fence) is located northeast of plot 5-in (also fenced). Plot 4-out is northwest of 4-in, and 5-out is east of 5-in.