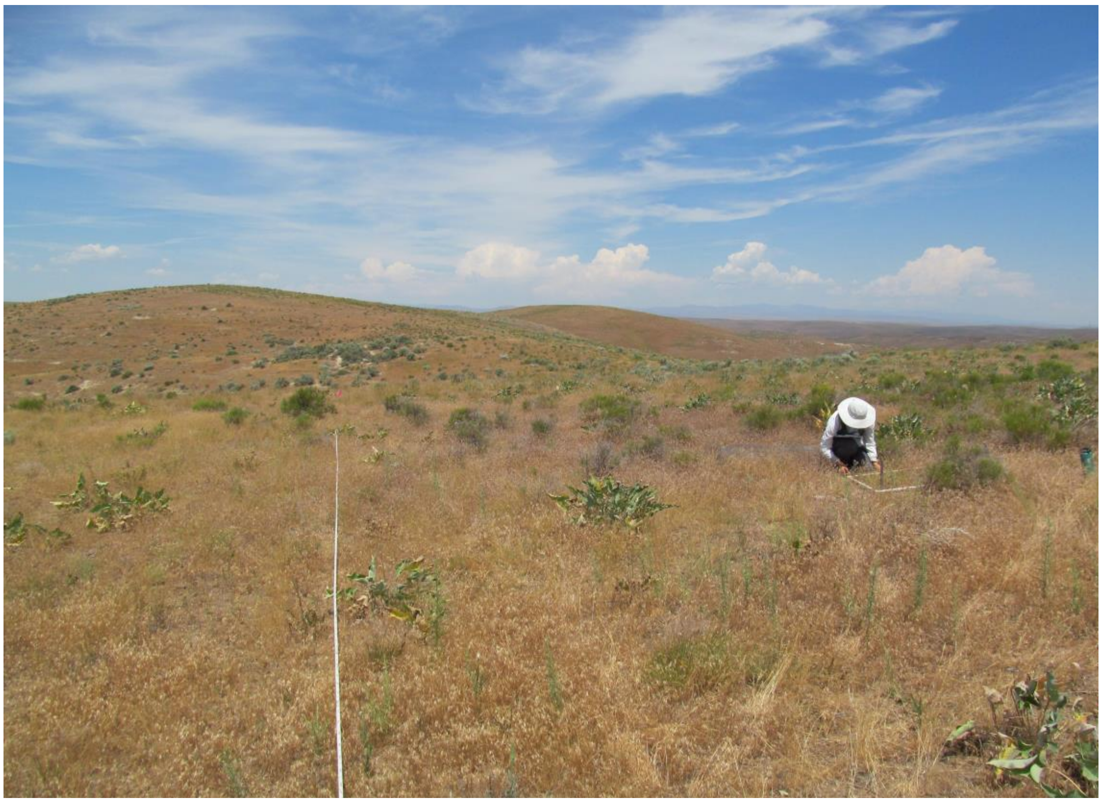
Astragalus mulfordiae: Population dynamics and the effect of cattle grazing in the Vale District, BLM



2017

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

Report prepared by Meaghan Petix, Erin Gray, and Matt Bahm

Institute for Applied Ecology

Institute for Applied Ecology

PREFACE

This coordinated by the Institute for Applied Ecology (IAE) and is funded by the Bureau of Land Management. IAE is a non-profit organization whose mission is conservation of native ecosystems through restoration, research and education. IAE provides services to public and private agencies and individuals through development and communication of information on ecosystems, species, and effective management strategies. Restoration of habitats, with a concentration on rare and invasive species, is a primary focus. IAE conducts its work through partnerships with a diverse group of agencies, organizations and the private sector. IAE aims to link its community with native habitats through education and outreach.

Institute for Applied Ecology

Questions regarding this report or IAE should be directed to:

Matt Bahm

Conservation Research Program Director

Institute for Applied Ecology

563 SW Jefferson Avenue

Corvallis, Oregon 97333

phone: 541-753-3099

fax: 541-753-3098

email: mattab@appliedeco.org

ACKNOWLEDGEMENTS

Funding for this project was provided by the Cooperative Challenge Cost Share Programs and the Interagency Special Status/Sensitive Species Program. The authors gratefully acknowledge the contributions and cooperation by the Vale District Bureau of Land Management, especially Susan Fritts. In 2017, work was supported by IAE staff members Michelle Allen, Lucy Keehn, Nadav Mouallem, Abbie Harold, and Tom Kaye.

Cover photograph: Mulford's milkvetch (*Astragalus mulfordiae*) habitat and monitoring plots at South Alkali.

Suggested Citation

Petix, M.I., E.C. Gray, and M.A. Bahm. 2017. *Astragalus mulfordiae:* Population dynamics and effects of cattle grazing in the Vale District BLM. Institute for Applied Ecology, Corvallis, Oregon and USDI Bureau of Land Management, Vale District. vi + 64 pp.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This document summarizes monitoring of *Astragalus mulfordiae* (Mulford's milkvetch) on land managed by the BLM Vale District. In 2017, we monitored plots testing for effects of herbivory on *A. mulfordiae* in permanent plots along with transects monitoring long-term population trends and plant community composition.

- In 2017 we observed an increase in number of *A. mulfordiae* from 2016. We counted 242 plants total, with 78 in caged plots and 164 in uncaged plots. 124 new plants were observed in 2017. Despite there being over a two-fold increase since 2014, total number of plants still remains less than numbers observed in 2008-2010.
- In 2017, 18 plots that were once established due to high densities of *A. mulfordiae* no longer contained the species. However, 8 plots that were found empty last year were found to have new *A. mulfordiae* individuals in 2017.
- We found that size of *A. mulfordiae* differed significantly by site and by treatment (caged or uncaged) for certain sites in 2017. Plants at Snively, South Alkali, and Brown Butte were the largest while those at North Harper North and Double Mountain were the smallest.
- Reproductive effort was variable across sites, with Double Mountain and North Harper North having the fewest reproductive plants (2 and 5, respectively) and South Alkali having the most reproductive plants (38). North Harper South and Brown Butte had the highest average number of fruits per reproductive plant (120 and 74, respectively), which was mainly due to just a few large plants that produced many fruits.
- In plots established in 2008, we observed an increase in total number of plants from 2016 to 2017. It is promising to observe an increasing trend over the last three years after the decline in *A. mulfordiae* that had been exhibited from 2008-2014 across all plots and sites.
- In population monitoring transects, number of *Astragalus mulfordiae* increased from 77 to 134 in 2017. Despite this increase, total number of plants is still less than that observed in 2010 (178 plants total).
- In 2017, 19% of plants observed along the transects were reproductive, which was a decrease from that seen in 2016 (40%). In 2017, 45% were seedlings, which was an increase from 30% observed in 2016.
- The plant communities at these sites have varied from 2010 to 2017. Exotic species cover (as percent of total cover), primarily composed of *Bromus tectorum* (cheatgrass), has increased from 2010 to 2017 at all sites except North Harper North and South Alkali. In 2017, all sites were exotic-dominated except for North Harper North.
- We found little evidence that cattle grazing has had consistent effects on the populations of *A. mulfordiae* at these sites. While stocking rates have remained similar on sites, populations have varied greatly over the years. The one site with a higher stocking rate, South Alkali, is grazed during the winter, so impacts on the plants are likely minimal.
- Continued monitoring and immediate attention may be necessary to mitigate any future losses of this rare species.

Astragalus mulfordiae: Population dynamics and the effect of cattle grazing in the Vale District, BLM

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

INTRODUCTION

Astragalus mulfordiae (Fabaceae, Mulford's milkvetch; Figure 1) is listed as a Sensitive Plant Species by the USDI Bureau of Land Management, a Species of Concern by the United States Fish and Wildlife Service, and endangered by the state of Oregon Department of Agriculture (ORBIC 2013). In 1995, there were 34 known *A. mulfordiae* populations in Idaho and 38 in Oregon (DeBolt 1995). Oregon Natural Heritage Information Center currently notes 29 occurrences scattered over 1191 km^2 in Oregon with a total metapopulation size of less than 12,000 (ORNHIC 2009).

FIGURE 1. MULFORD'S MILKVETCH (*ASTRAGALUS MULFORDIAE*) IN FRUIT.

Astragalus mulfordiae is found from the Owyhee Uplands of Malheur County, Oregon east to the Owyhee Front and Boise Foothills of western Idaho. It primarily occurs in shrub-steppe and desert shrub communities on sandy substrates derived from lacustrine and alluvial sediments, including old river deposits, sandy places near rivers, sandy bluffs, and dune-like talus. Primary plant associates include *Hesperostipa comata* (needle-and-thread grass), *Achnatherum hymenoides* (Indian ricegrass), *Chrysothamnus viscidiflorus* (green rabbitbrush), *Penstemon acuminatus* (sharpleaf penstemon), and *Poa secunda* (Sandberg bluegrass).

Astragalus mulfordiae relies on environmental cues in late winter and early spring to initiate its regrowth and phenological stages (DeBolt 1995). In general, regrowth begins in early March, followed by flowering in April, May, and sometimes into June. The pollination mechanism is unknown; flying insects or self-pollination are likely options (DeBolt 1995). Fruits mature in June and July and plants senesce shortly thereafter. *Astragalus mulfordiae* reproduces only by seed, which is dispersed by gravity and wind (DeBolt 1995).

Monitoring studies of *A. mulfordiae* provide evidence for a drastic decline in population sizes (CPC 2009). Some populations have been extirpated through ORV use, cattle grazing, and fire. Plants were typically absent after the third year of cattle grazing (DeBolt 2001). In a study of areas seeded with *Agropyron desertorum*, fruits per inflorescence, inflorescences per plant, and adult plant survival of *A. mulfordiae* were all lower in areas grazed by cattle (David Pyke, personal communication). However, populations appear to vary in their ability to withstand disturbances (DeBolt 1995, 2001) and there may be a genetic difference between populations that are more susceptible or more tolerant of disturbance (DeBolt 2001).

Competition with exotic plant species, particularly *Agropyron desertorum* (desert wheatgrass), *Chondrilla juncea* (rush skeletonweed), and *Bromus tectorum* (cheatgrass), may also impact populations of *Astragalus mulfordiae*. Competition with exotic species appears to be particularly problematic in areas that have recently burned and/or are heavily grazed.

This project provides long-term data on the population biology and trends of *A. mulfordiae* in the Owyhee Uplands of eastern Oregon. In order to determine the effects of ungulates on *A. mulfordiae*, we used small cages to protect groups of plants that experience different levels and types of grazing. Data resulting from this project provides valuable information to assist agencies making listing decisions for the species, managing livestock grazing in various allotments, and planning conservation strategies and recovery plans. More specifically, this study was designed to:

1. Document long-term trends in population size and structure.
2. Document long-term trends in habitat quality and plant community dynamics in areas occupied by *A. mulfordiae*
3. Determine the effect of grazing on population size and reproduction.
4. Determine the role of climatic variation (e.g., annual changes in precipitation) in observed differences in population size and reproduction (requires 10 years of sequential data).
5. Compare Oregon population dynamics with Idaho population dynamics.

METHODS

Field Sites

All sites are located near Vale, Oregon in the Vale District, BLM. After initial site visits in 2007, six *A. mulfordiae* populations were chosen for plot establishment: Brown Butte, Double Mountain, North Harper North, North Harper South, South Alkali ACEC, and Snively (Table 1Table 1, Appendix B).

Table 1. Site characteristics including total # of plots present in 2017.

Site (location of GPS pt)	Location (Nad83, Zone11)	Fire history	Grazing	# plots
South Alkali #1 (plot 648)	0484252E 4878746N	unknown	fall cattle grazing	3 caged 3 uncaged
South Alkali #2 (plot 653)	0486054E 4878989N	unknown	fall cattle grazing	3 caged 4 uncaged
South Alkali #3 (transect start)	0485982E 4877837N	unknown	fall cattle grazing	4 caged 4 uncaged
Brown Butte (transect start)	0489997E 4842103N	Fire: late 90's	summer cattle grazing	6 caged 5 uncaged
Snively (transect start)	0484372E 4840786N	unknown	spring cattle grazing	5 caged 4 uncaged
Double Mountain (transect start)	0476635E 4853382N	Fire: 2005	not grazed	5 caged 3 uncaged
North Harper North (transect start)	0481055E 4857204N	unknown	summer cattle grazing	5 caged 5 uncaged
North Harper South (plot 675)	0481446E 4856682N	unknown	summer cattle grazing	6 caged 6 uncaged

Herbivory Study

FIGURE 2. *ASTRAGALUS MULFORDIAE* CONTROL (UNCAGED) MONITORING PLOT. THE CORNERS ARE MARKED WITH 10" NAILS.

In 2008, we established 10-15 plots at each study site to determine the effects of ungulates (primarily sheep and cattle) on *A. mulfordiae* and track individual plants over time (Table 1). Plot locations were systematically selected to maximize the number of individuals within a 1m^2 area. Half of the plots were uncaged (Figure 2), the other half were caged. We did not use a random sampling design because we wanted to ensure that there were enough plants within each plot to detect differences in growth, survival, and reproduction; we additionally wanted the caged and control plots to be well distributed throughout the population. All plots were marked in each corner with 10 inch steel nails and/or wooden stakes protruding from the soil surface. The plots were aligned with the cardinal directions; an aluminum tag noting the plot number the southeast corner of each plot. Caged plots allowed us t grazing and trampling by sheep and cattle on *A. mulfordiae* when collected data was compared to data from uncaged plots. The cage design also inhibited native ungulate grazing and trampling, but small mammals and birds could still access the space within the cages. Although we did not pair uncaged and caged plots, we attempted to locate one of each type within close proximity to control for the effects of microclimate and micro-topography. Each caged plot was covered on the top and sides with hogwire. The cages stood approximately 0.3 m high and were slightly larger than 1m^2. They were held in place with wire tied to wooden stakes sunk into the corners of the plots. Plots were monitored in 2008-2010 and 2012-2017.

Twenty-five additional plots were added in 2012 due to high mortality observed and the lack of *A. mulfordiae* in 22 of the existing plots (2 of which were not present in 2009 monitoring). We targeted areas where there would be at least 2 *A. mulfordiae* per plot, which were often difficult to find due to low densities. We sought to replace caged and uncaged plots in their general proximity to maintain similar numbers of each treatment while targeting areas with *A. mulfordiae* (Figure 2). Though in 2013 many plots had no *A. mulfordiae* present, we did not replace them because at many sites it was difficult finding locations that fulfilled our minimum qualification of at least two plants per plot. Given the large number of empty plots, we removed plot markings for plots that had been empty from 2012-2014 (16 plots, Appendix C).

We divided each plot into four 0.5 m^2 subplots using a divided quadrat frame (Figure 2). Within each subplot, we mapped all *A. mulfordiae* individuals using a grid system so that recruitment, mortality, and overall trends in the plants' growth can be ascertained over time (Appendix A). We also measured the maximum diameter (cm), length of longest stem (cm), number of fruits, and evidence of insect and large ungulate grazing (yes/no) of every plant. Similar methods have been used to monitor the population dynamics of *A. tyghensis* in the Tygh Valley (Prineville District, BLM; Thorpe and Kaye 2008).

Population and Community Monitoring

This monitoring protocol follows the methods used by the Idaho Conservation Data Center to monitor populations of *A. mulfordiae* in southwestern Idaho (Mancuso 2001, Mancuso and Colket 2005, ICDC 2008). The monitoring protocol details procedures to collect *A. mulfordiae* and other plant species abundance, ground disturbance data, plant community information, and photo points. Five monitoring transects were established in 2009. Each transect was 20 meters long and monumented with a piece of red-painted rebar at the starting point and a large metal spike at the ending point. Sampling occurred along a meter tape running between the rebar and spike (Figure 3). A 1 m^2 quadrat frame was placed flush against the tape beginning at the 0 m mark. Sampling occurred at each consecutive meter mark along the transect tape. We documented the GPS coordinates of the starting and ending point, azimuth, and side of the tape sampled for each transect (Table 2. Location of *Astragalus mulfordiae* population and community monitoring transects.We also completed a transect information form that included information to help relocate the transects.

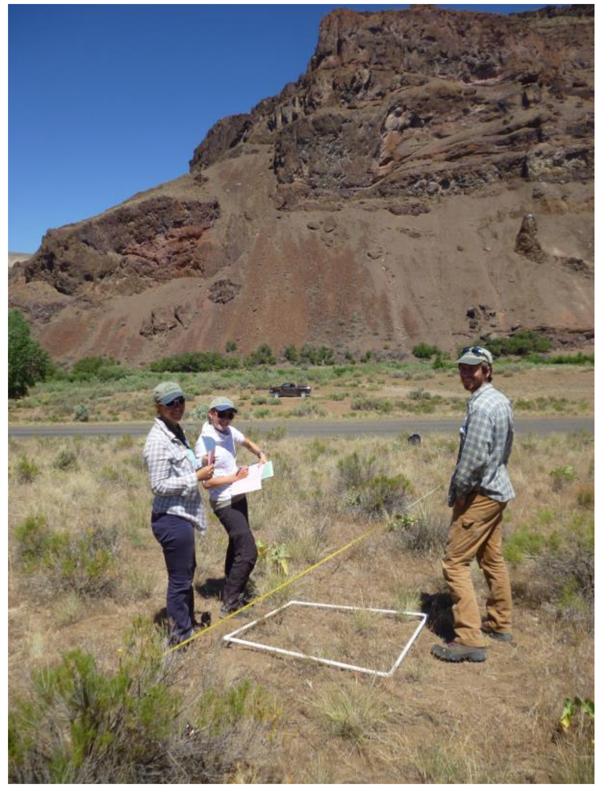


FIGURE 3. *ASTRAGALUS MULFORDIAE* POPULATION AND COMMUNITY MONITORING AT SNIVELY, 2013.

Each *A. mulfordiae* individual rooted within the quadrat was counted and assigned to one of three life stage class categories:

- Reproductive class (R) - individuals with flowers and/or fruits
- Non-reproductive class (N) - individuals >4 cm tall without flowers or fruits
- Seedling class (S) - non-reproductive individuals <4 cm tall (or taller if cotyledons present)

Application of the size standard may inadvertently result in small plants greater than one year old being recorded as seedlings. The seedling life stage should therefore be interpreted as possibly including individuals that did not recently germinate. If two *A. mulfordiae* stems were less than 3 cm apart, they were considered one plant.

TABLE 2. LOCATION OF *ASTRAGALUS MULFORDIAE* POPULATION AND COMMUNITY MONITORING TRANSECTS.

Area	Transect	Azimuth/side of tape monitored
Brown Butte	198	200°/east
Double Mountain	196	281°/south
North Harper North	200	26°/west
Snively	199	0°/east
South Alkali	197	354°/west

The location of each *A. mulfordiae* plant was recorded by referencing the appropriate quadrat cell in which it occurred. We divided the quadrat frame into 9 equal cells referenced by the letters "A" through "I" ( ). Cell "A" was positioned at the top left corner and cell "I" at the bottom right corner, similar to reading a page of text. Cells "G", "H", and "I" were positioned flush against the transect tape, whether sampling started on the left or right side of the tape (Table 2).

Each *A. mulfordiae* plant was inspected for evidence of insect/disease damage and non-insect herbivory/trampling damage. These data were recorded as presence/absence.

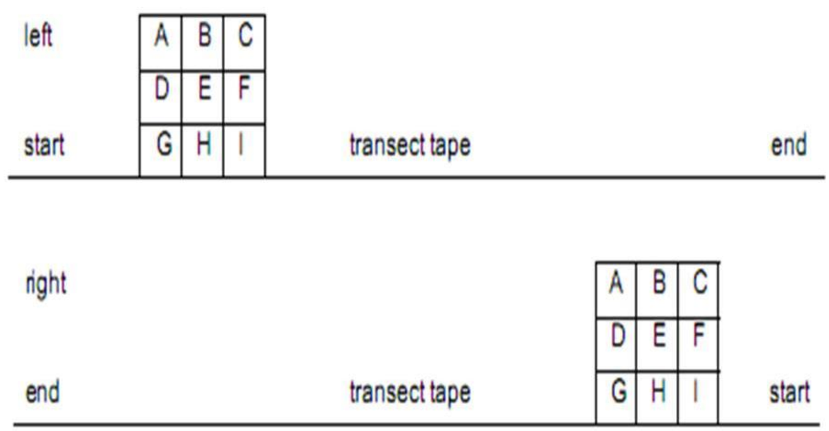


FIGURE 4. TRANSECT SETUP FOR *A. MULFORDIAE* POPULATION AND COMMUNITY MONITORING.

The cover of each native and exotic plant species (shrubs, graminoids, and forbs) rooted or hanging over each quadrat was estimated and assigned a cover class (Table 3). Ground covers of basal vegetation, bare ground, biological crust, rock/gravel (≥ 2mm), litter (< 2mm, including scat), completely dead attached shrub, and detached wood (≥ 2mm from shrub or tree) were also estimated and assigned cover classes. These data were recorded at each quadrat along the length of the belt transect. Nomenclature followed the U.S. Department of Agriculture Plants Database (USDA 2010).

The total area occupied by surface disturbances (e.g. ORV tracks, wildlife and cattle prints, gopher tunnels) within each quadrat was estimated and assigned a cover class (Table 3). Surface disturbances were additionally broken down by disturbance type; the cover class represented the percentage of ground surface within the quadrat that was clearly broken, crushed, or sloughed.

We took a minimum of 6 photos at each monitoring site. The origin rebar served as the reference point for four photos, taken at bearings of 0°, 90°, 180°, and 270°; these provided a panoramic overview of the monitoring area. We took a fifth photo standing 3 m behind the origin rebar looking towards the end spike; a sixth photo was taken standing 3 m behind the end spike looking towards the origin rebar. We took additional photos to show the plant community, disturbances, and other landscape features as needed. Sighting report forms were completed for each monitoring site, including a form for each sub-site (ex. South Alkali #1, #2, and #3).

Data Analysis

Population and community monitoring data were summarized descriptively at the functional group level. All data given cover classes were converted to midpoint percent cover values (Table 3). Raw data were used for analysis, except for specific cases where data were log-transformed to meet assumptions of statistical procedure(s).

TABLE 3. COVER CLASSES USED WHEN MONITORING PLANT SPECIES, GROUND COVER, AND SURFACE DISTURBANCES IN *A. MULFORDIAE* PLOTS.

Cover class	Percent cover range (%)	Midpoint to convert to (%)
0	0	0.0
1	<1 (trace)	0.5
2	1-4.9	3.0
3	5-9.9	7.5
4	10-24.9	17.5
5	25-49.9	37.5
6	50-74.9	62.5
7	75-94.9	85.0
8	95-100	97.5

The effect of caging on plant performance (plant size and reproduction) was tested using data from 2017 (all plots). We used an ANOVA (R Development Core Team 2009) to test for the responses of size of *A. mulfordiae* (diameter), using site and treatment (fencing vs. unfenced) as fixed factors for data from 2017. To test for the response of number of inflorescences (count data), we used a general linear model with a quasipoisson distribution, using site and treatment as predictors. We considered $p < 0.05$ to be significant.

We acquired grazing information from 2008-2013 including names of the allotment and pasture, allotment size, dates grazed, and number of animals (cows only). We used this information to calculate stocking rates ((# of animals X # of days)/acres) for each site. We correlated these values with number of plants in uncaged plots in 2010, 2012, and 2013 to explore the relationship between stocking rates and population dynamics.

Climate data [monthly precipitation (in), monthly minimum temperature (°F), and monthly maximum temperature (°F)] from 2011- 2017 were acquired from the PRISM climate group (PRISM 2017). Monthly averages were combined into seasonal means (winter = December-February, spring = March-May, summer = June-August, fall = September-November) to look at trends over time. To conduct a more complex climate analysis, we need at least 10 years of data.

RESULTS AND DISCUSSION

Herbivory Study

2017 Plant Trends

In 2017, a total of 242 *A. mulfordiae* plants were monitored in 71 experimental plots (37 caged and 34 uncaged), with 78 plants occurring in caged plots and 164 plants in uncaged plots (Table 4). This is an increase from 2016 values where there were 164 live plants, with 65 plants occurring in caged plots and 99 plants in uncaged plots (Table 4). Despite there being over a two-fold increase since 2014 (Table 4), total number of plants still remains less than numbers observed in 2008-2010.

TABLE 4. LIVE PLANTS, MORTALITY, AND NUMBER OF NEW PLANTS FOUND IN 2014, 2015, 2016, AND 2017.

	Year			
	2014	**2015**	**2016**	**2017**
Live Plants	109	164	164	242
Mortality	34	26	62	55
New Plants	8	78	62	124

Mortality in 2017 was less than in 2016 with 55 plants dying, compared to the 62 that died in 2016 (Table 4). Mortality occurred at all sites (except for South Alkali #2) in both caged and uncaged plots, with the most occurring at North Harper South (15 plants total, 12 in uncaged plots and 3 in caged; Figure 5). This is consistent with 2016 where North Harper South also experienced the highest mortality (24 plants). High mortality at North Harper South in 2016 and 2017 was likely due to there being a large number of seedlings present in the preceding year (i.e. 2015 and 2016) which did not all survive. North Harper South was the site with the highest number of new individuals, 38, 22, and 79, respectively, in 2015, 2016, and 2017. As in 2016, the number of live plants in 2017 was greater than those that died (242 and 55, respectively), with 124 new plants found (Table 4).

Eighteen plots had no living *A. mulfordiae* in 2017, which was a slight decrease from that in 2016 (24 plots). Three plots were found empty that had *A. mulfordiae* in the past two years, but eight plots were found to have new *A. mulfordiae* individuals that had been empty in the past year(s). These formerly empty plots with new *A. mulfordiae* individuals were found at all sites except for Snively. While in 2012 we added 25 new plots targeting areas of high abundance for *A. mulfordiae*, the number of plants recorded this year (242 in 71 plots) still remains less than those in plots measured in 2010 (278 plants in 67 plots). However, the number of plants recorded this year is higher than recent years (2012-2016). Total number of *A. mulfordiae* per plot ranged from 0 to 40 across all of the sites.

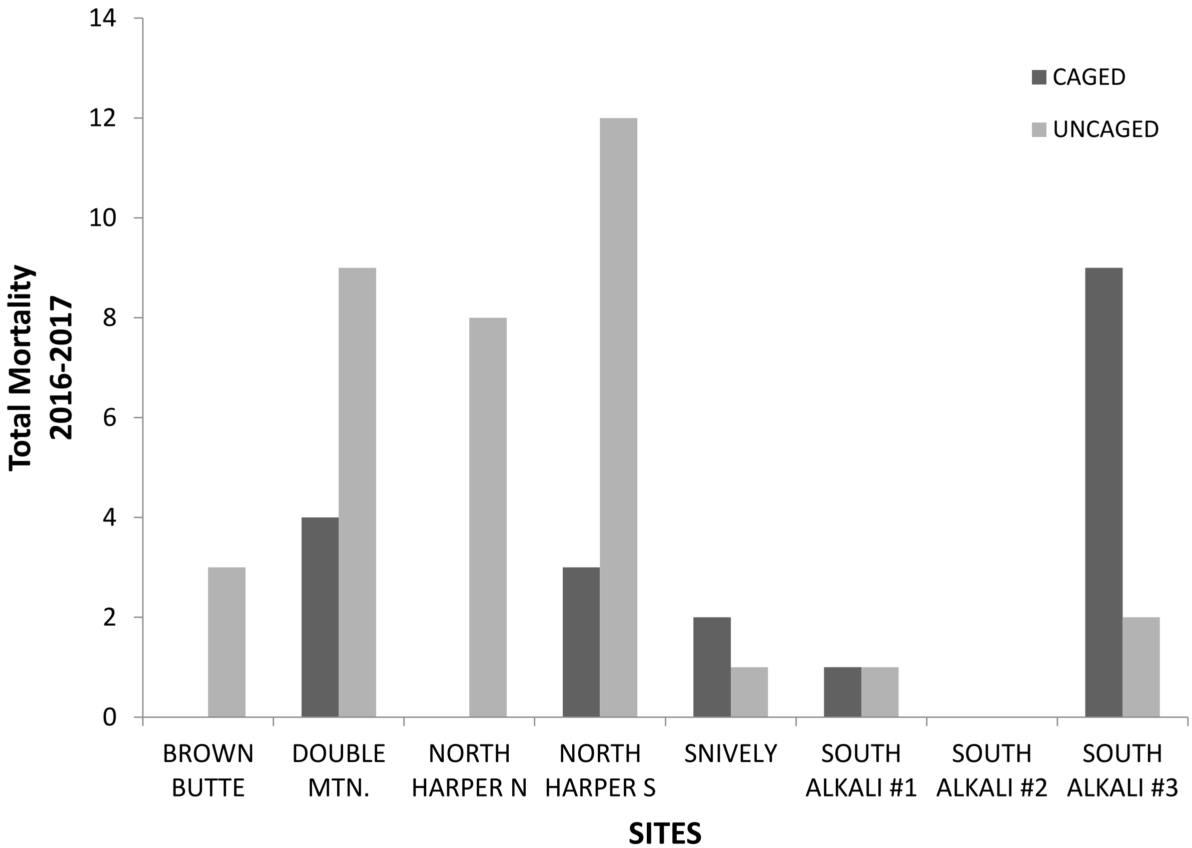


FIGURE 5. TOTAL MORTALITY OF *A. MULFORDIAE* FROM 2016 TO 2017, BY SITE AND TREATMENT (CAGED/UNCAGED).

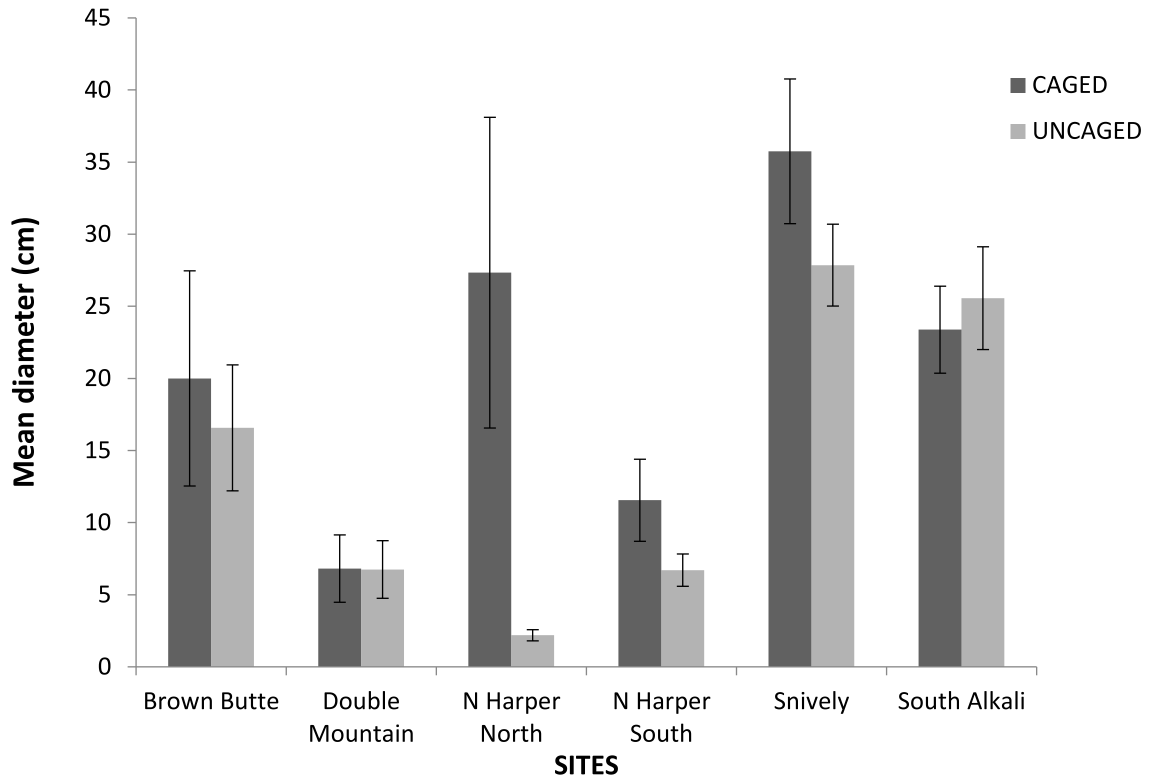
In 2017, size of *A. mulfordiae* differed by site and by treatment (caged or uncaged) ($p < 0.001$) (Figure 6, Appendix E). Plants from Snively, South Alkali, and Brown Butte were the largest while North Harper North and Double Mountain had the smallest individuals (Figure 6). North Harper North and North Harper South both had significantly larger plants in caged plots compared to uncaged plots ($p < 0.05$) (Figure 6, Appendix E). In 2017, North Harper South was the site that had the greatest number of new *A. mulfordiae* individuals (79), most of which were under 5 cm in diameter; 72 of these new individuals were located in uncaged plots, which likely contributed to the significantly smaller mean diameter of plants in uncaged plots. Plant size ranged from 1 to 73 cm (diameter) across all plots, which was similar to 2016.

The effects of the caging treatments on size of *A. mulfordiae* have varied over the years. In 2013, the size of plants differed significantly between caged and uncaged treatments (Gray 2013), however those results were not consistent across sites. In 2014 and 2015, the effects of treatment were not significant. In 2016, size of plants differed by treatment, but as in 2013, results were not consistent across sites. In 2017, size of plants differed by treatment; however, since there were also differences in size of plants by site, we analyzed each site separately and found that size of plants differed significantly between caged and uncaged treatments only at North Harper North and North Harper South. As discussed above, plants were significantly smaller in uncaged plots at North Harper North and North Harper South.

Reproductive effort was variable across sites, with North Harper North and Double Mountain having the fewest reproductive plants (2 and 5, respectively) and South Alkali having the most reproductive plants (38), which was consistent with 2016. North Harper South and Brown Butte had the highest average number of fruits per reproductive plant (120 and 74, respectively), which was mainly due to just a few large plants that produced many fruits. For example, North Harper South had two plants with > 300 fruits and Brown Butte had one plant with > 300 fruits. There was no difference between reproductive effort (number of inflorescences) in caged/uncaged plots. The proportion of live plants that were reproductive varied from 10.5% (North Harper North) to 90.9% (Snively) (Table 5).

TABLE 5. PROPORTION OF REPRODUCTIVE PLANTS BY SITE IN 2017.

Site	Proportion of reproductive plants
Brown Butte	35.0
Double Mountain	20.8
North Harper North	10.5
North Harper South	11.2
Snively	90.9
South Alkali	73.1



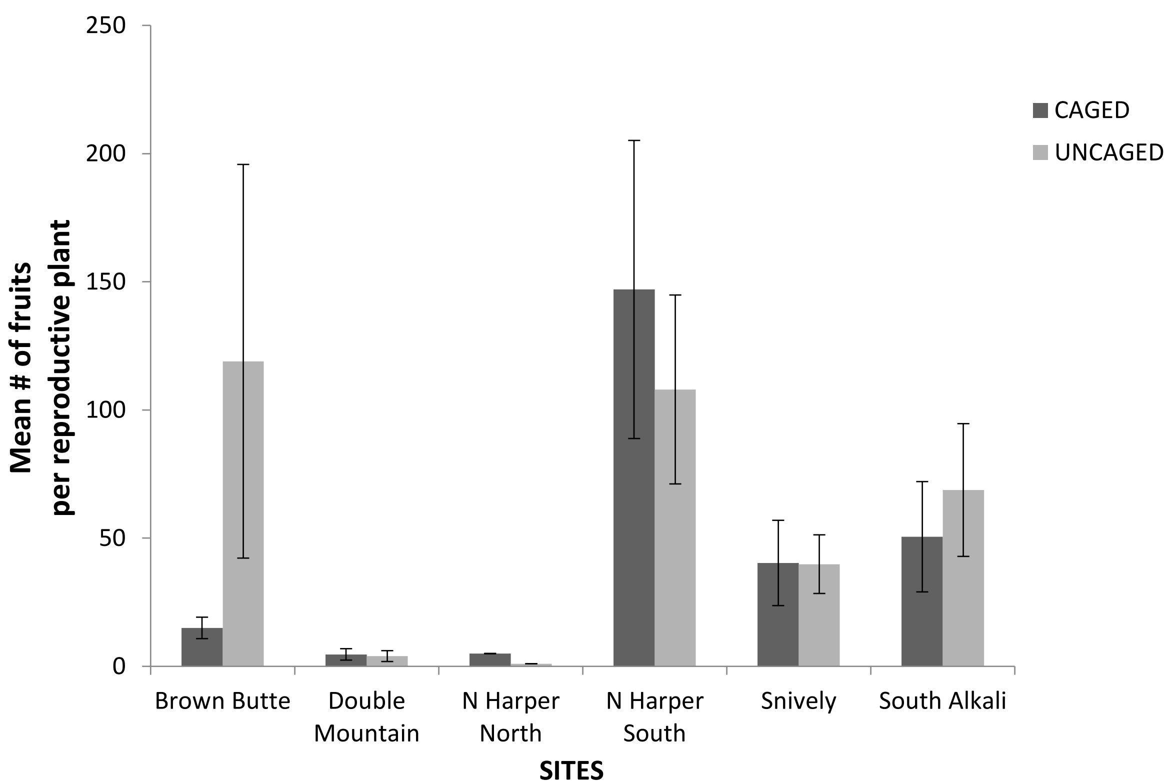


FIGURE 6. MEAN DIAMETER AND NUMBER OF FRUITS PER REPRODUCTIVE *A. MULFORDIAE* IN CAGED AND UNCAGED PLOTS IN 2017. ERROR BARS ARE ± 1 S.E.

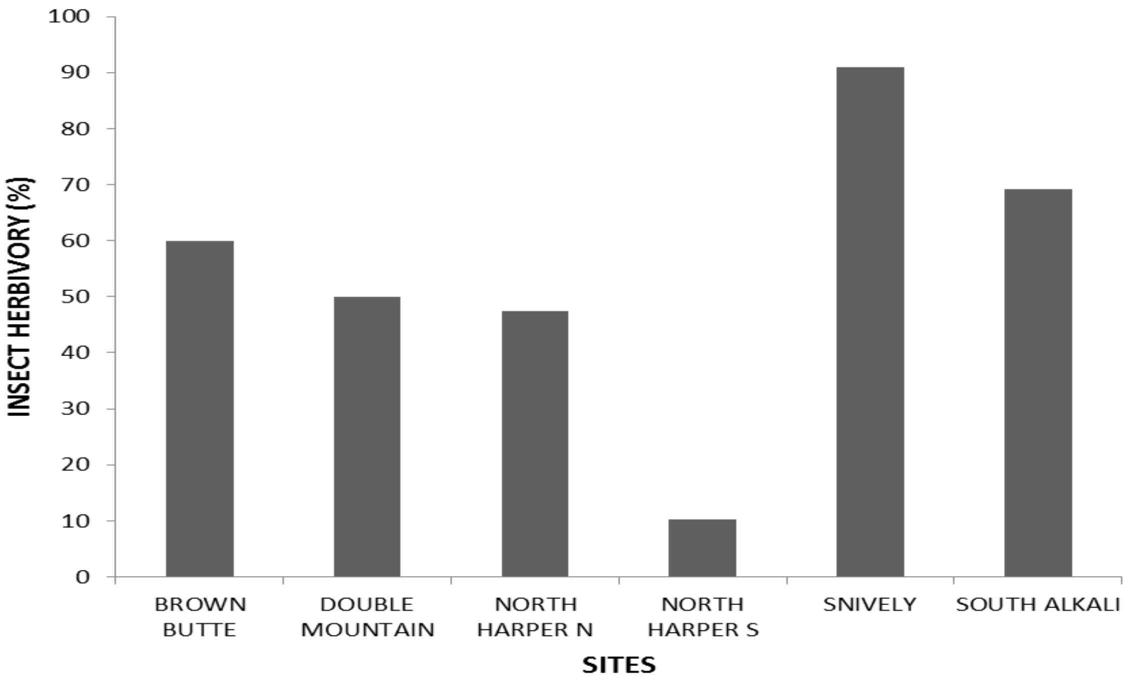


FIGURE 7. PERCENT OF PLANTS THAT EXPERIENCED INSECT HERBIVORY IN ALL PLOTS IN 2017.

Insect herbivory ranged from 10.3% to 90.9% of all plants at each site, with the most occurring at Snively and South Alkali (Figure 7). Presence of insect herbivory has varied greatly between years and between sites. Impacts from mammal herbivory were only documented at one site, South Alkali (1.9%).

Herbivory by mammals has been noted but has been extremely variable each year. In 2014 we explored the potential effects of grazing on *A. mulfordiae* using grazing data provided by the BLM. Stocking rates, which take into account the number of animals, number of days grazed, and acreage, have not changed much over the years with regard to each site (Table 6), though stocking rates did differ between sites. We correlated stocking rates with total number of plants in uncaged plots in 2010, 2012, and 2013, and found no clear trends associated with stocking rate and number of plants. South Alkali was the most heavily grazed, though it was grazed in the winter, so most likely had the least impacts on *A. mulfordiae*. This site has consistently had some of the highest numbers of plants. The other sites had relatively lower stocking rates and varied seasonality (Table 6). These data suggest that while grazing likely impacts *A. mulfordiae* plants and the associated plant community, it does not seem to be the major driver in the patterns we have observed over the years. These findings are not meant to be representative of all *A. mulfordiae* populations, particularly ones with heavier grazing during the growing season.

TABLE 6. GRAZING DATA FOR SITES 2008-2013.

			Stocking rate (# of cows*days/# acres)					
ASMU site	Allotment	Season	2008	2009	2010	2011	2012	2013
Brown Butte	Black Jack	summer	0.94	0.94	0.95	0.92	0.95	1.43
Double Mtn	Dry Creek		0.00	0.00	0.00	0.00	0.00	0.00
North Harper	North Harper	summer	0.79	0.33	1.00	0.92	0.73	0.43
Snively	Nyssa	spring	3.36	3.05	3.36	3.16	2.24	3.05
South Alkali 1-3	South Alkali	winter	5.86	6.73	6.95	6.73	6.08	6.81

Trends over time

This discussion is limited to data from plots established in 2008. Number of *A. mulfordiae* in 2017 was higher than recent years (2012-2016), but was still lower than earlier years of this study (2008-2010) across all treatments and sites, except for North Harper South (Figure 8). 2014 had the lowest number of plants since 2008 (Figure 8); from 2008 to 2014, 83% of plants initially present had either died or could not be located again. 2015 was the first year from 2008-2015 that the number of plants across all sites increased from the previous year's total. In 2016 and 2017 we continued to observe an increase in the total number of plants across all sites (Figure 8). In 2017, North Harper South had the largest increase in number of plants from the previous year, increasing from 38 to 93 plants located within plots. Additionally, North Harper South was the only site that had a higher number of plants in 2017 than in all previous years of this study (2008-2016), with an over two-fold increase observed from 2008 to 2017 (Figure 8). It is promising to observe an increasing trend over the last three years after the decline in *A. mulfordiae* that had been exhibited from 2008-2014 across all treatments and sites (Figure 8).

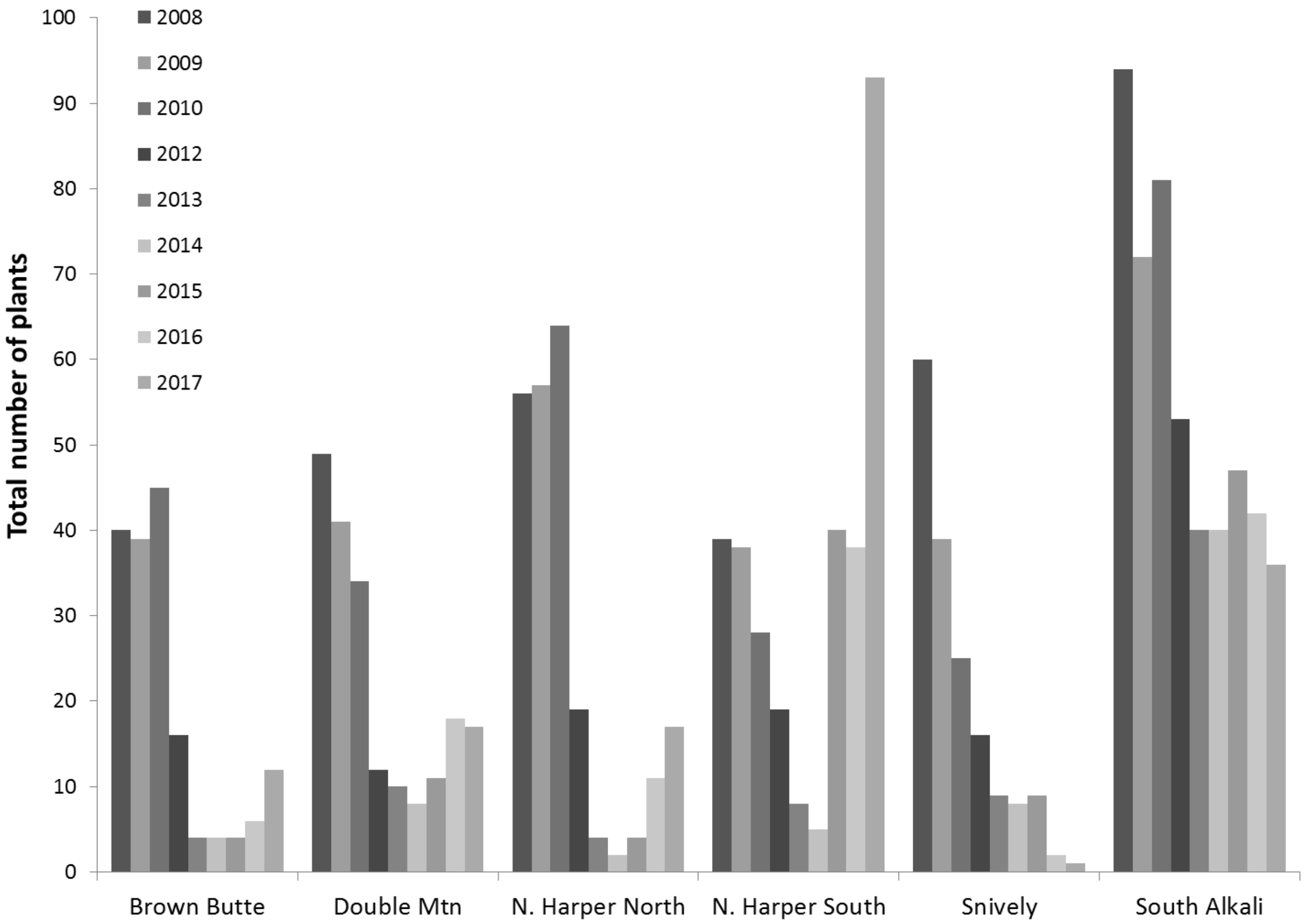
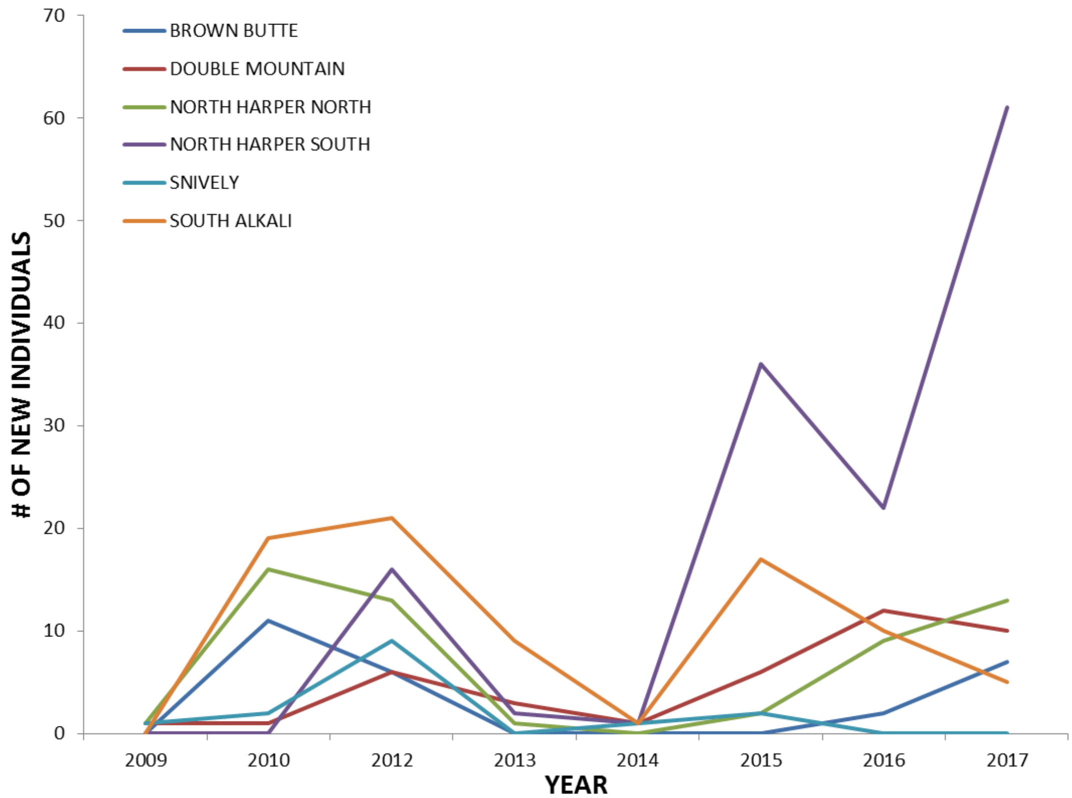


FIGURE 8. TOTAL *A. MULFORDIAE* IN CAGED AND UNCAGED TREATMENT PLOTS FROM 2008 TO 2017 (PLOTS ESTABLISHED IN 2008 ONLY).

North Harper South had the greatest number of new *A. mulfordiae* individuals in 2017, with over 4 times the number of new individuals than any other site (Figure 9). North Harper South had the greatest number of new *A. mulfordiae* individuals in 2016 as well, but there were nearly 3 times as many new individuals in 2017 than 2016 at this site. At North Harper South, the uncaged plots had the greatest addition of new individuals (57 out of 61 new individuals). In 2017, across all sites, caged plots had 18 new individuals while uncaged plots had 78 new individuals (however, this difference is mainly driven by uncaged plots at North Harper South) (Figure 9).



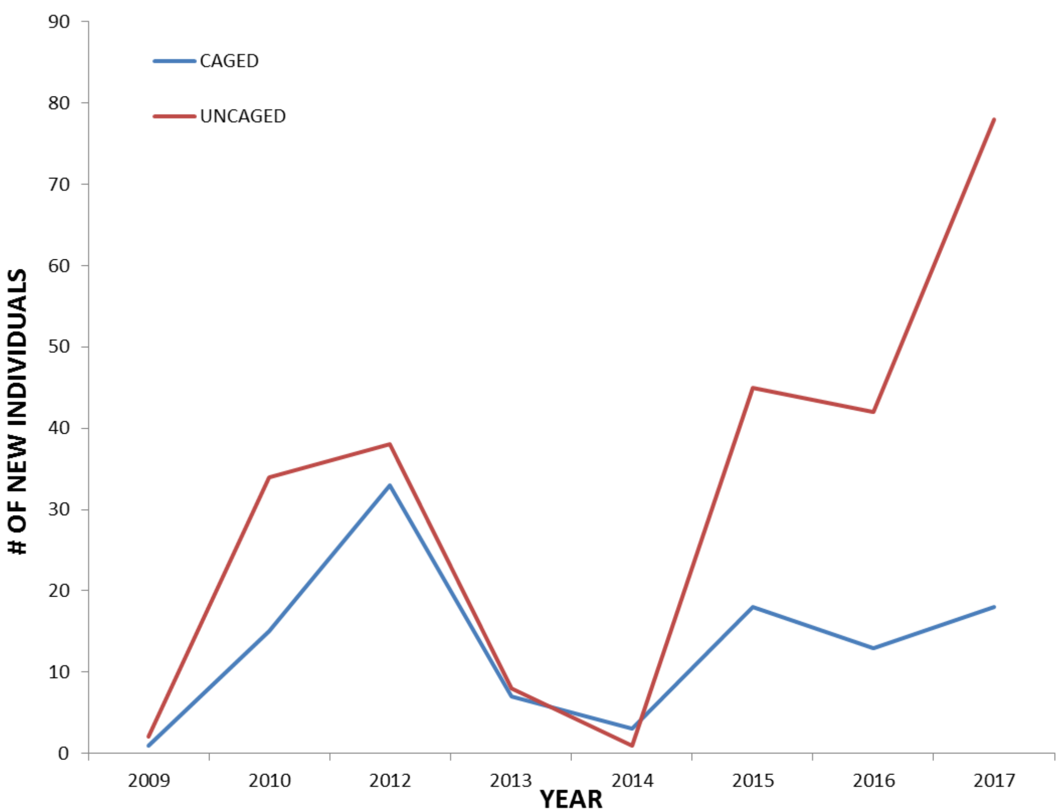


FIGURE 9. TOTAL NUMBER OF NEW A. MULFORDIAE INDIVIDUALS AT EACH SITE (ABOVE) AND IN CAGED AND UNCAGED TREATMENT PLOTS (BELOW) FROM 2009 TO 2017 (PLOTS ESTABLISHED IN 2008 ONLY).

TABLE 7. MEAN DIAMETER, MEAN NUMBER OF FRUITS PER REPRODUCTIVE PLANT, AND TOTAL NUMBER OF REPRODUCTIVE PLANTS IN CAGED AND UNCAGED STUDY PLOTS FROM 2010-2017 (PLOTS ESTABLISHED IN 2008 ONLY).

	Mean diameter (cm)																				
	2010			2012			2013			2014			2015			2016			2017		
Site	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean
Brown Butte	33.6	26.9	30.0	5.2	15.5	12.3	N/A	21.5	21.5	N/A	29.8	29.8	N/A	39.0	39.0	N/A	31.2	31.2	2.7	16.7	13.2
Double Mountain	18.7	16.2	17.5	9.5	4.3	6.9	20.2	5.0	14.1	17.7	16.0	16.8	12.8	6.4	9.9	17.3	7.6	9.8	8.4	6.8	7.6
N. Harper North	27.2	15.7	22.2	5.4	4.7	4.9	16.0	8.7	10.5	22.0	44.0	33.0	28.0	6.3	11.8	51.0	5.3	9.5	21.5	2.2	4.5
N. Harper South	27.7	31.6	30.1	6.5	11.6	8.7	10.0	9.5	9.8	9.0	10.0	9.5	6.4	3.3	3.9	10.3	6.8	7.1	7.5	6.9	7.0
Snively	19.0	29.8	21.1	8.9	13.5	11.2	19.0	13.6	15.4	25.3	26.8	26.1	19.0	27.4	23.7	40.0	N/A	40.0	43.0	N/A	43.0
South Alkali	26.6	22.2	24.3	21.1	19.0	20.2	28.9	30.9	29.7	35.1	29.8	32.4	20.3	20.3	20.3	18.7	38.9	23.5	21.2	28.8	23.6

	Mean number of fruits per reproductive plant																				
	2010			2012			2013			2014			2015			2016			2017		
Site	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean	Caged	Uncaged	Mean
Brown Butte	23	19	21	N/A	N/A	N/A	N/A	2	2	N/A	27	27	N/A	27	27	N/A	95	95	N/A	14	14
Double Mountain	13	11	12	N/A	N/A	N/A	9	N/A	9	16	5	10	1	38	20	26	45	32	7	4	5
N. Harper North	21	15	19	N/A	N/A	N/A	N/A	4	4	N/A	3	3	N/A	N/A	N/A	69	222	146	5	1	3
N. Harper South	23	19	21	1	6	5	N/A	N/A	N/A	N/A	N/A	N/A	8	N/A	8	119	32	44	98	74	76
Snively	17	25	18	1	16	8	11	5	8	55	85	70	14	116	65	280	N/A	280	81	N/A	81
South Alkali	22	17	19	57	75	63	108	66	91	122	89	110	76	56	69	66	93	74	34	128	64

	Total number of reproductive plants																				
	2010			2012			2013			2014			2015			2016			2017		
Site	Caged	Uncaged	Total	Caged	Uncaged	Total	Caged	Uncaged	Total	Caged	Uncaged	Total	Caged	Uncaged	Total	Caged	Uncaged	Total	Caged	Uncaged	Total
Brown Butte	21	24	45	0	0	0	0	1	1	0	1	1	0	4	4	0	4	4	0	2	2
Double Mountain	17	17	34	0	0	0	4	0	4	2	2	4	1	1	2	2	1	3	2	2	4
N. Harper North	36	28	64	0	0	0	0	1	1	0	1	1	0	0	0	1	1	2	1	1	2
N. Harper South	11	17	28	1	4	5	0	0	0	0	0	0	1	0	1	1	6	7	1	8	9
Snively	20	5	25	2	2	4	1	1	2	3	3	6	3	3	6	2	0	2	1	0	1
South Alkali	39	42	81	25	12	37	18	13	31	20	12	32	12	6	18	16	6	22	17	8	25

With the exception of Snively, mean plant size (diameter, cm) has reduced from 2010 to 2017 (Table 7). This reduction in mean plant size is likely due to the increase in new individuals in recent years; seedlings are often under 5cm in diameter, which brings down the mean plant size at sites with many seedlings. In 2017, Snively had the highest mean plant size, and did not have any new individuals; on the other hand, North Harper North and North Harper South had the lowest mean plant size, and had the greatest number of new *A. mulfordiae* individuals (Figure 9). Additionally, in 2015 and 2016, mean plant size was lowest at North Harper South, which was the site that had the greatest number of new *A. mulfordiae* individuals in those years. From 2010 to 2017, mean diameter of plants (cm) were found to differ by the interaction of year, site, and treatment (caged or uncaged) ($p < 0.001$). Plant diameter has differed over the years and across sites and treatment; for example, in 2014, North Harper North had larger plants within uncaged plots and South Alkali had larger plants in caged plots, while in previous years these sites had larger plants in the opposite treatment.

In 2017, there were reproductive plants at all sites, however only 24.4% of total plants were reproductive compared to 83.5% of plants in 2008. In 2017, reproductive effort decreased across all sites, except for North Harper South (Table 7). North Harper South had a higher mean number of fruits per reproductive plant (76 fruits/plant) as well as a higher total number of reproductive plants (9) than in 2016. Snively had the highest mean number of fruits per reproductive plant (81 fruits/plant), but only had one reproductive individual in 2017. Snively also had the highest mean number of fruits per reproductive plant (280 fruits/plant) in 2016 based on its total of two reproductive plants, but the high reproductive effort of these two plants did not translate to new individuals the following year. Differences between caging treatments were not apparent for number of inflorescences across all sites. These results are consistent with past comparisons that indicated that the caging treatment did not yield consistent differences in plant size or reproductive ability of *A. mulfordiae* across sites.

While there tended to be some differences between size and reproductive effort between caged and uncaged plots across the years of this study, the lack of consistent trends suggests that other factors might have a greater effect on plant population dynamics than large mammal herbivory. The extreme variability experienced across all sites is likely related to variability in climate and site-specific differences. Annual population fluctuations have been documented in other parts of *A. mulfordiae*'s range (ICDC 2008). From 2008 to 2014, total *A. mulfordiae* in treatment plots declined severely, reaching their lowest numbers in 2014 (Figure 8). While in 2015-2017 we observed increases from 2014 values, number of *A. mulfordiae* plants still remain much fewer than in 2008-2010. Though each site shows some variability from year to year, this declining trend is consistent across all sites (except for North Harper South) and is likely indicative of climate variability and potential threats from other disturbance such as invasion by exotic plant species.

Maximum and minimum temperature have followed somewhat similar trends to long-term normals (1971-2000, PRISM climate group) over the years, however maximum temperatures in 2015 and 2016 were greater than long-term normals across all seasons (Figure 10, top). In 2017, maximum temperatures were lower than long-term normals in the winter, higher than long-term normals in the summer, and similar to long-term normals in the spring and fall. Mean precipitation has varied greatly from 2010-2017 (Figure 10, bottom). Winters of 2010 and 2011 were relatively wet in comparison to long-term normals, while 2012-2014 all had lower than normal precipitation (Figure 10, bottom). Winter of 2015 had precipitation levels similar to long-term normals, while winter of 2016 and 2017 levels were higher than long-term normals. Winter precipitation in 2017 was over 70% higher than long-term normals. While the site experienced a wet spring in 2011, spring precipitation was less than long-term normals from 2013-2016 (Figure 10, bottom). However, in 2017 spring precipitation was again higher than long-term normals. Recent summer precipitation has remained drier than long-term normals with the exception of summer of 2010 (Figure 10, bottom). The high temperatures seen over the course of this study relative to long-term normals could have an effect on the population trends seen in recent years. Precipitation has been variable over the years and in recent years mean values have remained mostly less than long-term normals, which could be a factor in the decline of this species, particularly given that rainfall is limiting in these systems. Precipitation in 2014 was lower than long-term normals in all seasons, however the winter of 2015 had rainfall similar to long-term normals and then the winters of 2016 and 2017 had rainfall greater than long-term normals. The increase in number of plants in 2015-2017 could be the result of wetter winters after numerous years of conditions that were drier than long-term normals. Similar trends were observed for another rare plant species, *Lupinus lepidus* var. *cusickii* (Cusick's lupine), at Denny Flat, Baker County, OR, located about 70 miles to the northwest; *L. lepidus* var. *cusickii* counts were much higher in 2015 and 2016 following winters with greater precipitation than preceding years (Petix et al. 2016). Despite the increases seen in 2015-2017, the rapid decline in *A. mulfordiae* population numbers observed in the preceding years coupled with the decrease in their size and variability in reproductive effort over the course of this study suggest that continued monitoring of this rare species will be essential for managing for persistence of this species, especially when facing current and ongoing climate changes.

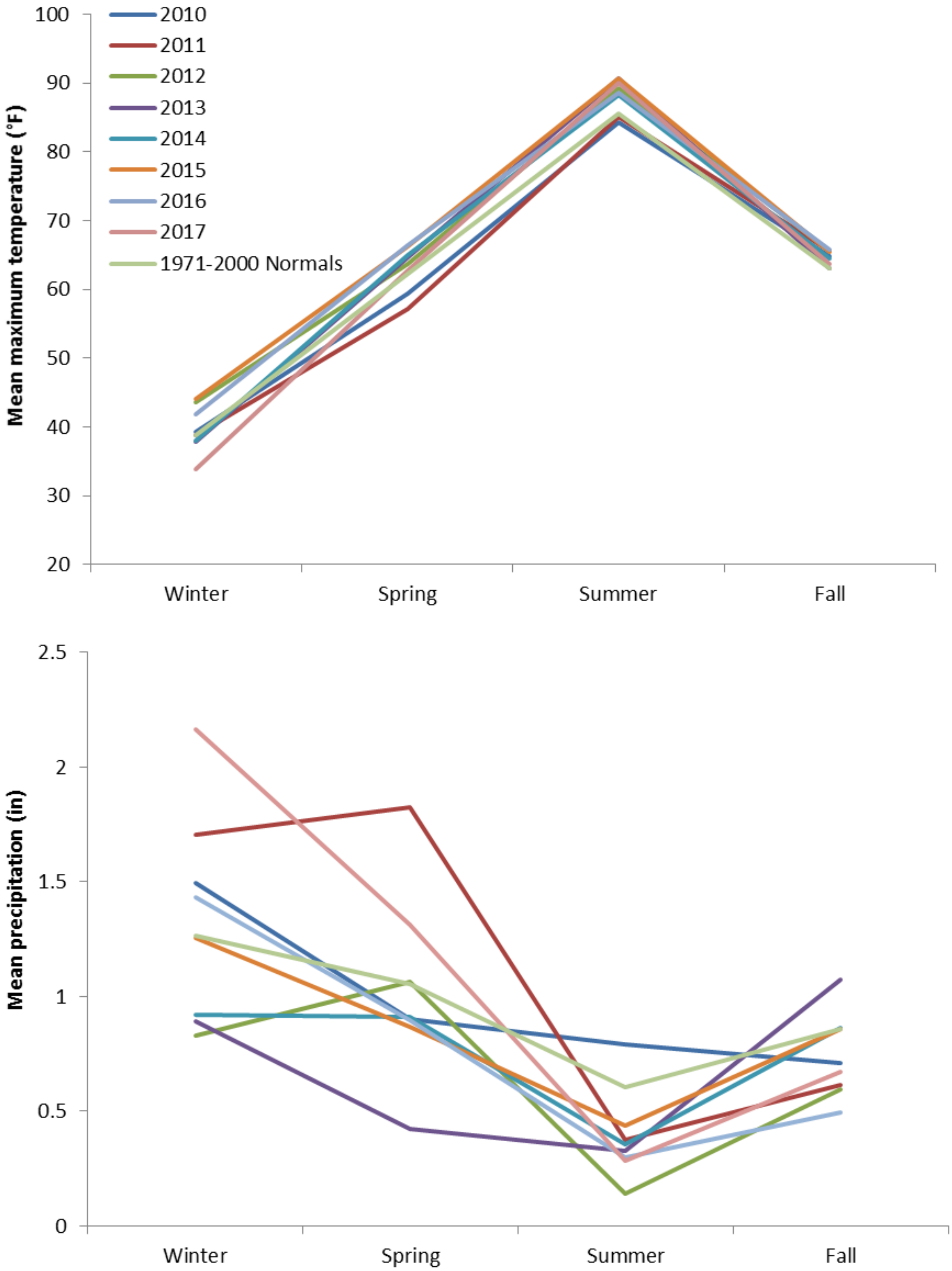


FIGURE 10. MEAN MAXIMUM TEMPERATURE AND MEAN PRECIPITATION FROM 2010-2017 WITH LONG-TERM CLIMATE NORMALS AT NORTH HARPER NORTH (PRISM CLIMATE GROUP 2017).

Population and Community Monitoring

In 2017, a total of 134 *A. mulfordiae* plants were observed along five transects, which was the second highest number of plants observed along the transects since they were established in 2009 (Table 8). 2010 still remains the year with the highest number of plants (178), but number of *A. mulfordiae* along the transects has been increasing since 2015, which is a positive trend. The majority of the plants occurred along the transects at Brown Butte (69 plants) and South Alkali (34), with number of plants gradually declining over the years at Snively (Table 8). While the transect at Double Mountain had no plants in 2013, there was one plant observed in 2014-2016 and 3 plants observed in 2017. Seedlings accounted for the majority of total plants observed in 2017 (45%), which was an increase from 2016 when seedlings accounted for 30% of the total. The number of seedlings observed has increased since 2015, with 2017 having the second highest number of seedlings observed along the transects since they were established in 2009 (2010 had the highest number of seedlings along with the highest number of plants). In 2017, seedlings were present at every site except for Double Mountain. Reproductive plants accounted for 19% of total plants observed, which was a decrease from the previous four years (2013-2016) which had 40-76% of total plants being reproductive. Non-reproductive plants (>4cm tall) constituted 36%.

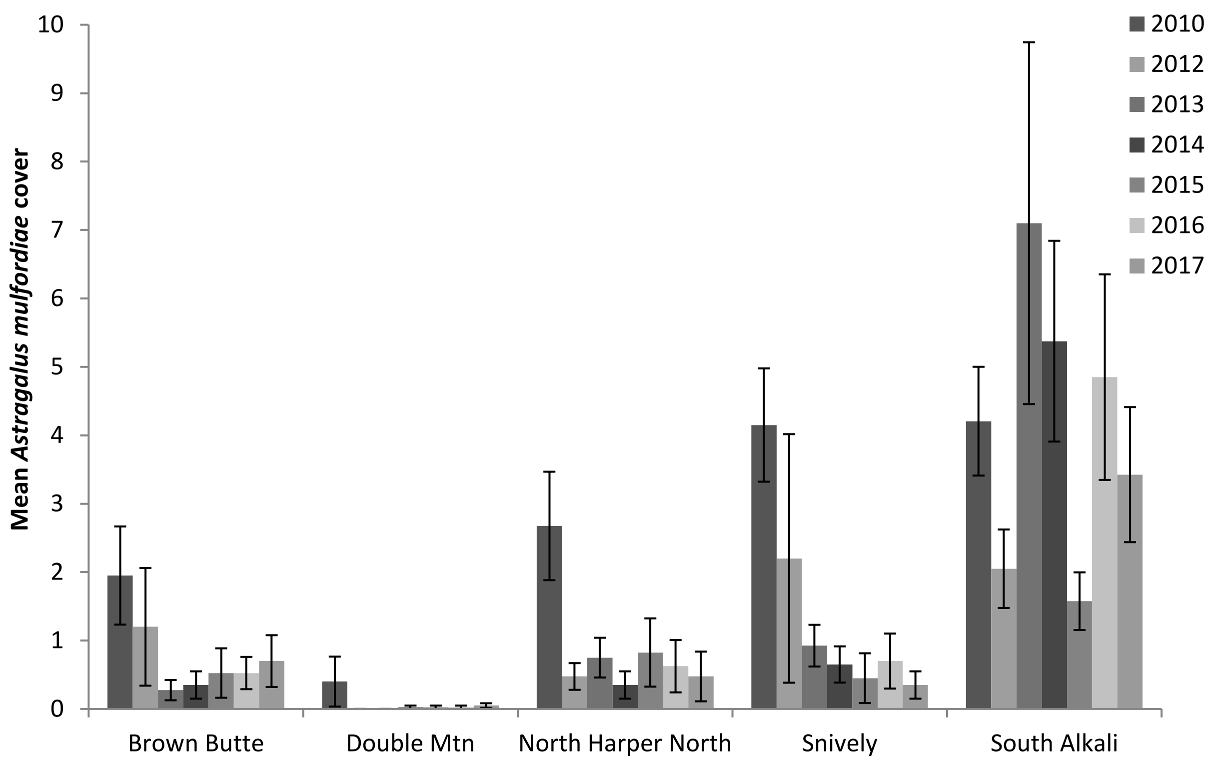
TABLE 8. NUMBER AND CLASS OF *ASTRAGALUS MULFORDIAE* FOUND IN COMMUNITY TRANSECTS IN 2009, 2010, 2012, 2013, 2014, 2015, 2016, AND 2017.

Area	Year	Reproductive	Non-reproductive	Seedling	TOTAL
Brown Butte	2009	13	0	3	16
	2010	8	11	6	25
	2012	0	12	2	14
	2013	1	3	5	9
	2014	2	1	3	6
	2015	1	3	6	10
	2016	2	14	20	36
	2017	2	38	29	69
Double Mountain	2009	3	0	0	3
	2010	2	1	0	3
	2012	0	1	0	1
	2013	0	0	0	0
	2014	0	0	1	1
	2015	1	0	0	1
	2016	0	1	0	1
	2017	0	3	0	3

Area	Year	Reproductive	Non-reproductive	Seedling	TOTAL
North Harper North	2009	22	4	11	37
	2010	19	4	28	51
	2012	4	6	9	19
	2013	3	2	0	5
	2014	0	4	0	4
	2015	1	2	4	7
	2016	4	5	2	11
	2017	1	4	19	24
Snively	2009	21	1	3	25
	2010	21	1	0	22
	2012	4	8	2	14
	2013	6	2	0	8
	2014	6	0	0	6
	2015	3	1	0	4
	2016	3	1	0	4
	2017	2	1	1	4
South Alkali	2009	40	10	1	51
	2010	38	0	39	77
	2012	11	18	44	73
	2013	18	4	0	22
	2014	24	1	0	25
	2015	22	0	9	31
	2016	22	2	1	25
	2017	21	2	11	34

In comparison to 2010, cover of *A. mulfordiae* has declined notably at all sites except for South Alkali (Figure 11). South Alkali experienced an increase in cover in 2013 and 2014, but then experienced a decline in 2015 to the lowest value over the years of this study. Cover of *A. mulfordiae* increased at South Alkali in 2016 and 2017, but was not as high as 2013 or 2014 (Figure 11). Brown Butte had a slight increase in cover of *A. mulfordiae* from 2016 to 2017, but still remains less than cover in 2010 (Figure 11). Although Brown Butte had the highest number of plants observed along transects (Table 8), it did not have the highest mean *A. mulfordiae* cover across the sites (Figure 11). Many of the plants observed at Brown Butte in 2017 were non-reproductive individuals or seedlings (Table 8), which are typically smaller than reproductive individuals, so cover remained fairly low at the site (mean cover <1%). The decline in *A. mulfordiae* at most sites could be associated with the increase in cover of *B. tectorum* over the years of this study, which ranged from 2-16% cover across the sites in 2010 and now ranged from 22-49% in 2017 (Figure 11). At all sites *B. tectorum* has increased since 2010 (Figure 11). In 2017 *B. tectorum* cover increased from 2016 values at Double Mountain, Snively, and South Alkali, but decreased at Brown Butte and North Harper North (Figure 11). This invasive species is known to compete with native vegetation and to fill in the interspaces between native perennial bunchgrasses (Knapp 1996), where *A. mulfordiae* tends to grow.

Plant community composition within the transects has changed from 2010 to 2017 (Figure 12). Exotic species cover (as percent of total cover) has increased from 2010 to 2017 at all sites, except North Harper North and South Alkali. Proportions of native species have also declined from 2010 to 2017 at all sites except North Harper North and South Alkali (Figure 12). In 2010, all sites were native dominated except for South Alkali, but by 2015 all sites were exotic dominated. In 2017, North Harper North was the only site that was native dominated.



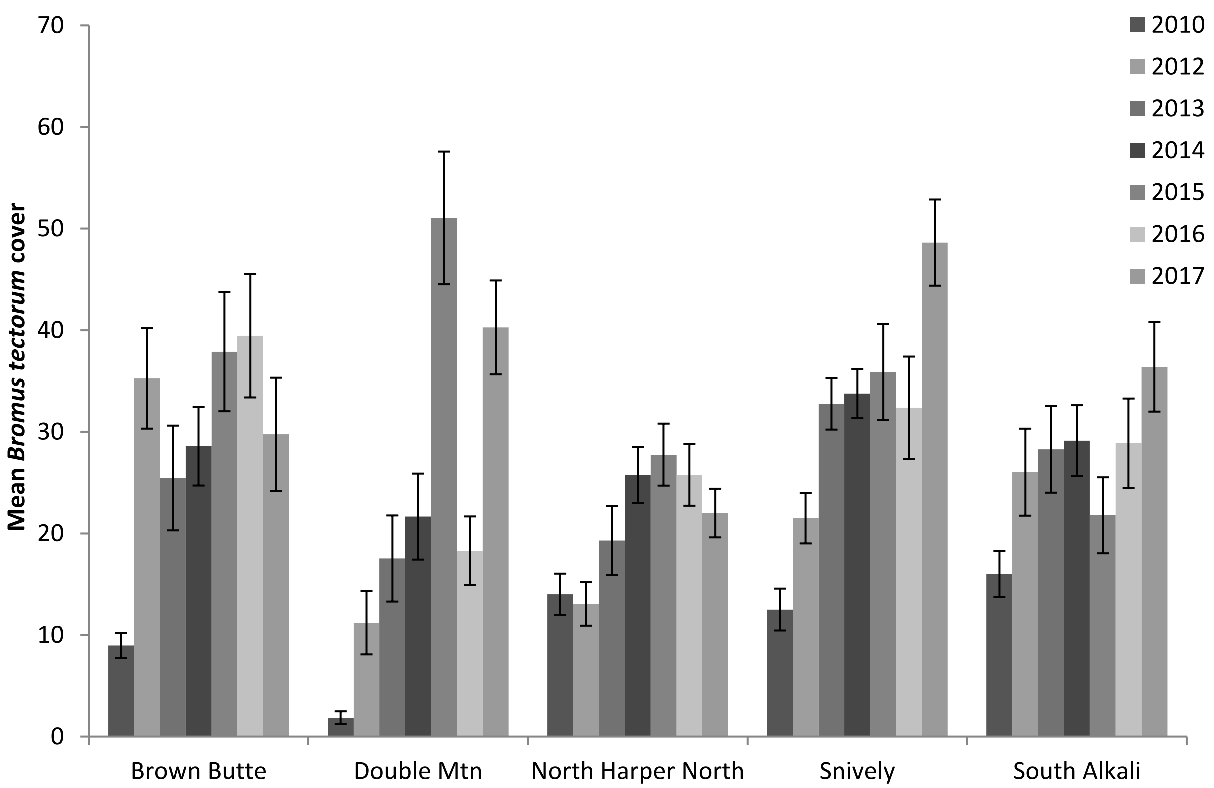


FIGURE 11. MEAN *A. MULFORDIAE* (ABOVE) AND *B. TECTORUM* (BELOW) COVER (%) IN COMMUNITY MONITORING TRANSECTS IN 2010, 2012, 2013, 2014, 2015, 2016, AND 2017. ERROR BARS ARE ± 1 S.E. NOTE THE DIFFERENCE IN THE Y AXES.

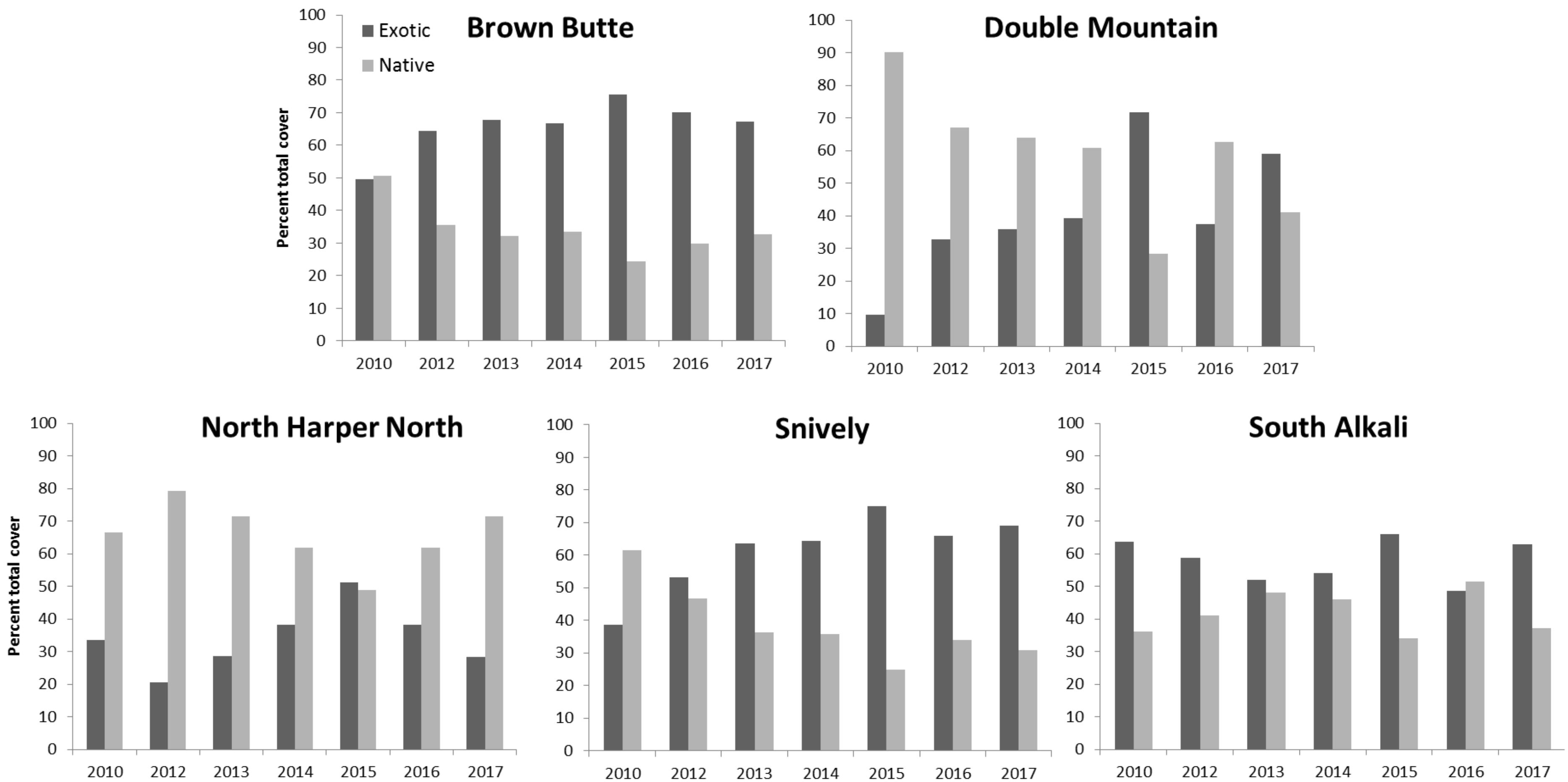


FIGURE 12. PERCENT (%) OF TOTAL COVER OF NATIVE AND EXOTIC SPECIES, BY SITE, IN 2010, 2012, 2013, 2014, 2015, 2016, AND 2017.

Of the seven exotic species recorded along transects in 2017, two were graminoids and five were forbs (Appendix D). *Bromus tectorum* dominated exotic species cover ranging from 22.0-48.6% across all transects, and composing 93.8-99.9% of total exotic species cover (Appendix D). Other exotic species included *Erodium cicutarium, Alyssum desertorum, Lactuca serriola, Salsola tragus, Sisymbrium altissimum*, and *Poa bulbosa*. Though these other exotic species were present, their total cover was minimal, suggesting that without the invasion of *B. tectorum* at these sites, the plant community would have remained native-dominated. The most abundant native species present along transects were perennial bunchgrasses *Achnatherum hymenoides, Poa secunda,* and *Hesperostipa comata*. *Chrysothamnus viscidiflorus* was the primary shrub present in all transects. Mean cover of *A. mulfordiae* ranged from 0.05-3.4%, with South Alkali having the highest cover and Double Mountain having the lowest cover. While most of the non-native taxa were annuals, native species were a mix of annuals and perennials. The non-vegetated ground surface was composed largely of bare ground accounting for 55% of mean cover which was similar to 2015 and 2016 values (Table 9). Litter cover has increased over three-fold since 2010, from 19% in 2010 to 61% in 2017 (Table 9); these changes are likely due to the presence and abundance of *B. tectorum* across all sites. Smaller amounts of rock/gravel, dead shrub, biological crust, and basal vegetation were also present (Table 9). Snively had the highest cover of the beneficial biological soil crust (3%), but this value was lower than the 5% noted in 2015 (Table 9).

TABLE 9. MEAN COVER OF GROUND SURFACE CATEGORIES IN 2017.

	Average % cover					
	Brown Butte	**Double Mtn**	**North Harper North**	**Snively**	**South Alkali**	***Mean***
Basal veg (cut off at ground)	16.0	16.6	22.0	21.5	20.0	19.2
Bare ground	41.1	43.5	66.2	62.1	64.3	55.4
Biological crust	0.0	0.0	0.0	3.1	0.1	0.6
Rock/gravel (≥ 2mm)	0.5	1.8	0.0	2.5	0.3	1.0
Litter (< 2mm), including scats	53.7	56.3	66.6	56.6	69.7	60.6
Completely dead shrub, attached	4.7	2.3	2.6	2.3	2.0	2.8
Wood (≥ 2mm), not attached -- must be wood from shrub/tree	0.9	1.7	2.2	1.3	0.6	1.3

The loose, sandy substrate characterizing *A. mulfordiae* habitat readily leaves evidence of physical disturbances. Disturbances recorded in 2017 varied by site (Table 10). Double Mountain experienced the most disturbance, which was composed primarily of game trails, insect burrows, and a kangaroo rat burrow system. Snively experienced the second-highest amount of disturbance, primarily due to cattle prints and divots. North Harper North had high cover of cattle feces (older than 1 year), which were present in 2016 as well. Brown Butte, which had the highest total ground disturbance in 2016, experienced the least disturbance in 2017, mostly composed of rills (shallow channels) from erosion. Individual disturbance categories with the highest abundance included cattle feces, divots, and insect burrows (Table 10). The invasion of these areas by *B. tectorum* could be influenced by disturbances occurring at these sites. Though anthropogenic disturbances were relatively uncommon, increased disturbance could act as a conduit to further invasion at these sites. Within the transects, herbivory and trampling damage to *A. mulfordiae* occurred on 53 plants, which was much higher than the 5 plants affected in 2016. Insect damage and disease occurred on 20 plants, which was higher than 2016 when only 8 plants had insect damage/disease.

At the time of this report, updated data from Idaho were not available. We will delay comparing population dynamics from the two states until data are available from Idaho. Likewise, after collecting 10 years of consistent data we will be able to make comparisons between population dynamics and climate variability at the Oregon occurrences.

TABLE 10. TOTAL % COVER OF DISTURBANCES OBSERVED ALONG TRANSECTS IN 2017.

	Total % Cover					
Disturbance Category	**Brown Butte**	**Double Mountain**	**North Harper North**	**Snively**	**South Alkali**	***Total Cover***
anthill	0	3	0.5	0	0	3.5
bird feces (other)	0	0.5	0.5	0	0	1
burrow	3	0.5	0	0	0	3.5
canine feces (coyote, fox, domestic dog)	0	0	1.5	0	0	1.5
cattle feces-older (>1 year)	0	0	35.5	6.5	24.5	66.5
cattle prints	0	0	0	10	0	10
deer feces	0	0	1	0	0	1
divot	6.5	8.5	0	28	1.5	44.5
game trails	0.5	12.5	0	0	0	13
human footprints (NOT researcher)	0.5	7.5	0	0	0	8
human footprints (researcher)	3.5	3	0	0	3	9.5
insect burrow (diameter <1 cm)	7	10	6.5	9	1	33.5
medium sized rodents (pocket gopher, kangaroo rat, ground squirrel)	0	9	0	0	0	9
rabbit feces	1	0	5	0	9	15
rills (erosion)	14	0	0	0	0	14
unknown animal prints	0.5	6	0	0	3	9.5
Total ground disturbance	36.5	60.5	50.5	53.5	42	

CONCLUSIONS

In recent years we had observed a decline in *A. mulfordiae* at all of our study sites. In 2014, the density of *A. mulfordiae* was the lowest since 2008, with pronounced declines observed between 2012 and 2013. However, in the last three years (2015-2017) we have observed increases in the number of *A. mulfordiae*. The number of *A. mulfordiae* observed in monitoring plots has increased over two-fold since 2014, but total number of plants still remains less than numbers observed in 2008-2010. We did see very high numbers of new plants at North Harper South in 2015, 2016, and 2017, which accounted for the highest count at this site in 2017 over the course of this study. This year there more new plants and fewer plants that died across all sites than in 2016. In previous years, densities were so low that while re-establishing plots in 2012, we often had a difficult time finding suitable habitat that had 2 or more plants within a $1m^2$ area. In 2013 and 2014, we didn't consider re-establishing plots because we couldn't find areas to place them due to the lack of abundance of this species. In 2017, although 3 plots were found empty that had *A. mulfordiae* present in the past two years, 8 plots were found to have new *A. mulfordiae* individuals that had been empty in the past year(s). Monitoring in 2018 will be very important to elucidate if this is the beginning of a positive trend or if this increase is a short-term event.

Along with long-term decline in number of *A. mulfordiae,* size and reproductive effort of *A. mulfordiae* have varied over the years and across treatments. Despite the increase in plants noted in the last three years, the overall decline observed across recent years is cause for alarm, particularly in conjunction with the documented increase of *B. tectorum* and the variable climate experienced in recent years. Though population dynamics were difficult to discern in previous years (Newton et al. 2010), the consistent decline across all sites indicates that this species might be sensitive to climate variability along with other factors including possible competition from invasive plant species. Future monitoring is necessary to determine if additional management actions are needed.

From 2014-2015 we found no significant difference between plants within caged/uncaged plots, though these treatments were significant in 2013, 2016, and 2017. Plants within caged and uncaged plots have shown great variability over the years, and even when these have been noted as significant difference(s) there was little consistent evidence that grazing by cattle and/or sheep directly affected *A. mulfordiae* population size and reproductive success. We found no pattern associated with number of plants present in relation to stocking rates. While some of the sites are grazed annually, stocking rates have not varied between years within sites. The one site with the highest stocking rate (South Alkali) most likely had minimal impact on the plants because it was grazed during the winter. Plants were not consistently larger or smaller in caged plots than uncaged plots, and size varied with relation to the treatments over the years. Insect herbivory was common across all sites, though we did not see differences in herbivory between caged and uncaged plots. Cattle and sheep may affect *A. mulfordiae* populations indirectly by disturbing the ground surface either in or adjacent to plots due to the loose, sandy substrate. Cattle and human prints could alter surface hydrology and potentially cause some of the erosion events that have led to plant mortality at many of the sites.

Invasive plant species were ubiquitous in *A. mulfordiae* sampling plots, and have increased in recent years. Between 2010 and 2017, plant community composition has varied, however, several sites have transitioned from a native-dominated community to one dominated by exotic species. In 2017, the plant communities at all sites were dominated by *B. tectorum*. *Bromus tectorum* germinates earlier than native species and rapidly depletes soil moisture, increasing its competitive ability (Knapp 1996). The prolific seed production of *B. tectorum* enables the species to rapidly invade the interspaces between plants creating consistent fuel loads that can be detrimental in the case of a wildfire (Knapp 1996). This species poses a serious threat to *A. mulfordiae* and other native species in these sensitive habitats. Continued population and community monitoring is necessary to document the impacts of invasive plant species on *A. mulfordiae* populations.

The climate experienced at the sites in recent years tended to be drier than long-term precipitation normals, which could have an impact on the long-term decline we have observed. However, winter of 2015 had precipitation levels similar to long-term normals, and winter of 2016-2017 had levels that were higher than long-term normals; additionally, spring precipitation, which had been less than long-term normals from 2013-2016, was higher than long-term normals in 2017. In these cold-desert ecosystems, most precipitation occurs during winter and early spring. The increase in number of plants noted in the last three years could be the result of wetter winters (and a wetter spring in 2017) after numerous years of conditions that were drier than long-term normals. Climate change projections suggest increasing temperatures especially in summer months throughout the Pacific Northwest (Mote and Salathé 2010). While forecasts for precipitation are more variable, they include enhanced seasonal changes (Mote and Salathé 2010). These increased temperatures, if coupled with decreased or sporadic precipitation, could greatly affect native species in sagebrush steppe habitats. In a recent model for climate change effects on sagebrush steppe ecosystems in Oregon, the authors concluded that climate change would yield increases in exotic grasses and an overall decline in sagebrush steppe habitat, transitioning into salt desert shrub communities (Creutzburg et al. 2015). These landscape scale changes will greatly impact native species, particularly local endemics such as *A. mulfordiae*.

Comparison of Oregon and Idaho *A. mulfordiae* population dynamics should commence cautiously and only on a same-year basis; Idaho Conservation Data Center (ICDC) data show *A. mulfordiae* population densities can fluctuate from year-to-year. The establishment of population transects in 2009 using the same protocol as the ICDC (2008) will enable comparisons once data are made available.

Given declines observed in recent years across all sites, we recommend continued monitoring in order to determine long-term population trends and to describe areas where the species seems particularly vulnerable or changes are occurring rapidly. Although there were increases in the number of *A. mulfordiae* observed in the past three years, numbers are still less than those at the beginning of this study. While there were many new *A. mulfordiae* individuals in 2017, many of these were concentrated at North Harper North and South, while Snively had none. Continuation of the long-term monitoring of this species is essential in providing valuable site-specific information regarding population trends and changes in the plant community. To mitigate for future loss, we recommend efforts focused on seed collection for banking, and potentially conducting a complete census of these and other populations to yield a greater understanding of the current status and extent.

LITERATURE CITED

Center for Plant Conservation. 2009. CPC national collection plant profile: Mulford's milkvetch. http://www.centerforplantconservation.org/. Accessed: 03/18/2009.

Creutzburg, M.K., J.E. Halofsky, J.S. Halofsky, and T.A. Christopher. 2015. Climate change and land management in rangelands of central Oregon. *Environmental Management* 55(1): 43-55.

DeBolt, A. 1995. Habitat Conservation Assessment for Mulford's Milkvetch (*Astragalus mulfordiae*). Unpublished report. Bureau of Land Management.

DeBolt, A. 2001. E-mail communication. 12/5/01. In BBG files. *in* Center for Plant Conservation 2008. CPC national collection plant profile: Mulford's milkvetch. http://www.centerforplantconservation.org/. Accessed: 03/18/2009.

Gray, E.C. 2013. *Astragalus mulfordiae:* Population dynamics and effects of cattle grazing in the Vale District BLM. Institute for Applied Ecology, Corvallis, Oregon and USDI Bureau of Land Management, Vale District. viii + 62 pp.

Idaho Conservation Data Center (ICDC). 2008. Mulford's milkvetch (*Astragalus mulfordiae*) monitoring in southwestern Idaho: 2007 results. Idaho Department of Fish and Game, Boise, Id. 40pp. plus appendices.

Knapp, P.A. 1996. Cheatgrass (*Bromus tectorum*) dominance in the Great Basin Desert: History, persistence, and influences to human activities. *Global environmental change* 6: 37-52.

Mancuso, M. 2001. Monitoring Mulford's milkvetch (*Astragalus mulfordiae*) in the Boise Foothills: 2000 results. Idaho Department of Fish and Game, Idaho Conservation Data Center, Boise, ID. 12 pp. plus appendices.

Mancuso, M., and B. C. Colket. 2005. Monitoring Mulford's milkvetch (*Astragalus mulfordiae*) on the Owyhee Front: 2004 results. Idaho Department of Fish and Game, Idaho Conservation Data Center, Boise, Id. 15 pp. plus appendices.

Massatti, R.T., A.S. Thorpe, and T.N. Kaye. 2009. *Lupinus lepidus* var. *cusickii* population monitoring in Denny Flat, Baker County, Oregon. Institute for Applied Ecology, Corvallis, Oregon and USDI Bureau of Land Management, Vale District. iv + 16 pp.

Mote, P.M, and E.P. Salathé. 2010. Future climate in the Pacific Northwest. *Climatic Change* 102: 29-50.

Newton, R.E., R.T. Massatti and A.S. Thorpe. 2010. *Astragalus mulfordiae*: Population dynamics and the effect of cattle grazing in the Vale District, BLM. Institute for Applied Ecology, Corvallis, Oregon and USDI Bureau of Land Management, Vale District. v + 21 pp.

Oregon Biodiversity Information Center. 2013. Rare, Threatened and Endangered Species of Oregon. Institute for Natural Resources, Portland, Oregon. 111 pp.

Oregon Natural Heritage Information Center. 2009. Oregon Threatened and Endangered Plant Field Guide. http://oregonstate.edu/ornhic/plants/view_plants2.php. Accessed: 03/18/2009.

Petix, M.I., M.A. Bahm, and Erin C. Gray. 2016. Assessing the status and extent of *Lupinus lepidus* var. *cusickii* in Denny Flat, Baker County, Oregon. Institute for Applied Ecology, Corvallis, Oregon and USDI Bureau of Land Management, Vale District. vii + 44 pp.

The PRISM Climate Group, Oregon State University. 2017. United States Average Monthly temperature or Annual Precipitation, 1971-2000. Corvallis, OR, USA. Available at: http://prism.oregonstate.edu/explorer/. Accessed 15 December 2017.

R Development Core Team. 2009. R: A language and environment for environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, Available at: http://www.R-project.org. Accessed 19 March 2013.

Thorpe, A.S., and T.N. Kaye. 2008. *Astragalus tyghensis* population trends: Actual vs. predicted population sizes. Final Report. Prepared by the Institute for Applied Ecology for the USDI Bureau of Land Management, Prineville District. Corvallis, Oregon. iii + 14.

USDA, NRCS. 2010. The PLANTS Database (http://plants.usda.gov, 25 January 2010). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

APPENDIX A. DATASHEET FOR *ASTRAGALUS MULFORDIAE* MONITORING.

Astragalus mulfordiae demographic monitoring plot

Site: ________________________________

Plot #: ________ Caged or Uncaged

Date: ________________________________

Names: ____

Note location of rebar posts and compass bearing to top of page

Compass bearing:

							Herbivory			
	X-coord	Y-coord	Diam (cm)	longest stem (cm)	#Infl.		Insect		Deer / Cattle	Notes
Plant #										

APPENDIX B. GPS COORDINATES FOR ALL PLOT AND TRANSECT LOCATIONS.

Set Datum to "NAD83"

Set Position Format to "hddd.ddddd"

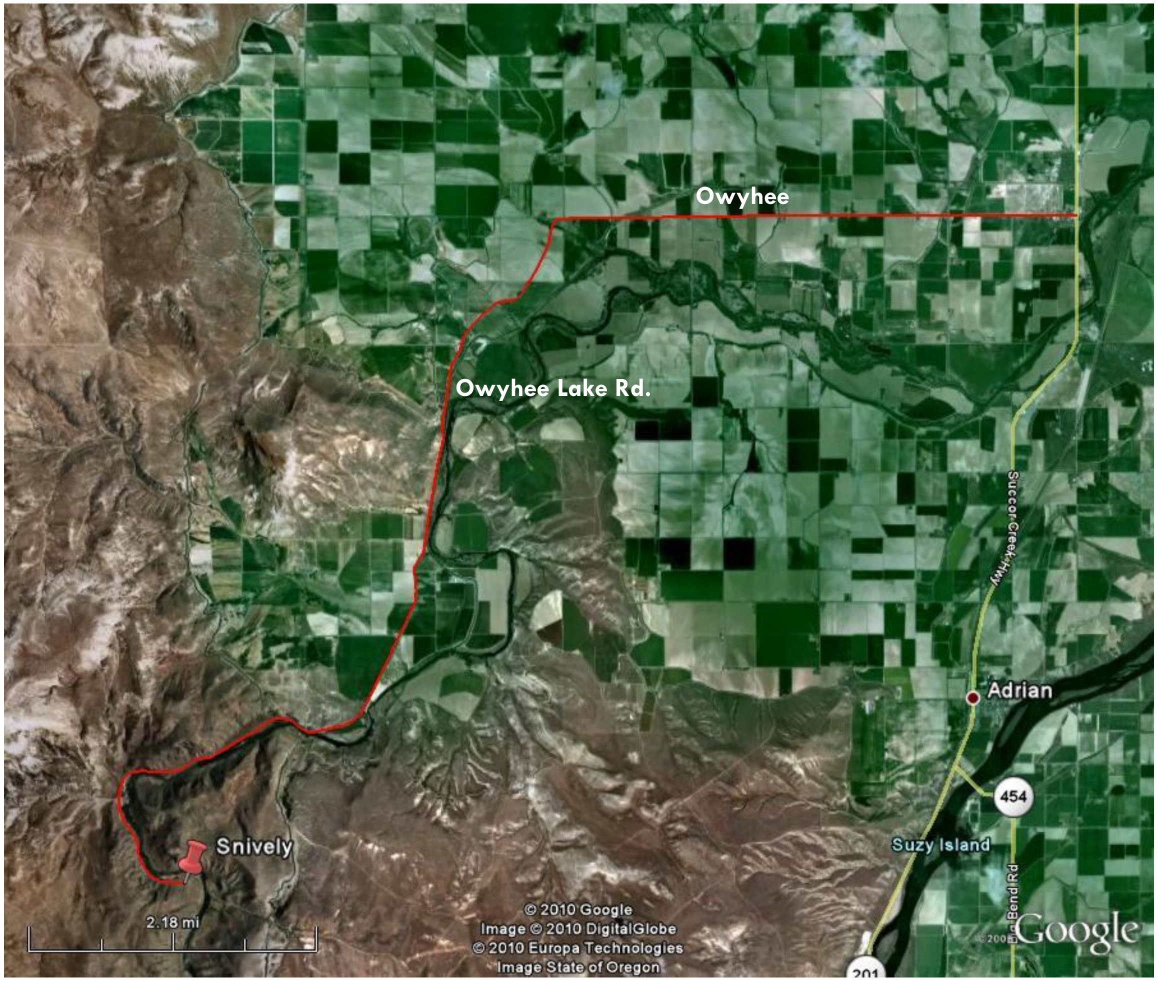
						Notes			
Site	**Sub-site**	**Plot #**	**Treatment**	**LAT**	**LONG**	**2012**	**2013**	**2014**	**2015**
Brown Butte		End	Transect	43.73173	-117.12424				
Brown Butte		Start	Transect	43.73190	-117.12421				
Brown Butte		86	Caged	43.73237	-117.12403	New			
Brown Butte		88	Caged	43.73187	-117.12437	New			
Brown Butte		538	Caged	43.73180	-117.12432				
Brown Butte		541	Caged	43.73227	-117.12406				
Brown Butte		543	Caged	43.73222	-117.12398				
Brown Butte		545	Caged	43.73218	-117.12373				
Brown Butte		87	Uncaged	43.73195	-117.12425	New			
Brown Butte		537	Uncaged	43.73181	-117.12429				
Brown Butte		540	Uncaged	43.73233	-117.12415				
Brown Butte		544	Uncaged	43.73214	-117.12392				
Brown Butte		546	Uncaged	43.73211	-117.12381				
Double Mountain		End	Transect	43.83319	-117.29086				
Double Mountain		Start	Transect	43.83315	-117.29061				
Double Mountain		269	Caged	43.83327	-117.29037	New			
Double Mountain		270	Caged	43.83346	-117.29051	New			
Double Mountain		679	Caged	43.83325	-117.29030				
Double Mountain		680	Caged	43.83332	-117.29047				
Double Mountain		683	Caged	43.83306	-117.29095				
Double Mountain		268	Uncaged	43.83334	-117.29044	New			
Double Mountain		272	Uncaged	43.83269	-117.29130	New			
Double Mountain		678	Uncaged	43.83326	-117.29034				
Double Mountain		682	Uncaged	43.83302	-117.29093			Plot missing	Plot missing

North Harper	North	End	Transect	43.86769	-117.23576				
North Harper	North	Start	Transect	43.86768	-117.23577				
North Harper	North	528	Caged	43.86786	-117.23558				
North Harper	North	530	Caged	43.86786	-117.23563				
North Harper	North	532	Caged	43.86757	-117.23510				
North Harper	North	534	Caged	43.86782	-117.23509				
North Harper	North	79	Caged	43.86790	-117.23538	New			
North Harper	North	78	Uncaged	43.86760	-117.23532	New			
North Harper	North	527	Uncaged	43.86783	-117.23576				
North Harper	North	529	Uncaged	43.86791	-117.23558				
North Harper	North	533	Uncaged	43.86758	-117.23524				
North Harper	North	535	Uncaged	43.86777	-117.23521				
North Harper	South	73	Caged	43.86304	-117.23103	New			
North Harper	South	667	Caged	43.86389	-117.23113		Plot missing		
North Harper	South	669	Caged	43.86382	-117.23115		Plot missing		
North Harper	South	670	Caged	43.86317	-117.23102				
North Harper	South	672	Caged	43.86305	-117.23102	Plot missing	Plot missing		
North Harper	South	673	Caged	43.86269	-117.23064	Plot missing	Plot missing		
North Harper	South	74	Caged	43.86284	-117.23062	New			
North Harper	South	75	Uncaged	43.86292	-117.23095	New			
North Harper	South	576	Uncaged	43.86385	-117.23113	New			
North Harper	South	77	Uncaged	43.86381	-117.23113	New		Plot missing	Plot missing
North Harper	South	666	Uncaged	43.86392	-117.23116				
North Harper	South	671	Uncaged	43.86308	-117.23099				
North Harper	South	674	Uncaged	43.86293	-117.23082				
North Harper	South	675	Uncaged	43.86300	-117.23089	Plot missing			

Snively		End	Transect	43.72012	-117.19399				
Snively		Start	Transect	43.71994	-117.19401				
Snively		69	Caged	43.72001	-117.19503	New			
Snively		71	Caged	43.71998	-117.19470	New			
Snively		72	Caged	43.72005	-117.19387	New			
Snively		547	Caged	43.71979	-117.19368				
Snively		553	Caged	43.71994	-117.19364				
Snively		70	Uncaged	43.72001	-117.19506	New			
Snively		550	Uncaged	43.71977	-117.19473				
Snively		552	Uncaged	43.72003	-117.19368				
Snively		554	Uncaged	43.71993	-117.19353				
South Alkali	#1	646	Caged	44.06173	-117.19659				
South Alkali	#1	649	Caged	44.06177	-117.19658				
South Alkali	#1	650	Caged	44.06161	-117.19660				
South Alkali	#1	647	Uncaged	44.06175	-117.19654				
South Alkali	#1	648	Uncaged	44.06171	-117.19662				
South Alkali	#1	651	Uncaged	44.06160	-117.19636				
South Alkali	#2	80	Caged	44.06403	-117.17443	New			
South Alkali	#2	83	Caged	44.06392	-117.17404	New			
South Alkali	#2	652	Caged	44.06392	-117.17407				
South Alkali	#2	81	Uncaged	44.06406	-117.17443	New			
South Alkali	#2	82	Uncaged	44.06408	-117.17443	New			
South Alkali	#2	84	Uncaged	44.06385	-117.17415	New			
South Alkali	#2	655	Uncaged	44.06407	-117.17423	Plot missing			

South Alkali	#3	End	Transect	44.05372	-117.17505				
South Alkali	#3	Start	Transect	44.05357	-117.17499				
South Alkali	#3	659	Caged	44.05362	-117.17496				
South Alkali	#3	660	Caged	44.05366	-117.17484				
South Alkali	#3	663	Caged	44.05369	-117.17520				
South Alkali	#3	665	Caged	44.05336	-117.17495				
South Alkali	#3	658	Uncaged	44.05360	-117.17479				
South Alkali	#3	662	Uncaged	44.05367	-117.17519				
South Alkali	#3	664	Uncaged	44.05332	-117.17494				

DRIVING DIRECTIONS TO SNIVELY



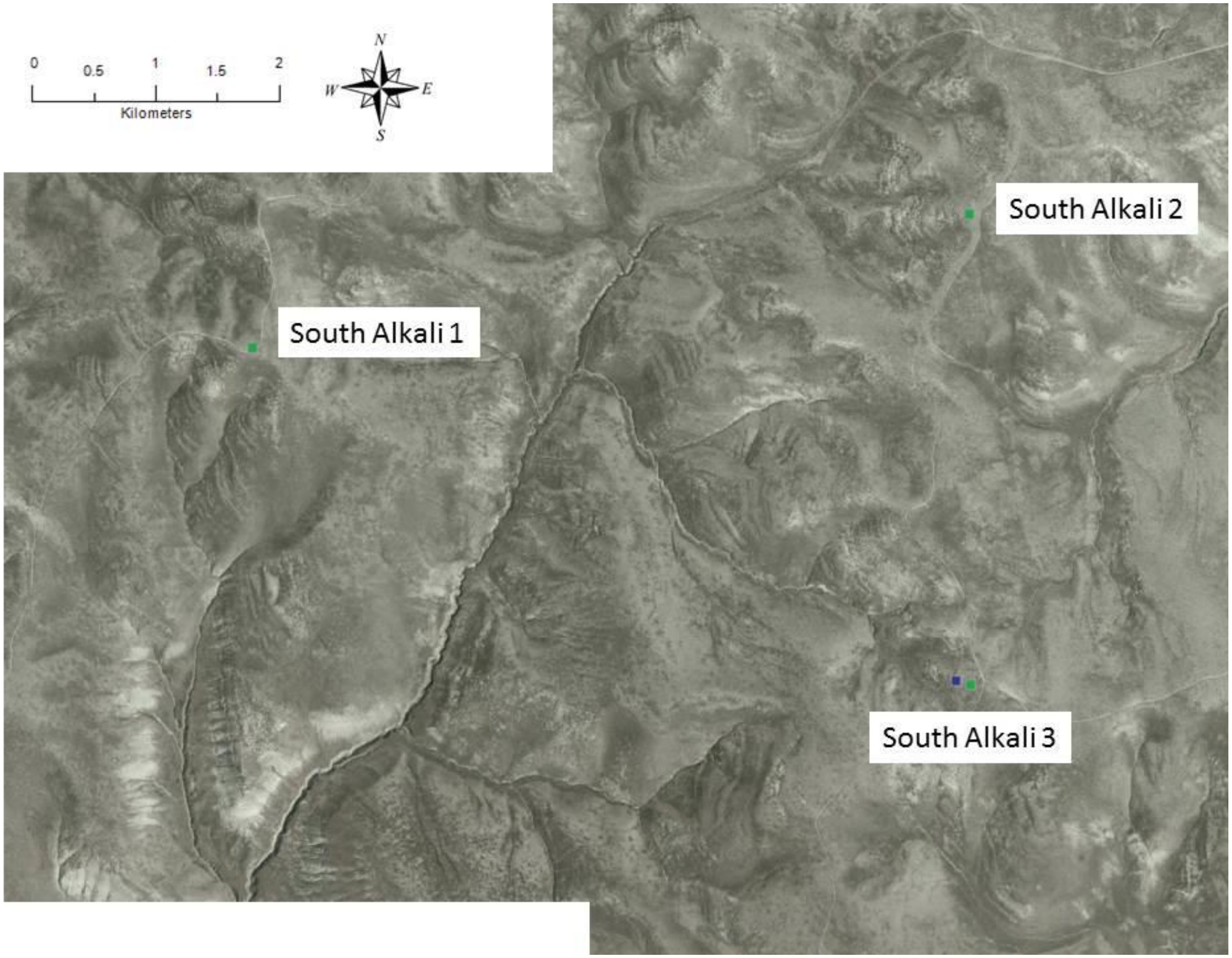
Driving route to Snively from State Route 201. Written driving directions can be found in Appendix C.


Snively overview

DETAILED MAP OF THE SNIVELY FIELD SITE.

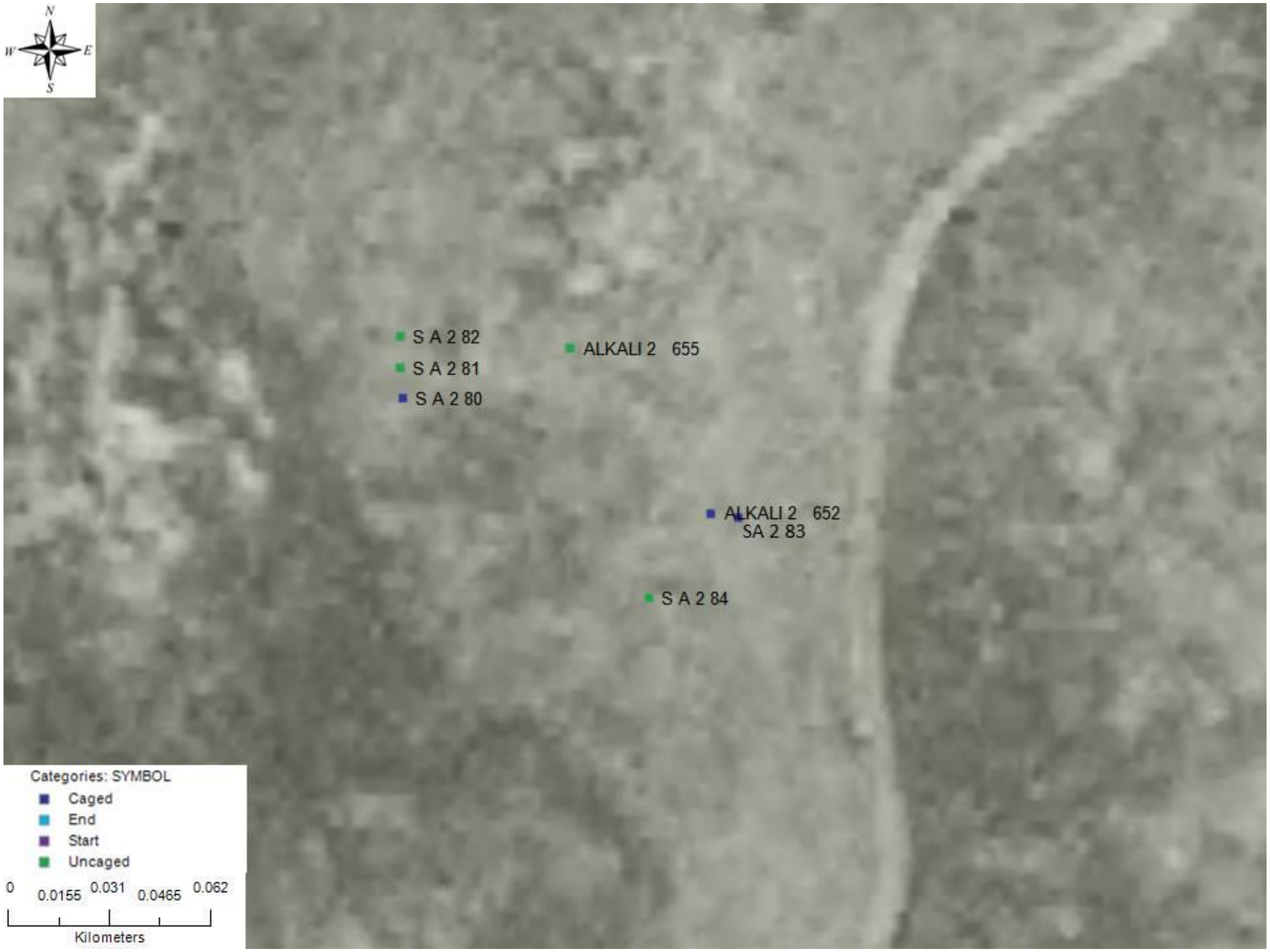
Driving route to South Alkali 1, 2, and 3. From Jordan Waterhole, it is advisable to drive clockwise around the loop, visiting S. Alkali 1 first. The road basically stays on top of a ridgeline all the way around this valley. Follow the 7.5" USGS topo map and written driving directions (Appendix C) carefully, especially once you are on Valley View Road. 11T 0485982E 4877837N (start of transect at population 3, Nad83). Note, large washout occurred at the base of the valley to the right. Safest is to travel clockwise from SA1 to SA3, then turn back and travel counter-clockwise around the valley.

OVERVIEW OF SOUTH ALKALI



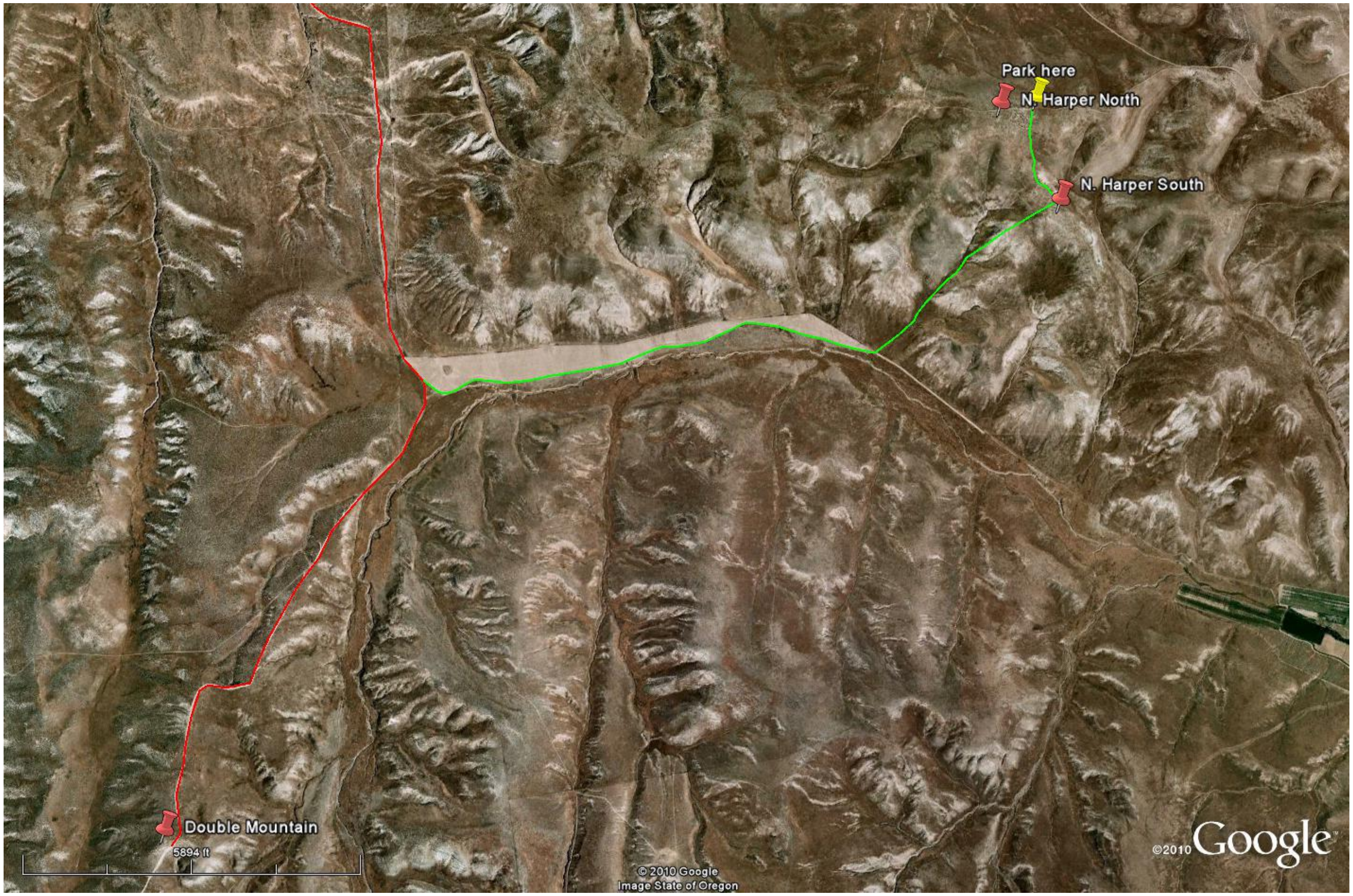
SOUTH ALKALI #1, DETAILED MAP

SOUTH ALKALI #2, DETAILED MAP



SOUTH ALKALI #3, DETAILED MAP

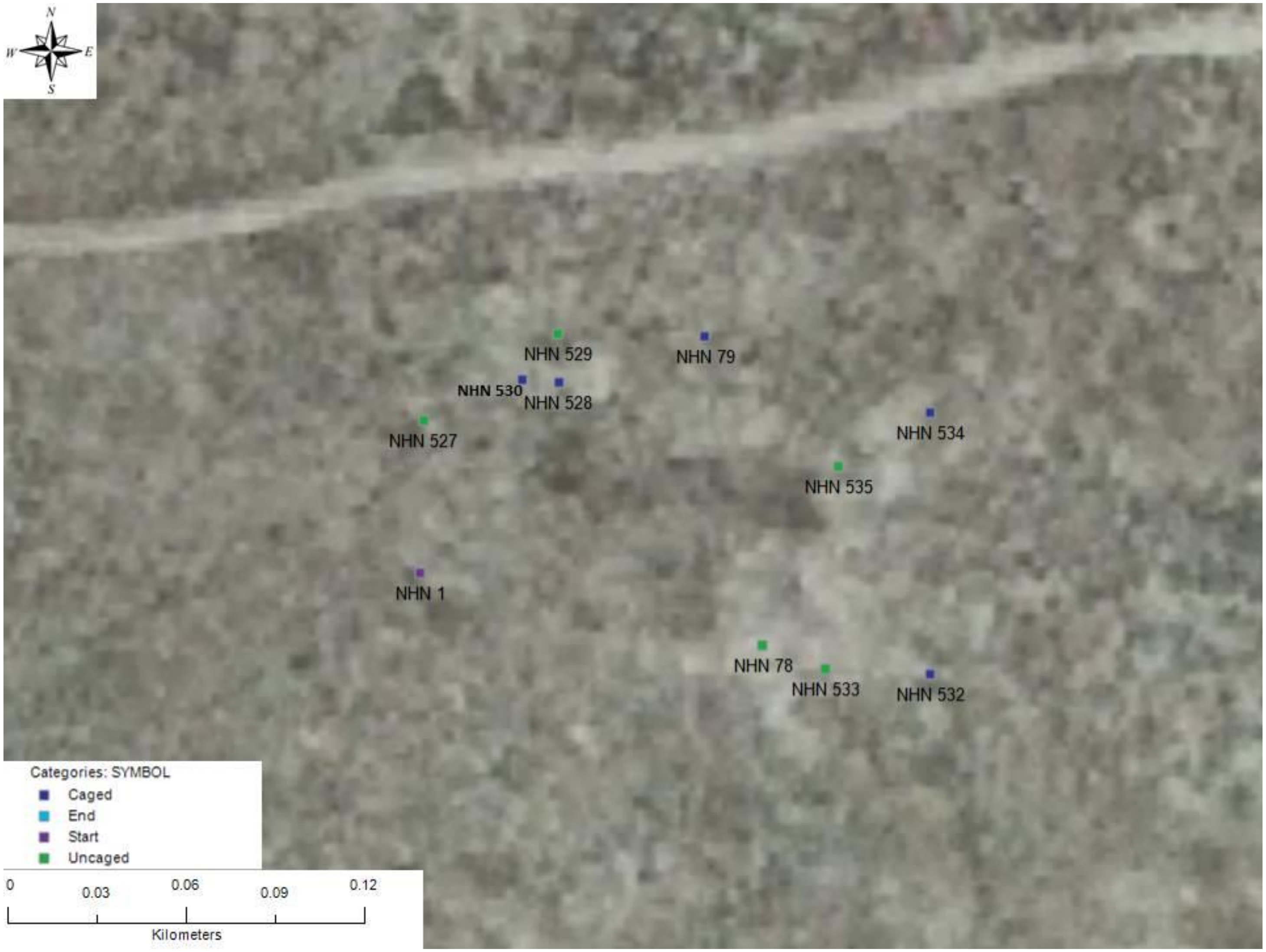
Driving Route to North Harper



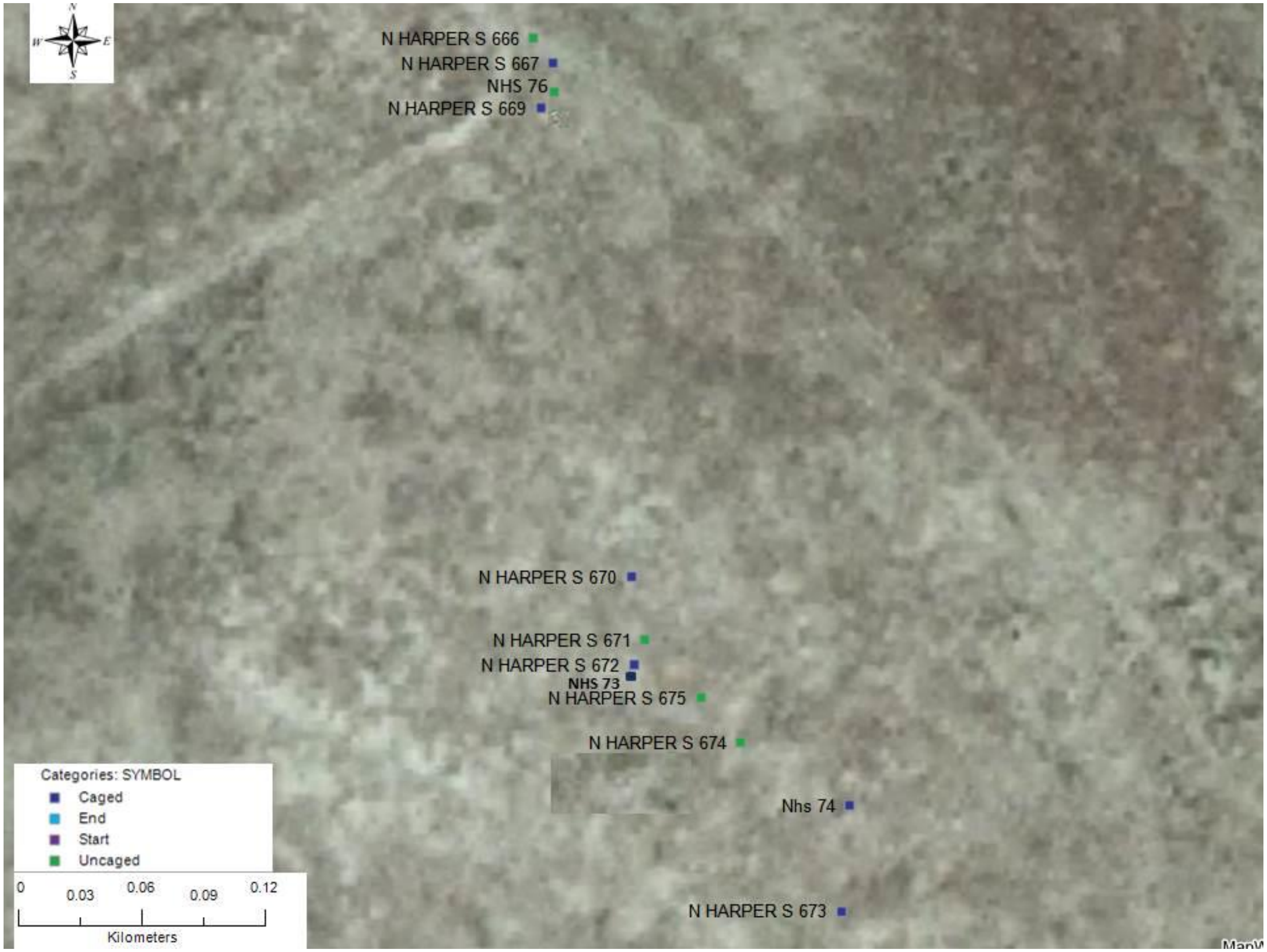
Driving directions to North Harper. Highway 20 is north on Russell Road. Follow the 7.5" USGS topo quad and written driving directions carefully (Appendix C).

OVERVIEW OF NORTH HARPER FIELD SITES

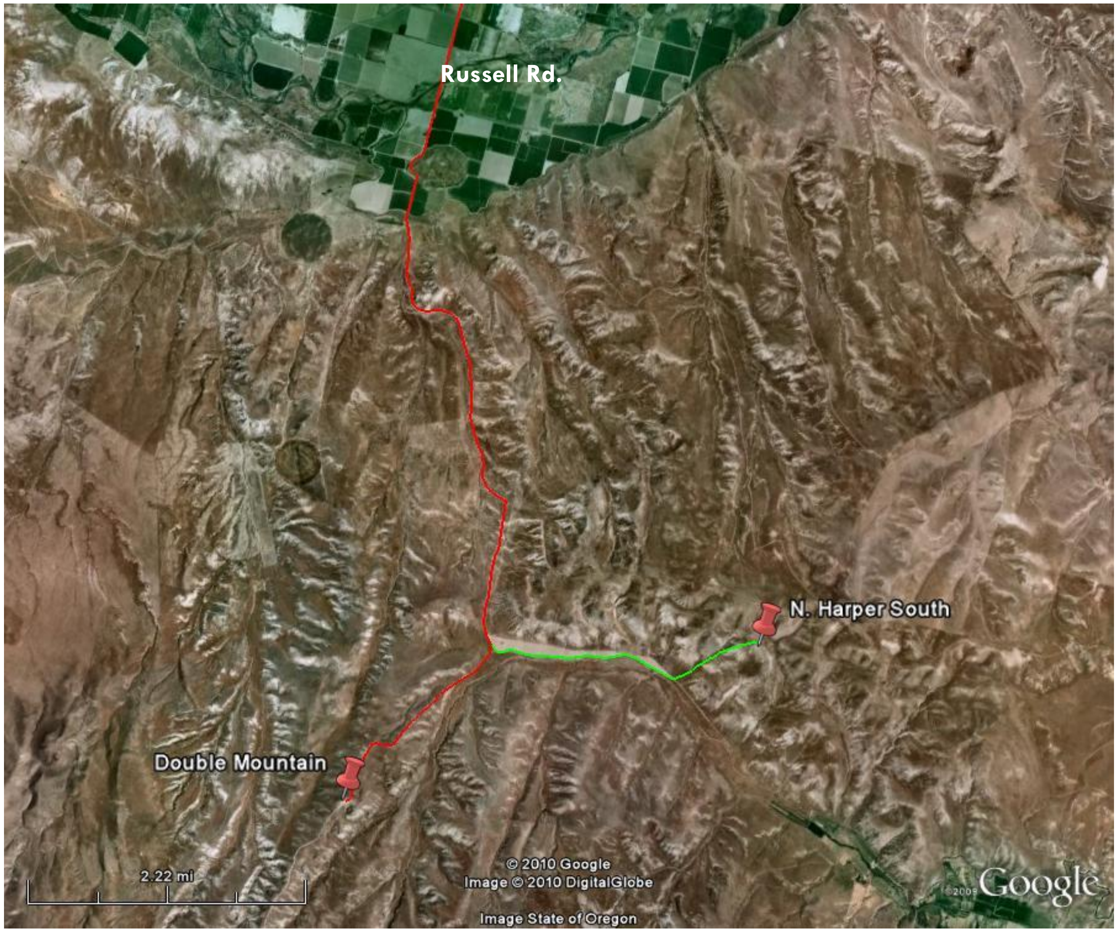
NORTH HARPER NORTH, DETAILED MAP



NORTH HARPER SOUTH, DETAILED MAP

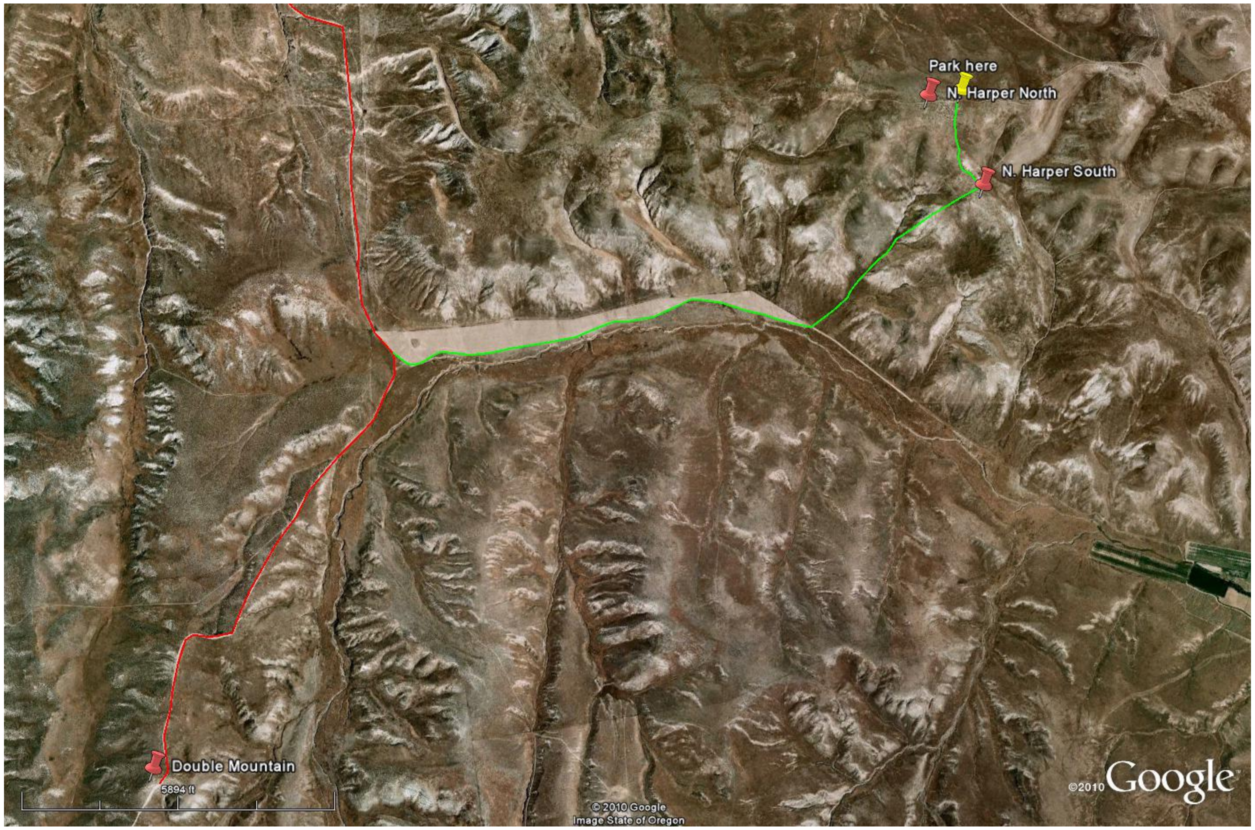


DRIVING ROUTE TO DOUBLE MOUNTAIN



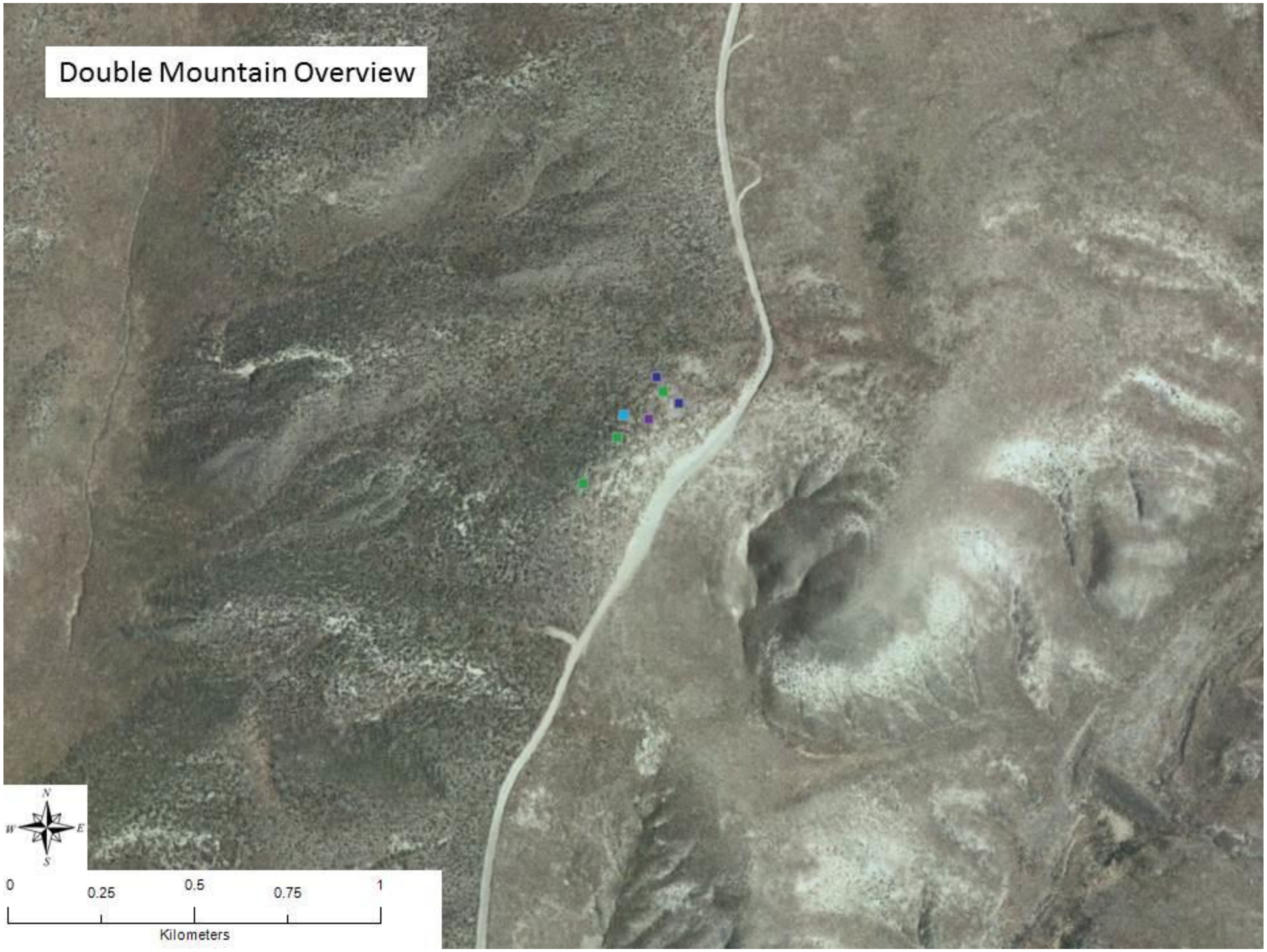
Driving route to Double Mountain (red) and alternative route to North Harper South (green). Highway 20 is north on Russell Road. Follow the 7.5" USGS topo quad and written driving directions carefully (Appendix C).

DRIVING ROUTE TO DOUBLE MOUNTAIN (ZOOM)



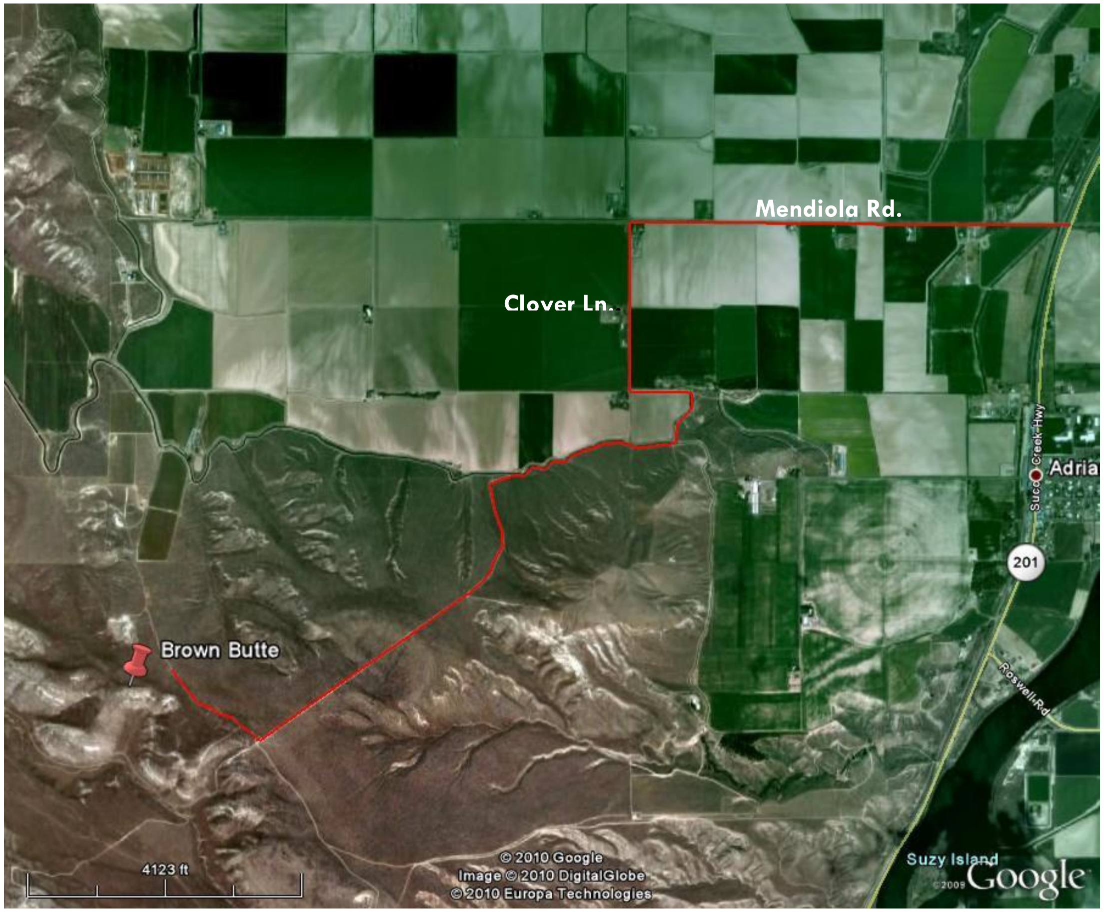
Driving route to Double Mountain (red) and alternate route to North Harper South and North (green). Highway 20 is north on Russell Rd. Follow the 7.5" USGS topo quad and written driving directions carefully (Appendix C).

OVERVIEW OF THE DOUBLE MOUNTAIN FIELD SITE



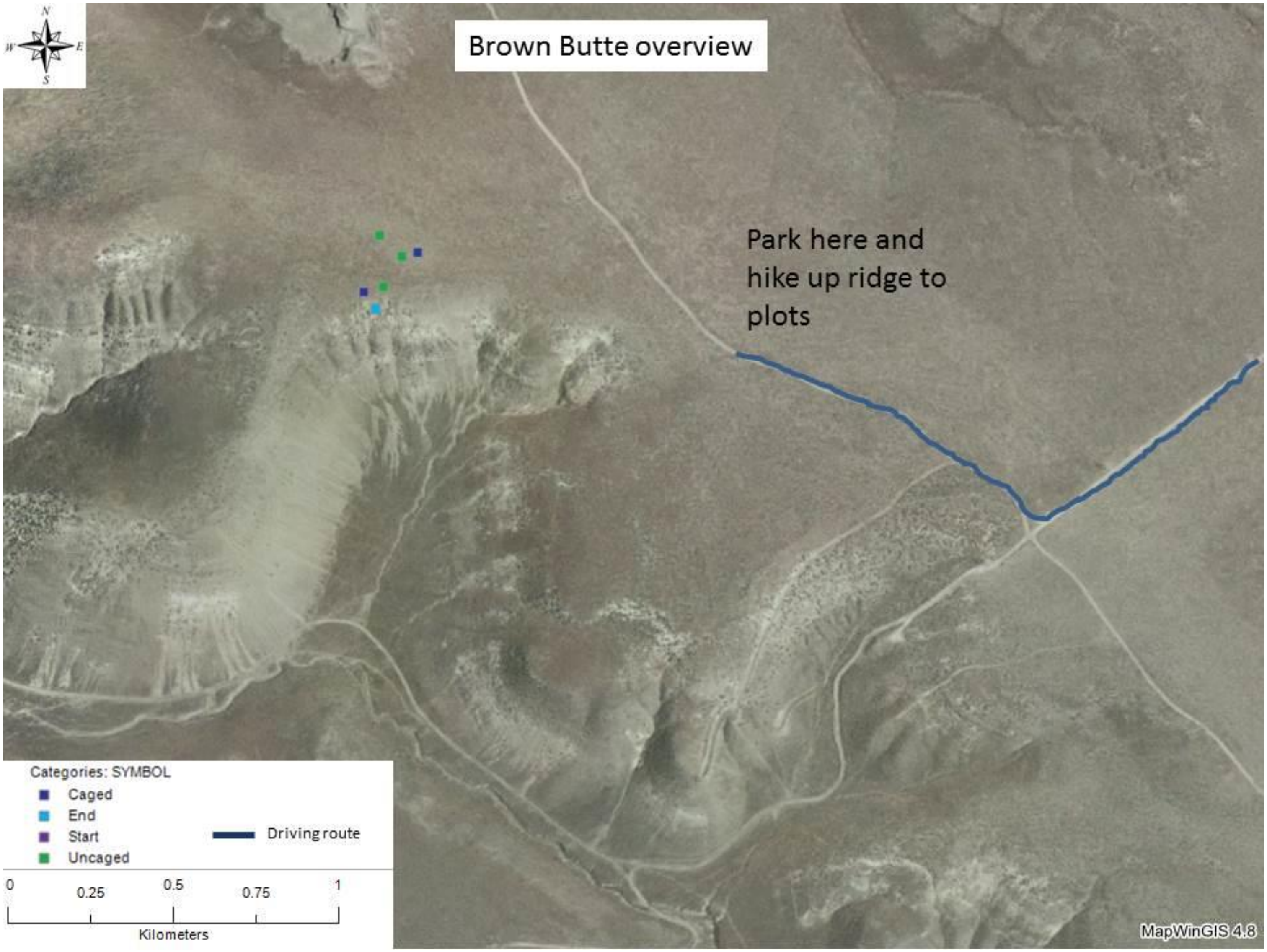
DETAILED MAP OF THE DOUBLE MOUNTAIN FIELD SITE

DRIVING ROUTE TO BROWN BUTTE

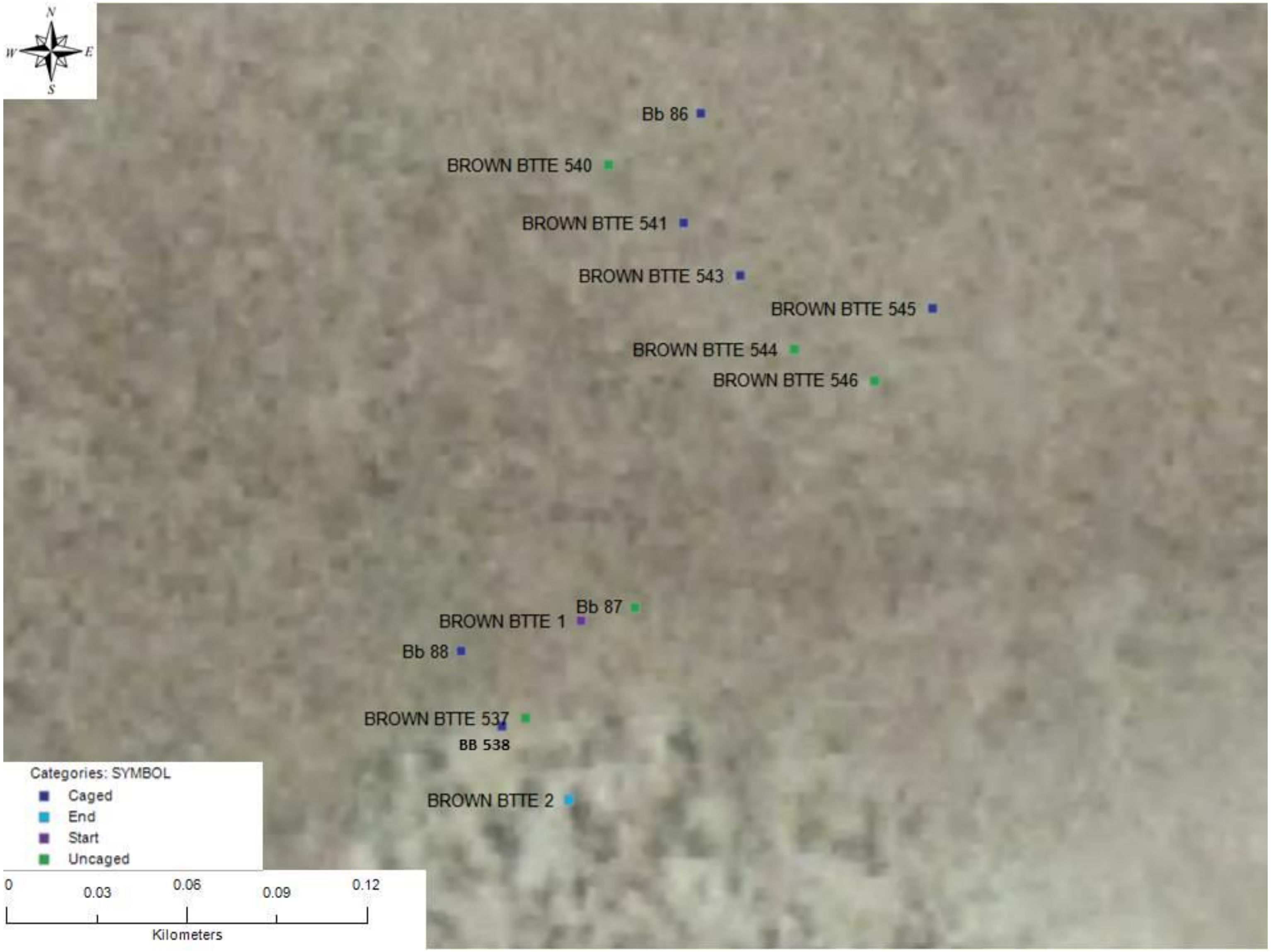


Driving route to Brown Butte sampling site from State Route 201. See Appendix C for written directions. After Clover Lane, follow the written directions carefully.

Overview of Brown Butte



DETAILED MAP OF BROWN BUTTE



Directions – Update directions as needed for future sampling. DO NOT assume directions, especially mileages, are precise. You can use the Google maps (above) and a compass to ensure you are always basically going in the right direction. Leave all gates as you find them (open or closed)!
Last updated 8/16 MP + SC

To Bully Creek Reservoir (camping)

From Vale → take Graham west for ~5.7 miles. Turn right (north) onto Bully Creek Road and travel for 3.7 miles to campground and reservoir. 2475 Bully Creek Road, (541) 473-2969, cash or check only.

South Alkali Field Site (Henry Gulch quad) - NOTE: While in the past we have completed this as a circuit, there looked like there was a washout in 2013. After South Alkali 3, it is safer to backtrack rather than making a circle.

From the BLM office, turn right onto Hwy 26/12th St/Glenn St. N and then left onto Hope St. E/Railroad Avenue E. After two blocks turn left onto 10th St. After one block, 10th curves to the right and turns into Lagoon Dr. Lagoon parallels railroad tracks until it dead ends, go left (north) onto Foothill Dr. At intersection, Foothill turns right, stay straight, road changes to Vale View Rd---RESET your odometer. After 0.5 miles Vale View will turn to the left (west)—don't do this. At this turn in the road, there will be a gravel road with a stop sign (may look like a driveway) → take this road. Go past Netcher Ln (on your right after ~0.1) and continue on this road (Right at the Y-intersection at 0.9) to a total of 1.2 miles where you will see a large gate with two tall rock columns. Go through this gate!

Follow the road to the right along the dyke and go through a gate that has two rock columns. Reset odometer—you are about to begin a 9 mile circuit of the ridge in front of you, following around the edge of the watershed/basin to your right. Reference a topo and/or aerial map of the area if you need help navigating. Continue on this road to the left (by Jordan Water Hole). The road goes up into the hills, along a ridge, with the valley on your right. At 0.4 → stay right. Stay Right at 1 mile. At 3.3 park at S. Alkali 1. At 4.7 go through gate and turn right. At 5.2 pass through a green gate. At 5.4 park at S. Alkali 2. At 6.2 park at S. Alkali 3. When finished, turn around and go back the way you came. [OLD DIRECTIONS TO COMPLETE CIRCUIT: At 9.2 go through gate (this gate was on your right when you first started the loop). At 9.25 pass thorough gate with two rock columns—you have completed a 9.25 mile circuit along the ridge line.]

Double Mountain Field Site (Double Mountain quad)

From the BLM office, turn right out of the BLM visitor's parking lot. Turn left onto 14th street. Turn right onto Hope Street. Turn left onto 17th street. Turn right onto Washington (20W). Take 20W past Vale. Turn left onto Russell Rd. Go 2 miles and turn left onto Dry Creek. 2.2 stay right, 2.6 stay left through gate, and 2.7 stay right. 4.6 cattle-guard, 6.5 and 6.9 cattle-guard. Park at 8.6 and hike uphill on the right to reach the site.

Brown Butte/Blackjack Field Site (Adrian quad)

Follow Lytle BLVD south out of Vale towards Adrian (about 13.8 miles). Take a sharp left on Janeta Ave, a sharp right on Jefferson Ave, and another sharp left on Owyhee Ave. Follow briefly (little over a mile) and then take a right onto HWY 201. Turn right onto Mendiola Road and reset odometer. At 1.2, turn left onto Clover Lane (will see stand of trees); where pavement ends (1.7), turn left on far side of irrigation ditch; cross canal and make a hard right turn (onto Road E). At 2.1 bear right, drive along base of butte, next to canal; cross over cattle guard at 2.6, make a right turn at intersection with power lines (~3.2) and follow road until you can park and hike uphill to plots (use GPS).

North Harper (North and South) (Mitchell Butte quad)
** **Do S first, then continue up road to N****

From Cow Hollow** [USE THESE]
From Vale, take 20 west. Turn left onto Russell Rd ~4miles out of town. Turn left onto Dry Creek/Twin Spring (Cow Hollow) → reset odometer. R at 0.1, after 4.5mi, turn left onto 2 track. At 5.2 stay straight and beware of large washout on right. At 5.7 go past cattle station (road goes through big thicket of Russian thistle, kind of invisible). Go through the gate on left (6.1) and continue to drive along the road. In 2015 the road was full of thistle! Follow the road to the left and up into the hills (along a drainage)—this has become increasingly hairy since 2012. This road will take you directly to the site-Park at 6.9. Stay on the road, continuing up the hill. For North Harper North, at the T in the road, go left and park ~7.3. ASMU is in the road. ****NOTE: In 2015, the road is getting increasingly sketchy/sandy from the cattle area to NHS → park below where it is flat and hike into both sites [bring plenty of food/water].**

From Lytle Blvd. (Use only as backup- Follow Cow Hollow directions)
Turn right onto dirt road (if coming from Vale) that cuts to northwest and goes behind ridge paralleling road. If you pass the dump, you went too far. Keep on dirt road for ~2.5 miles (always going ±NW) until you come to a triangle junction, turn left (towards water tower). Road runs ~SW for 0.9 miles before turning WNW (near the water tower). Drive 1.5 miles (total from last triangle junction), go through fence and turn left (south). Road will follow fenceline for ~1.25 miles until it reaches another triangle junction, take right fork, which will spit you out going west on new road after 1.35 total miles from last junction. After 0.1 miles, take left fork. In 0.3 miles you will reach another fork (with a large patch of *Oenothera cespitosa*). Go left and park at top of hill to walk down and sample N. Harper South, go right, drive 0.4 miles west, and park to sample N. Harper North. Follow USGS 7.5" topo carefully. Not necessary.

Snively Field Site (Owyhee Dam site)

From Vale: Follow Lytle BLVD south out of Vale towards Adrian. Take a sharp left on Janeta Ave, a sharp right on Jefferson Ave, and turn right onto Owyhee Avenue. Turn left onto Owyhee Lake Road. Follow past Snively Hot Springs, field site is across the road from a pull-out with cottonwoods.

SC 8/16: There is a shortcut between BB and Snively. Leaving BB, get back on Clover Ave. Pass Mendiola and Clover becomes Locust. Follow until it T's at Overstreet. Turn left on Overstreet. Follow until it T's on Owyhee Lake Rd, after crossing the Owyhee River. Turn left on Owyhee Lake Rd. Follow along river, pass Snively Hot Spring and keep an eye on the left hand side for a big pull-out. If you have access to google maps it will show up at Snively Gulch Rd. From the Owyhee River crossing to the pullout is ~4.6 miles.

APPENDIX C. HERBIVORY PLOT INFORMATION.

New plots were added in 2012. "y" indicates yes.

Site	Treatment	Plot #	Missing in 2012	New in 2012?	Empty in 2013?	Empty in 2014?	Empty in 2015?	Empty in 2016?	Empty in 2017?
Brown Butte	caged	86		y					
	caged	88		y					
	caged	538			y	y	y	y	y
	caged	541			y	y	y	y	
	caged	543			y	y	y	y	y
	caged	545			y	y	y	y	y
	uncaged	87		y		y	y		
	uncaged	537							
	uncaged	540							
	uncaged	544							
	uncaged	546							
Double Mountain	caged	269		y	y	y			
	caged	270		y					y
	caged	679							
	caged	680			y	y	y	y	y
	caged	683			y	y	y	y	
	uncaged	268		y		y	y	y	y
	uncaged	272		y	y	y	y	y	y
	uncaged	678							
North Harper North	caged	528			y	y	y	y	y
	caged	530			y	y	y	y	y
	caged	532				y	y	y	
	caged	534							
	caged	79		y					
	uncaged	78		y		y	y		
	uncaged	527				y	y	y	
	uncaged	529				y			
	uncaged	533				y	y	y	
	uncaged	535							

North Harper South	caged	73		y		y			
	caged	667			y	y	y	y	
	caged	669			y	y			
	caged	670							
	caged	672	y			y	y	not monitored	
	caged	74		y					
	uncaged	75		y					
	uncaged	76 [new tag #576]		y		y	y	y	
	uncaged	666							
	uncaged	671				y			
	uncaged	674				y	y		
	uncaged	675	y			y	y		
Snively	caged	69		y					y
	caged	71		y			y	y	y
	caged	72		y					
	caged	547			y	y	y	y	y
	caged	553							
	uncaged	70		y					
	uncaged	550						y	y
	uncaged	552						y	y
	uncaged	554				y	y	y	y
South Alkali 1	caged	646							
	caged	649							
	caged	650							
	uncaged	647							
	uncaged	648						y	y
	uncaged	651							
South Alkali 2	caged	80		y					
	caged	83		y					
	caged	652							
	uncaged	81		y					
	uncaged	655	y		y				
	uncaged	82		y					
	uncaged	84		y				y	
South Alkali 3	caged	659							
	caged	660			y	y			
	caged	663							
	caged	665			y	y			y

South Alkali 3 [CONT]	uncaged	85		y					
	uncaged	658				y		y	y
	uncaged	662				y			
	uncaged	664							

APPENDIX D. AVERAGE PERCENT COVER OF ALL VASCULAR PLANT SPECIES RECORDED AT THE FIVE TRANSECTS SAMPLED IN 2017. PLANTS ARE ORGANIZED BY NATIVE STATUS AND GROWTH HABIT.

Abbreviations include: "N" = native, "I" = invasive, "F" = forb, "G" = graminoid, "S" = shrub.

Code	Current Name	Common name	Habit	Nativity	Brown Butte	Double Mtn	North Harper North	Snively	South Alkali
ACHHYM	*Achnatherum hymenoides*	Indian ricegrass	G	N	3.23	6.75	1.10	0.15	0.00
ALYDES	*Alyssum desertorum*	desert madwort	F	I	0.00	0.00	0.00	1.05	2.10
ASTMUL	*Astragalus mulfordiae*	Mulford's milkvetch	F	N	0.70	0.05	0.48	0.35	3.43
ASTPUR	*Astragalus purshii*	woollypod milkvetch	F	N	0.00	0.00	0.00	0.00	0.03
BALSAG	*Balsamorhiza sagittata*	arrowleaf balsamroot	F	N	0.15	4.15	12.45	1.38	0.90
BROTEC	*Bromus tectorum*	cheatgrass	G	I	29.75	40.28	22.00	48.63	36.40
CHADOU	*Chaenactis douglasii*	Douglas' dustymaiden	F	N	0.00	0.00	0.00	0.00	0.18
CHAMAC	*Chamaesyce maculata*	small spotted sandmat	F	N	0.08	0.00	0.00	0.00	0.00
CHRVIS	*Chrysothamnus viscidiflorus*	green rabbitbrush	S	N	3.13	14.80	13.03	10.05	3.30
COMUMB	*Comandra umbellata*	bastard toadflax	F	N	0.73	0.00	0.00	0.00	0.00
CREACU	*Crepis acuminata*	tapertip hawksbeard	F	N	0.00	0.00	0.75	0.00	1.28
DESINC	*Descurainia incana*	mountain tansymustard	F	N	0.00	0.00	0.00	0.00	0.05
DESPIN	*Descurainia pinnata*	western tansymustard	F	N	0.63	0.25	0.25	0.03	0.40
ELYELYE	*Elymus elymoides* ssp. *elymoides*	squirreltail	G	N	0.00	0.80	1.08	0.00	1.05
ERIPUM	*Erigeron pumilus*	shaggy fleabane	F	N	0.00	0.00	0.00	0.00	2.25
ERISPA	*Eriastrum sparsiflorum*	Great Basin woollystar	F	N	0.00	0.00	0.00	0.00	0.20
ERIOG	*Eriogonum* sp.	buckwheat	S	N	0.00	0.00	0.00	2.25	0.00
EROCIC	*Erodium cicutarium*	redstem stork's bill	F	I	1.23	0.00	0.00	0.03	0.00
FRIPUD	*Fritillaria pudica*	yellow fritillary	F	N	0.00	0.00	0.00	0.13	0.00
GRASPI	*Grayia spinosa*	spiny hopsage	S	N	2.75	0.00	0.00	0.00	0.00
HESCOMC	*Hesperostipa comata* ssp. *comata*	needle-and-thread grass	G	N	2.58	0.00	10.95	5.50	0.00
LACSER	*Lactuca serriola*	prickly lettuce	F	I	0.03	0.03	0.03	0.03	0.00

Code	Current Name	Common name	Habit	Nativity	Brown Butte	Double Mtn	North Harper North	Snively	South Alkali
LINPUN	*Linanthus pungens*	granite prickly phlox	S	N	0.00	0.00	1.70	0.15	0.00
MACCAN	*Machaeranthera canescens*	hoary tansyaster	F	N	0.00	0.00	0.00	0.23	0.68
OENPAL	*Oenothera pallida*	pale evening primrose	F	N	0.00	0.00	0.00	0.00	0.78
OPUPOL	*Opuntia polyacantha*	plains prickly pear	F	N	0.00	0.00	0.88	0.00	0.00
PASSMI	*Pascopyrum smithii*	western wheatgrass	G	N	0.00	3.15	0.00	1.95	0.15
PENACU	*Penstemon acuminatus*	sharpleaf penstemon	F	N	0.00	0.00	0.20	0.00	0.53
PHAHET	*Phacelia heterophylla*	varileaf phacelia	F	N	0.00	0.00	0.15	0.00	0.33
PHALIN	*Phacelia linearis*	threadleaf phacelia	F	N	0.00	0.00	1.70	0.40	0.03
POABUL	*Poa bulbosa*	bulbous bluegrass	G	I	0.00	0.00	0.00	0.33	0.00
POASEC	*Poa secunda*	Sandberg bluegrass	G	N	0.70	0.00	10.88	0.50	7.20
SALTRA	*Salsola tragus*	prickly Russian thistle	F	I	0.05	0.10	0.00	0.55	0.00
SALTRA	*Salsola tragus* DEAD	prickly Russian thistle	F	I	0.00	1.43	0.00	0.55	0.00
SISALT	*Sisymbrium altissimum* DEAD	tall tumblemustard	F	I	0.00	1.13	0.00	0.50	0.00
SPHGRO	*Sphaeralcea grossulariifolia*	gooseberryleaf globemallow	F	N	0.45	0.00	0.00	0.00	0.00
VULPIA	*Vulpia* sp.	fescue	G	-	0.00	0.00	0.40	0.00	0.00
ZIGVEN	*Zigadenus venenosus*	meadow deathcamas	F	N	0.00	0.00	0.00	0.00	0.08

APPENDIX E. OUTPUT FROM STATISTICAL ANALYSES IN 2017.

Two factor analysis of variance (ANOVA) table for the mean diameter (cm; log-transformed) of *A. mulfordiae* in **2017 only**, by treatment (caged/uncaged) and site. Predictors with a *p*-value < 0.05 are in bold.

	Df	SS	MS	F value	*P* value
Treatment	1	20.184	20.1840	19.4974	**1.553e-05** ***
Site	5	109.436	21.8872	21.1427	**< 2.2e-16** ***
Treatment:Site	5	9.970	1.9939	1.9261	0.09087
Residuals	229	237.063	1.0352		

Analysis of variance (ANOVA) table for the mean diameter (cm; log-transformed) of *A. mulfordiae* in **2010-2017**, by site, treatment, and year. Predictors with a *p*-value < 0.05 are in bold.

	Df	SS	MS	F value	*P* value
Treatment	1	75.38	75.382	69.3288	**2.943e-16** ***
Site	5	187.64	37.529	34.5148	**< 2.2e-16** ***
Year	1	75.68	75.680	69.6024	**2.587e-16** ***
Treatment:Site	5	25.97	5.194	4.7766	**0.0002568** ***
Treatment:Year	1	0.19	0.192	0.1768	0.6742152
Site:Year	5	66.93	13.387	12.3119	**1.395e-11** ***
Treatment:Site:Year	5	24.01	4.803	4.4170	**0.0005560** ***
Residuals	934	1015.55	1.087		

Analysis of variance (ANOVA) table for the mean diameter (cm) of *A. mulfordiae* at **North Harper North in 2017 only,** by treatment (caged/uncaged). Predictors with a *p*-value < 0.05 are in bold.

	Df	SS	MS	F value	*P* value
Treatment	1	8.8241	8.8241	10.416	**0.004946** **
Residuals	17	14.4011	0.8471		

Analysis of variance (ANOVA) table for the mean diameter (cm) of *A. mulfordiae* at **North Harper South in 2017 only,** by treatment (caged/uncaged). Predictors with a *p*-value < 0.05 are in bold.

	Df	SS	MS	F value	*P* value
Treatment	1	4.745	4.7449	5.0754	**0.0262** *
Residuals	113	105.641	0.9349		