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

2015

Progress Report to the Bureau of Land Management Vale District

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

*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.

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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 2015, work was supported by IAE staff members Michelle Allen, Emma MacDonald, Connor Whitaker, Cecilia Welch, Sara Newman, Denise Giles-Johnson, and Tom Kaye. In 2015 Susan Fritts and two Conservation and Land Management Interns (CLM), Amanda and Lauren, also assisted us in the field.

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

**Suggested Citation**

Gray, E.C., M. Petix, and M. Bahm. 2015. *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. vii + 61 pp.

# EXECUTIVE SUMMARY

This document summarizes monitoring of *Astragalus mulfordiae* (Mulford's milkvetch) on land managed by the BLM Vale District. In 2015, we monitored plots testing for effects of herbivory on *A. mulfordiae* in permanent plots along with transects looking at long-term population trends and plant community composition.

- In 2015 we observed an increase in densities of *A. mulfordiae* from 2014, which had the lowest densities since 2008. We counted 164 plants total, with 75 in caged plots and 89 in uncaged plots. 78 new plants were observed in 2015. Despite a 50.5% increase from 2014, total number of plants still remains much less than numbers observed in 2008-2010.
- In 2015, 23 plots that were once established due to high densities of *A. mulfordiae* no longer contained the species. This was similar to the empty plots observed in 2012. In 2014, we removed plots that had been empty since 2012.
- We found that size of *A. mulfordiae* differed significantly by site, but not by treatment (caged or uncaged) in 2015. Plants at Brown Butte, North Harper North, and Snively were the largest while those at Double Mountain and North Harper South were the smallest.
- Reproductive effort varied across the sites. South Alkali had the highest number of fruits per plant while those at North Harper North had the lowest across the sites. All of the plants at Brown Butte were reproductive. One plant at South Alkali that had 615 fruits in 2014 had 344 fruits in 2015.
- In plots established in 2008, we observed an increase in total number of plants from 2014 to 2015. There was a very large increase in plants at North Harper South from 2014-2015 (700% increase), where we observed more plants in 2015 than there were in these plots in 2008 when plots were established. Although the increases in number of plants were slighter for the other sites, it is promising to observe an increasing trend after the decline that had been exhibited from 2008-2014 across all plots and sites.
- In population monitoring transects, number of *Astragalus mulfordiae* increased from 42 to 53 in 2015, following a severe decline exhibited in recent years (65% from 2012 to 2014). One seedling was found in the transect at Double Mountain in 2014, following a year with no plants in 2013. In 2015, the plant was reproductive.
- In 2015 53% of plants in the transects were reproductive, which was a slight decline from that seen in 2014 (76%). In 2015 19% were seedlings, which was an increase from 9% observed in 2014.
- The plant communities at these sites have varied greatly from 2010 to 2015. Cover of exotic species, particularly cover of *Bromus tectorum* (cheatgrass) has continued to increase at all sites, except South Alkali. While in 2010 all of the sites were native dominated, in 2015 all sites, except North Harper North, were dominated by exotic species.
- 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. Cattle grazing may have more impacts on *A. mulfordiae* in other populations with higher stocking rates and grazing during the growth period.
- Continued monitoring and immediate attention may be necessary to mitigate any future losses of this rare species.

# TABLE OF CONTENTS

# LIST OF FIGURES



# LIST OF TABLES

## List of Appendices

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

REPORT TO THE 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* (yellow 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 1, Appendix B).

Table 1. Site characteristics including total # of plots present in 2015

| 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 was tied with wire around the plot marker in the southeast corner of each plot. Caged plots allowed us to measure the approximate effects of 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 1 m$^2$. They were held in place with wire tied to wooden stakes sunk into the corners of the plots. Plots were monitored in 2008, 2009, 2010, 2012, 2013, 2014, and 2015.

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). We also completed a transect information form that included information to help relocate the transects.

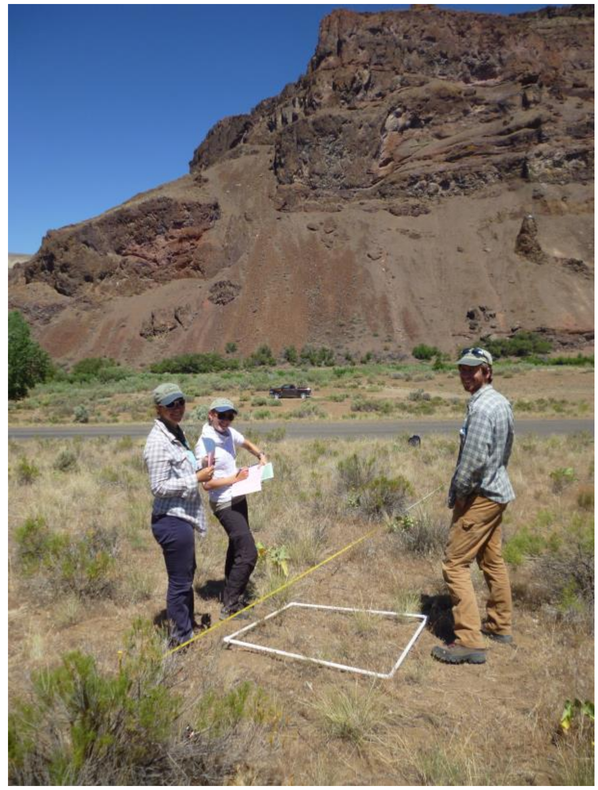


Figure 3. *Astragalus mulfordiae* population and community monitoring at Snively, 2013.

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" (Figure 4). 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.

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).

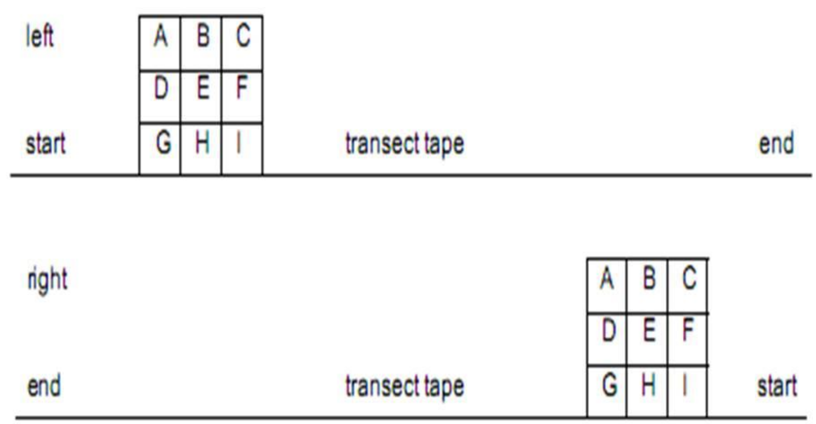



Figure 4. Transect setup for *A. mulfordiae* population and community monitoring.

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 (South alkali #1, #2, #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).

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 2015 (all plots). Plants that were new in 2015 and were under 5cm in diameter were removed for analysis due to the abundance of seedlings observed in 2015. 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 2015. 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. This analysis was conducted for reproductive plants only. 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- 2015 were acquired from the PRISM climate group (PRISM 2006). 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

### 2015 Plant Trends

In 2015, a total of 164 *A. mulfordiae* plants were monitored in 71 experimental plots (34 caged and 37 uncaged), with 75 plants occurring in caged plots and 89 plants in uncaged. In 2014 there were 109 plants present (Table 4). There were considerable increases for number of plants in 2015 in both caged plots (from 55 to 75) and uncaged plots (from 54 to 89). Between 2014 and 2015, we observed a 50.5% increase in plants present.

Mortality in 2015 was less than in 2014 with 26 plants dying, relative to the 34 that died in 2014 (Table 4). Mortality occurred at all sites (except for Brown Butte) in both caged and uncaged plots, with the most occurring in uncaged plots at South Alkali #2 and #3 (7 and 5 plants, respectively; Figure 5). This differs considerably from 2014, where South Alkali plots experienced the lowest mortality (only 4 plants combined from South Alkali #1-3) and North Harper South experienced the highest mortality (10 plants). As in 2014, the number of live plants in 2015 was much greater than those that died (164 and 26, respectively), with 78 new plants found (Table 4).

Table 4. Live plants, mortality, and number of new plants found in 2014 and 2015.

| | **2014** | **2015** |
|---|---|---|
| Live Plants | 109 | 164 |
| Mortality | 34 | 26 |
| New Plants | 8 | 78 |

Twenty-three plots had no living *A. mulfordiae* in 2015, which was a decrease from that in 2014 (32 plots). While in 2012 we added 25 new plots targeting areas of high abundance for *A. mulfordiae*, the number of plants recorded this year (164 in 71 plots) still remains much less than those in plots measured in 2010 (278 plants in 67 plots). Total number of *A. mulfordiae* per plot ranged from 0 to 14 across all of the sites.

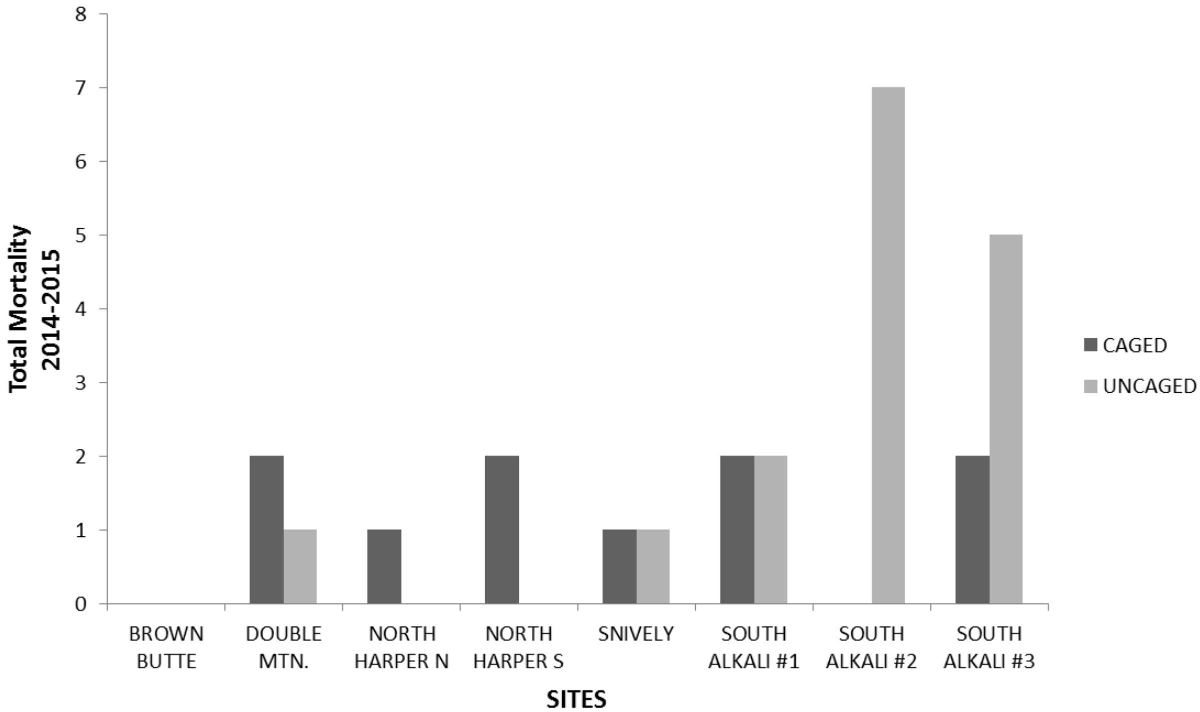


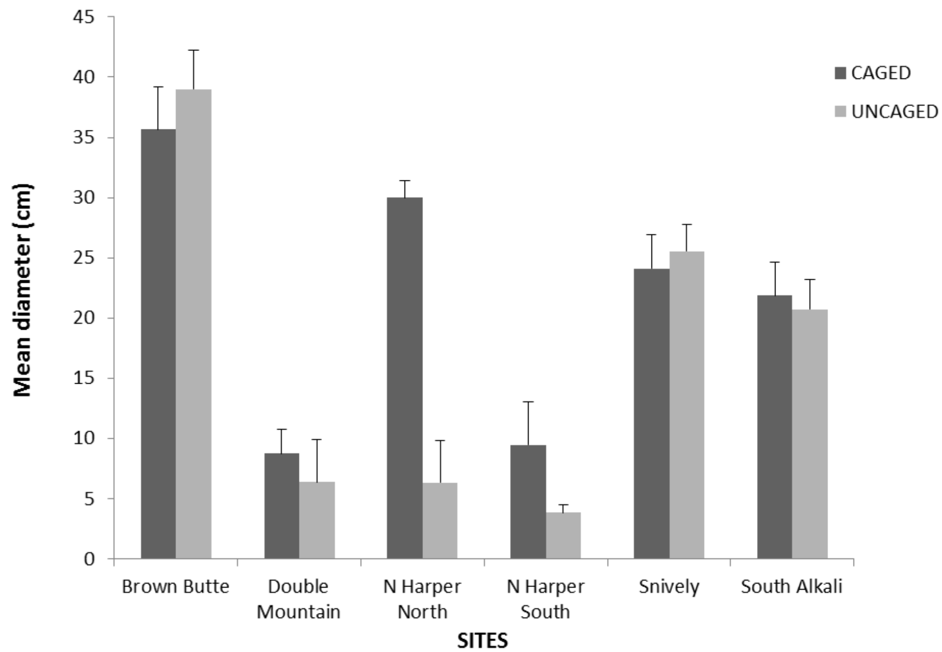

Figure 5. Total mortality of *A. mulfordiae* from 2014 to 2015, by site and treatment (caged/uncaged).

Table 5. Proportion of reproductive plants in 2015 by site

| Site | Proportion of reproductive plants |
|---|---|
| Brown Butte | 100.0 |
| Double Mountain | 11.1 |
| North Harper North | 20.0 |
| North Harper South | 4.4 |
| Snively | 86.4 |
| South Alkali | 49.3 |

In 2015, size of *A. mulfordiae* differed by site ($P<0.01$), but not by treatment (caged or uncaged) (Figure 6, Appendix E). Plants from Brown Butte, North Harper North, and Snively were the largest while Double Mountain and North Harper South had the smallest individuals. While plant size did not differ significantly within caged or uncaged plots, plants from Double Mountain, North Harper North, North Harper South, and South Alkali tended to be larger in caged plots, while plants at Brown Butte and Snively tended to be larger in uncaged plots. These trends differ greatly from year to year; for example in 2014, conversely from 2015, plants at Brown Butte tended to be larger in caged plots. Plant size ranged from 1 to 56 cm (diameter) across all plots; the maximum noted in 2015 (56cm) was appreciably smaller than the maximum size noted in 2014 (67cm).

Reproductive effort was extremely variable across sites, with North Harper North having the lowest reproductive effort (just one reproductive plant with one fruit) and South Alkali having the highest reproductive effort (31reproductive plants with an average of 55.5 fruits; Figure 6). Although South Alkali had very high reproductive effort relative to other sites, its high average number of fruits per reproductive plant was mainly due to just a few large plants that produced many fruits. For example, one plant at South Alkali had 344 fruits. We found no difference between reproductive effort (number of inflorescences) in caged/uncaged plots ($P$ >0.05). The proportion of live plants that were reproductive varied from 4.4% (North Harper South) to 100% (Brown Butte).



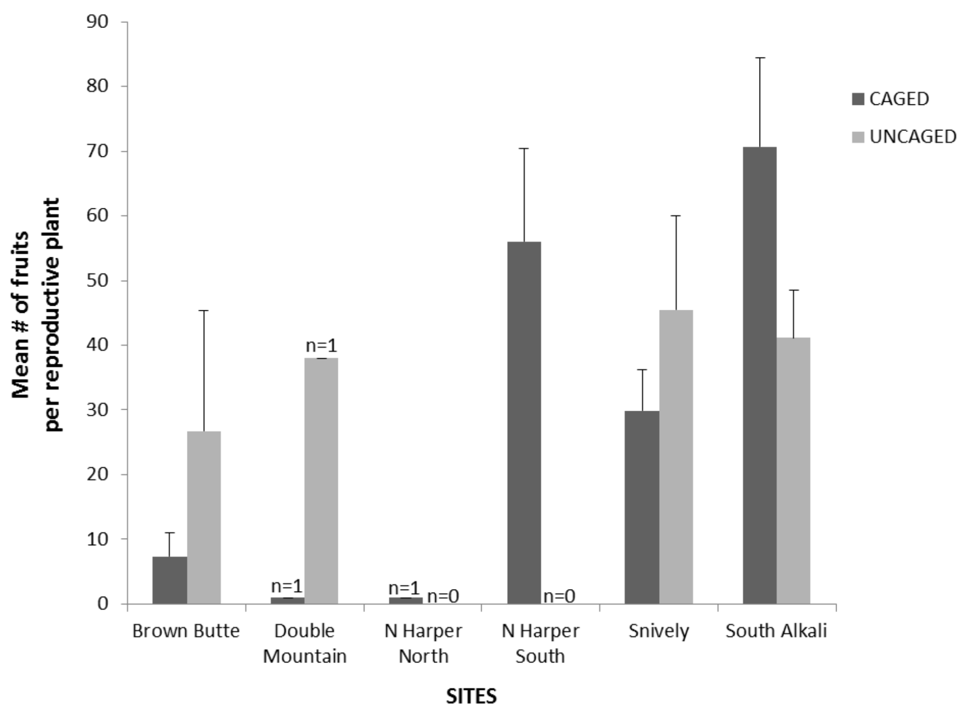




Figure 6. Mean diameter and number of fruits per reproductive *A. mulfordiae* in caged and uncaged plots in 2015. Error bars are ± 1 SE.

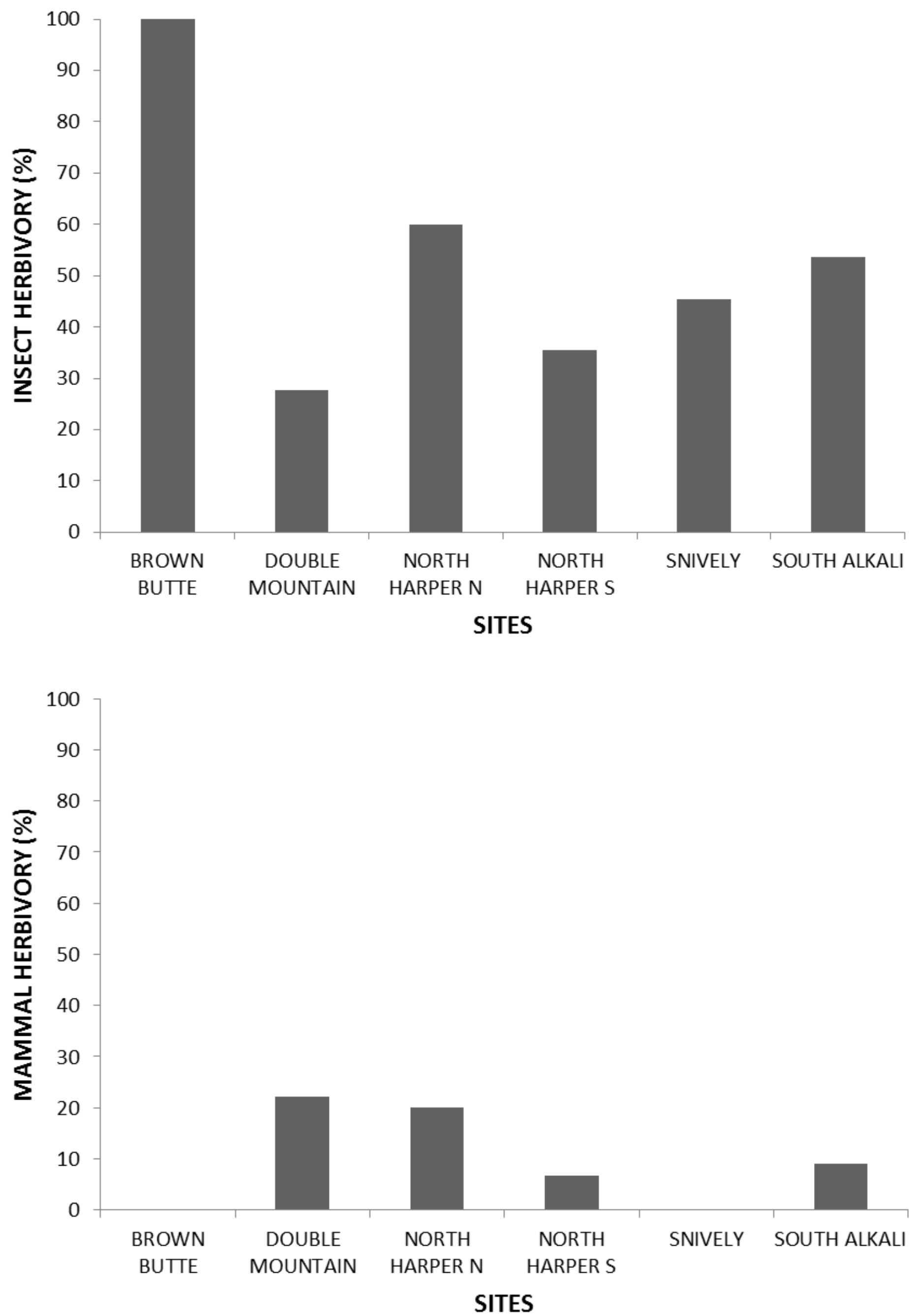



Figure 7. Percent of plants that experienced insect and mammal herbivory in all plots in 2015.

Insect herbivory ranged from 27.8% to 100% of all plants at each site, with the most occurring at Brown Butte and South Alkali #2 (Figure 7). Presence of insect herbivory has varied greatly between years between sites. Impacts from mammal herbivory ranged from 0-22.2% and was most common at Double Mountain and North Harper North (Figure 7). Brown Butte and Snively had no mammal herbivory present in 2015.

The effects of the caging treatments on number of *A. mulfordiae* have varied over the years. In 2013, the number 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 (Appendix E). Herbivory by mammals has also been noted but has been extremely variable each year. In 2014 we explored the potential effects of grazing on *A. mulfordiae* in 2014 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 the growing *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 |
| Snivley | 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 2015 was markedly higher than in 2014 but still much less than in previous years across all treatments and sites, except for North Harper South; North Harper South was the only site to have more plants in 2015 (40) than when plots were first established in 2008 (39) (Figure 8). 2014 had been the lowest year in 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. North Harper South and South Alkali had the greatest increases in number of plants from 2014 to 2015 – a 700% and 18% increase, respectively. Although the increases in number of plants were slighter for the other sites, it is promising to observe an increasing trend after the decline in *A. mulfordiae* that had been exhibited from 2008-2014 across all plots and sites (Figure 8).

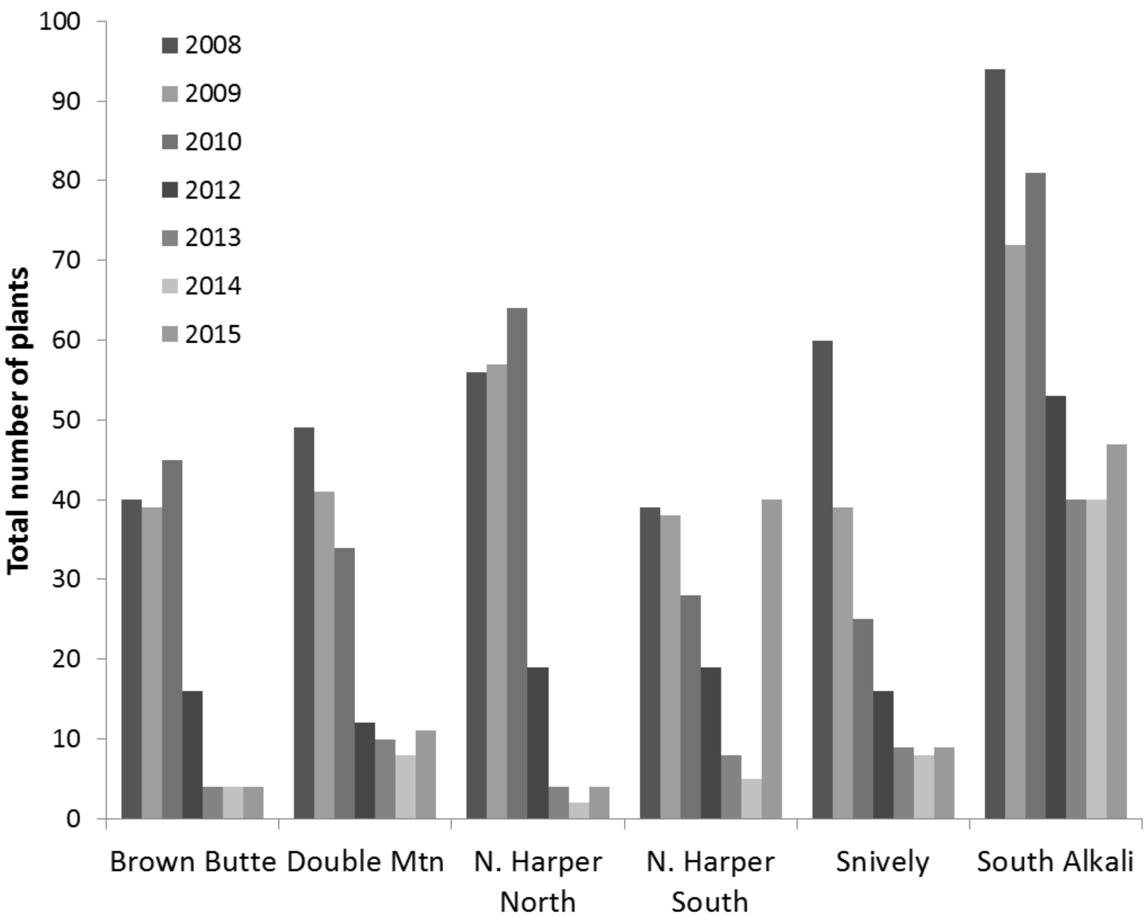



Figure 8. Total *A. mulfordiae* in caged and uncaged treatment plots from 2008 to 2015 (plots established in 2008 only).

North Harper South and South Alkali had the greatest number of new *A. mulfordiae* individuals in 2015 (Figure 9). For North Harper South, the uncaged plots had the greatest addition of new individuals (32 plants). In 2015, across all sites, caged plots had 18 new individuals while uncaged plots had 45 new individuals (however, this difference is mainly driven by uncaged plots at North Harper South) (Figure 9).

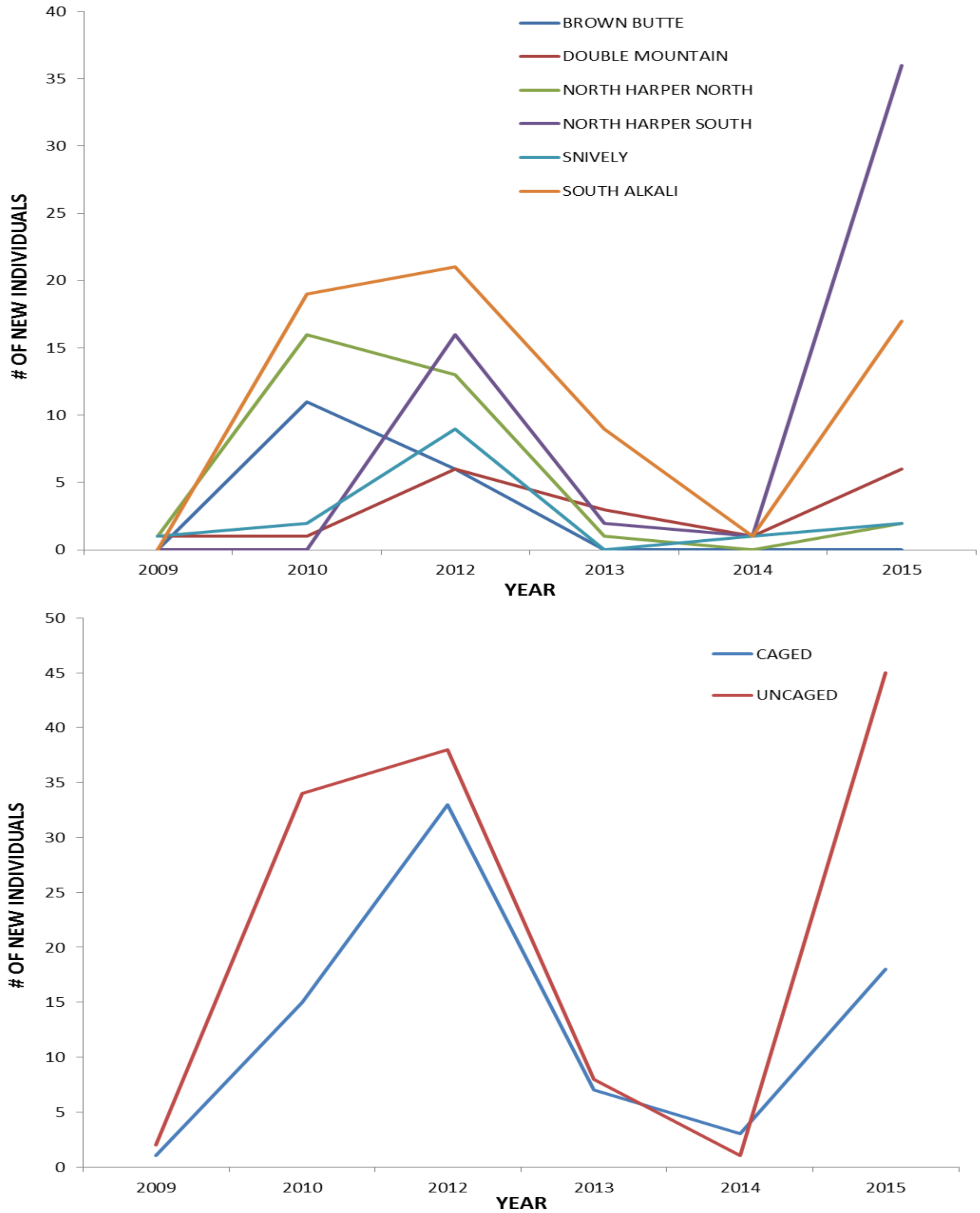



Figure 9. Total number of new *A. mulfordiae* individuals at each site (above) and in caged and uncaged treatment plots (below) from 2009 to 2015 (plots established in 2008 only).

Table 7. Mean diameter, mean number of fruits per reproductive plant, and total number of reproductive plants in caged and uncaged study plots from 2010-2015 (plots established in 2008 only).

| | 2010 | | | 2012 | | | 2013 | | | 2014 | | | 2015 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mean diameter (cm)** | 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 |
| 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 |
| North 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 |
| North 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 |
| 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 |
| 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 |

| | 2010 | | | 2012 | | | 2013 | | | 2014 | | | 2015 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Mean number of fruits per reproductive plant** | 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 |
| Double Mountain | 13 | 11 | 12 | N/A | N/A | N/A | 9 | N/A | 9 | 16 | 5 | 10 | 1 | 38 | 20 |
| North 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 |
| North Harper South | 23 | 19 | 21 | 1 | 6 | 5 | N/A | N/A | N/A | N/A | N/A | N/A | 8 | N/A | 8 |
| Snively | 17 | 25 | 18 | 1 | 16 | 8 | 11 | 5 | 8 | 55 | 85 | 70 | 14 | 116 | 65 |
| South Alkali | 22 | 17 | 19 | 57 | 75 | 63 | 108 | 66 | 91 | 122 | 89 | 110 | 76 | 56 | 69 |

| | 2010 | | | 2012 | | | 2013 | | | 2014 | | | 2015 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total number of reproductive plants** | 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 |
| Double Mountain | 17 | 17 | 34 | 0 | 0 | 0 | 4 | 0 | 4 | 2 | 2 | 4 | 1 | 1 | 2 |
| North Harper North | 36 | 28 | 64 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| North Harper South | 11 | 17 | 28 | 1 | 4 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Snively | 20 | 5 | 25 | 2 | 2 | 4 | 1 | 1 | 2 | 3 | 3 | 6 | 3 | 3 | 6 |
| South Alkali | 39 | 42 | 81 | 25 | 12 | 37 | 18 | 13 | 31 | 20 | 12 | 32 | 12 | 6 | 18 |

With the exception of Brown Butte and Snively, mean plant size (diameter, cm) has reduced from 2010 to 2015 (Table 7). In 2015, mean plant size was lowest at North Harper South, which was the site that had the greatest number of new *A. mulfordiae* individuals (most of which were under 5cm in diameter). 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 2015, there were reproductive plants at all sites except for North Harper North, however only 27% of plants were reproductive compared to 83.5% of plants in 2008. In 2015, reproductive effort remained the same or declined at all sites but Double Mountain and North Harper South; although mean number of fruits per reproductive plant at Snively and South Alkali decreased from 2014 to 2015, these values are substantially higher than in 2008 (Table 7). 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 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 and is likely indicative of climate variability and potential threats from other disturbance such as invasion by exotic 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 2014 and 2015 were greater than long-term normals across all seasons, with the highest temperatures observed in 2015 (Figure 10, top). Mean precipitation has varied greatly from 2010-2015 (Figure 10). Winter of 2010 was extremely wet in comparison to long-term normals, while 2011, 2013, and 2014 all had less precipitation (Figure 10). Winter of 2012 and 2015 had precipitation levels similar to long-term normals. While the site experienced a wet spring in 2011, spring maximum temperatures were drier than long-term normals in 2013, 2014 and 2015. Recent summer temperatures have 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. The increase in number of plants in 2015 could be the result of a wetter winter after numerous years of conditions that were drier than long-term normals. Despite the increase seen in 2015, the extreme 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.

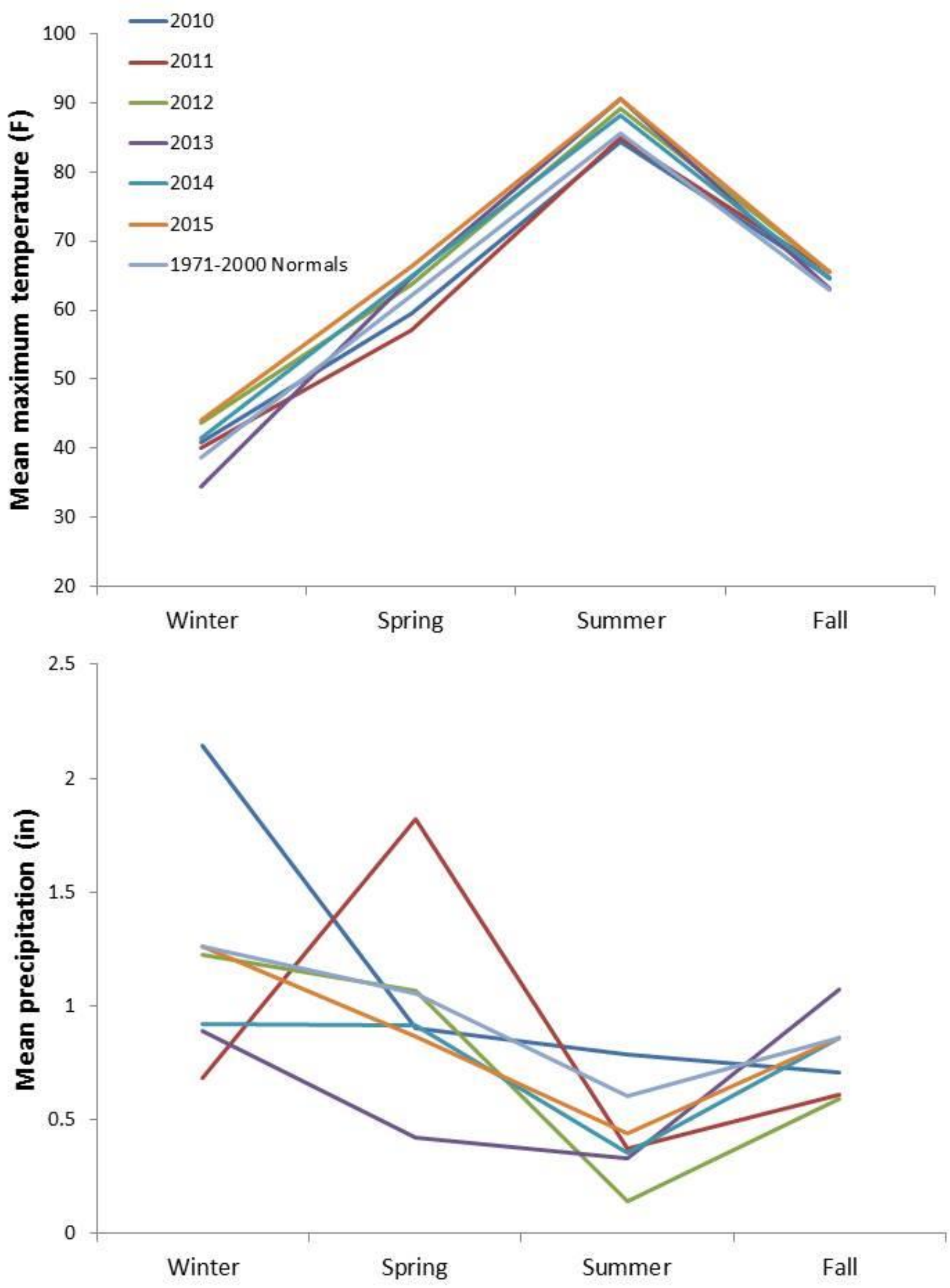



Figure 10. Mean maximum temperature and mean precipitation from 2010-2015 with long-term climate normals at North Harper North.

## Population and Community Monitoring

In 2014, a total of 53 *A. mulfordiae* plants were observed along five transects, which was an increase from the 42 plants found in 2014 (Table 8). While the transect at Double Mountain had no plants in 2013, there was one seedling present in 2014. In 2015 that plant was reproductive. In 2015 we observed 53 total plants, which was an increase since 2014. Despite this, total number of plants is still much less than that observed in 2012 (121 plants total). The majority of the plants (31) occurred in the transect at South Alkali, with number of plants gradually declining over the years at Snively (Table 8). Reproductive plants accounted for the majority of total plants observed (53%); this was a slight decrease from 2013 and 2014 when reproductive plants accounted from 64% and 76% of the total, respectively. Non-reproductive plants (>4cm tall) constituted 6%. Seedlings accounted for 19% of the total number of plants, which was an increase from those observed in 2014 (9%). Seedlings were present at Brown Butte, North Harper North, and South Alkali only.

Table 8. Number and class of *Astragalus mulfordiae* found in community transects in 2009, 2010, 2012, 2013, 2014, and 2015.

| 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 |
| 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* |

| 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* |
| 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* |
| 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* |

In comparison to 2010, cover of *A. mulfordiae* has declined notably (Figure 11). South Alkali experienced an increase in cover in 2013 and 2014, however this cover declined in 2015 to the lowest value over the years of this study (Figure 11). Brown Butte and North Harper North had an increase in cover of *A. mulfordiae* from 2014 to 2015, however, 2015 values still remain much less than those in 2010 (Figure 11). The decline in *A. mulfordiae* at most sites could be associated with the very large increase in cover of *B. tectorum* over the years of this study (Figure 11). At all sites *B. tectorum* increased drastically since 2010, with the highest values observed in 2015 at all sites but South Alkali which exhibited a slight decrease in 2015 from 2014 values. 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 has changed greatly from 2010 to 2015 within the transects (Figure 12). Exotic species have increased from 2010 to 2015 at all sites but South Alkali; at South Alkali the proportion of exotic species declined slightly in 2013 and 2014, but increased in 2015 to levels similar to those observed in 2010 (Figure 12). Proportions of native species have declined from 2010 to 2015 at all sites. In 2010, all sites were native dominated except for South Alkali; in 2015 the only site that remains native dominated is North Harper North. Brown Butte has had greater cover of exotic species than natives from 2012 to 2015, with an increase in exotic cover occurring each year. Double Mountain was native dominated from 2010 to 2014, however in 2015 we observed a sharp increase of exotic species and a decline of natives (Figure 12). Native species were dominant at North Harper North from 2010-2014, however in 2015 cover of exotic species surpassed that of natives; cover of exotics had been increasing from 2010 to 2015. At Snively, cover of exotic species increased each year from 2012 to 2015 while that of natives declined each year (Figure 12). At South Alkali cover of native increased slightly from 2010 to 2013, and then declined in 2015; this decline was associated with an increase in exotic species. Despite these patterns this site has been dominated by exotic species every year of the study. The increase in exotic species and subsequent decrease in cover of native species exhibited in these transects is cause for concern and documents a system that was initially native dominated changing to exotic dominance, most driven by the increase in *B. tectorum* noted at the field sites (Figure 11).

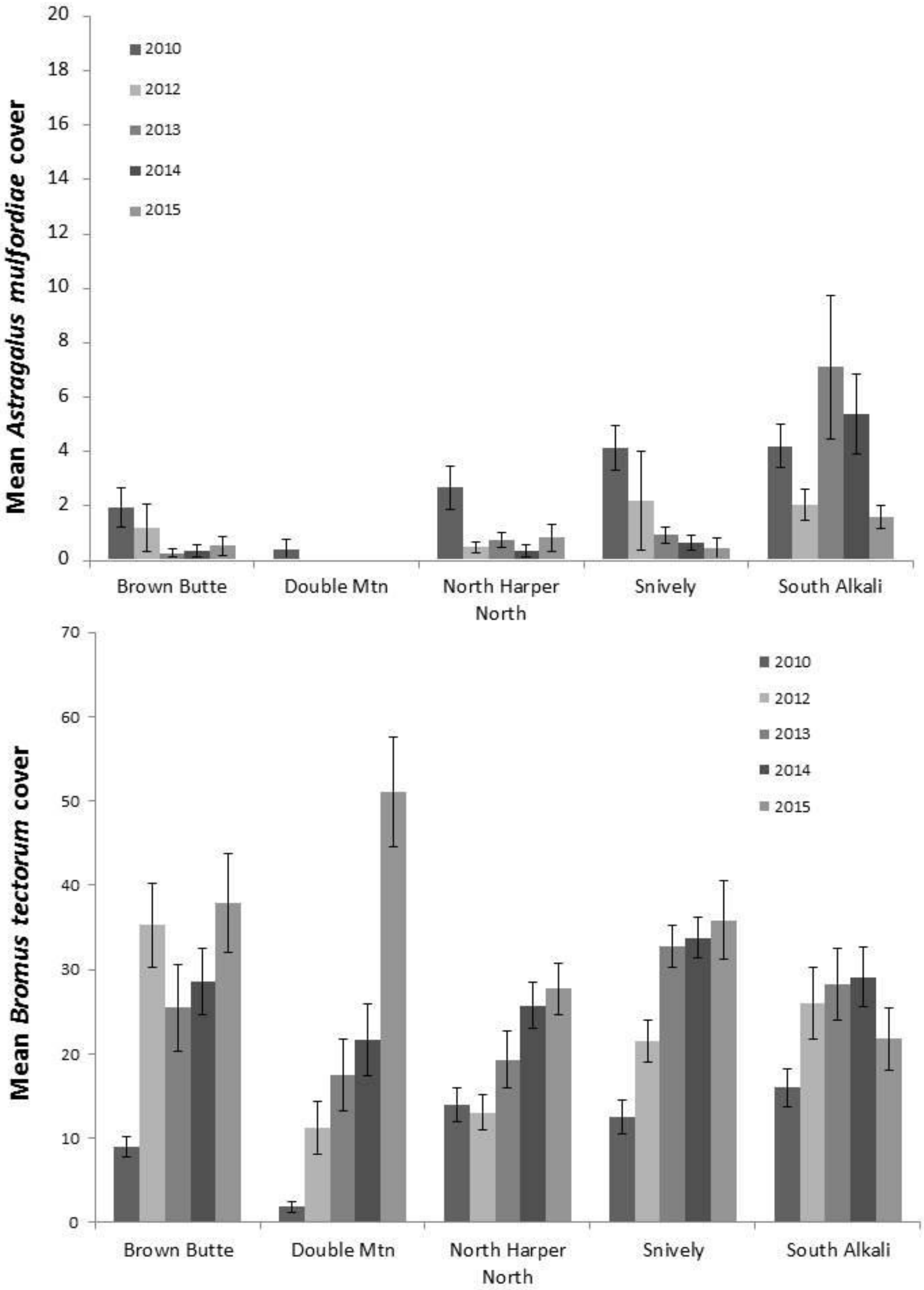



Figure 11. Mean *A. mulfordiae* (above) and *B. tectorum* (below) cover (%) in community monitoring transects, 2010, 2012, 2013, 2014, and 2015. Error bars are ± 1SE. Note the difference in the y axes.

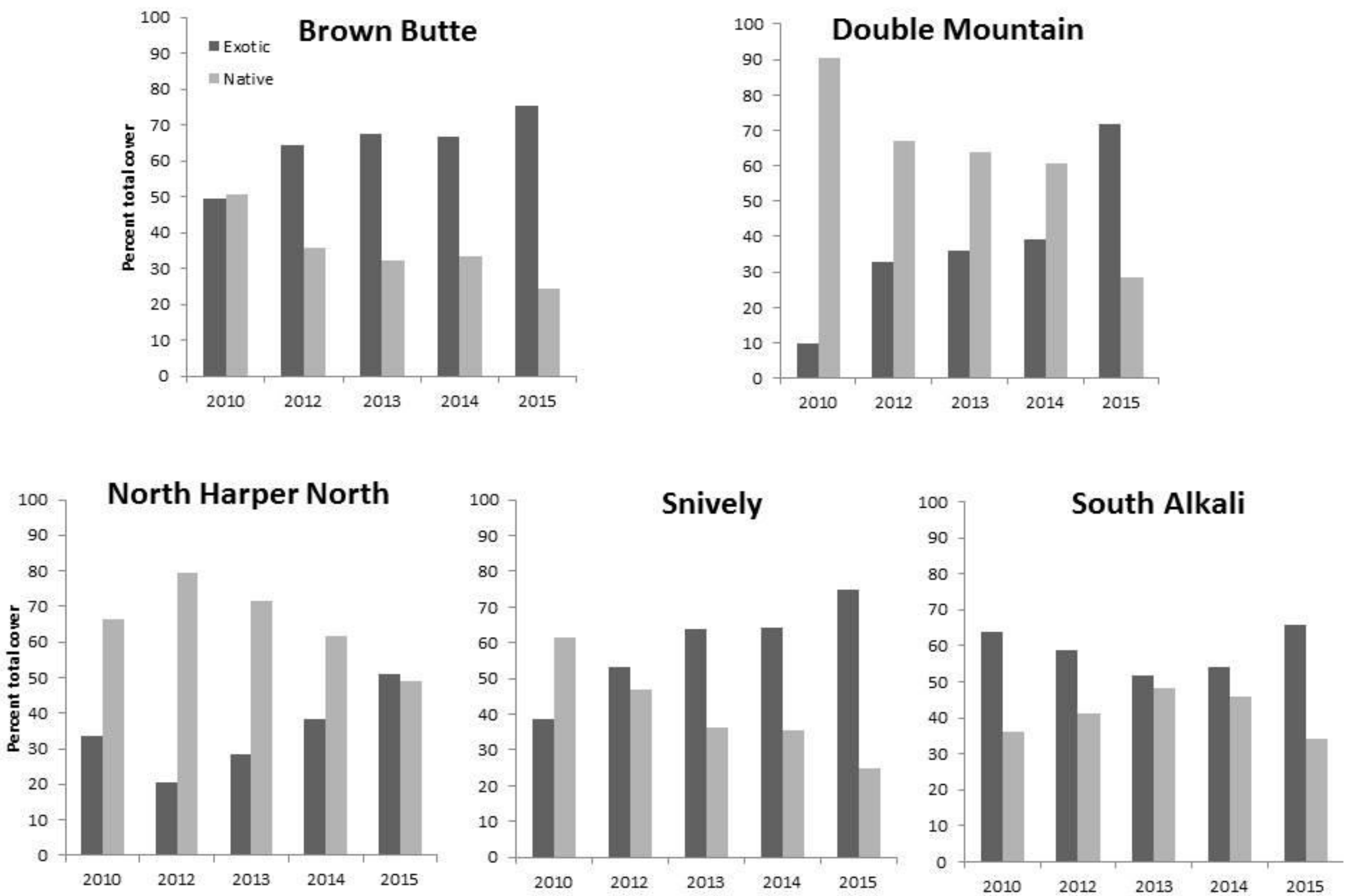



Figure 12. Percent of total cover of native and exotic species, by site in 2010, 2012, 2013, 2014 and 2015.

Of the ten exotic species recorded along transects in 2015, three were graminoids and seven were forbs (Appendix D). *Bromus tectorum* dominated exotic species cover ranging from 22-51% across all transects, and composing 95-98% of total exotic species cover (Appendix D). This was an increase from in 2014 where cover of *B. tectorum* accounted for 84-98% of exotic species cover. Other exotic species included *Erodium cicutarium, Alyssum desertorum, Poa bulbosa, Lactuca serriola, Salsola tragus, Sisymbrium altissimum,* and *Tragopogon dubius*. *Chamaesyce maculata* was observed at Brown Butte, Snively, and South Alkali when it had not been seen in previous years. 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, Balsamorhiza sagittata, Poa secunda,* and *Hesperostipa comata*. *Chrysothamnus viscidiflorus* was the primary shrub present in all transects. Total cover of *A. mulfordiae* per transect ranged from 0.5-31.5% (South Alkali having the greatest, Double Mountain having the lowest cover in the transect). 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 50% of mean cover which was a decrease from the 2014 value of 64% (Table 9). Litter was similar in 2015 (39%) to that noted in 2014 (35%). Litter had increased from 19% cover to 44.7% from 2010 to 2013, and decreased slightly in 2014 to 35%; all of these changes were likely due to the presence and abundance of *B. tectorum* across all sites (Table 9). 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 (5%), which was an increase from 3% noted in 2014. While in previous years the other sites had it in trace amounts, North Harper North had 2.5% biological crust cover in 2015 (Table 9).

Table 9. Mean cover of ground surface categories in 2015

| | Average % cover | | | | | |
|---|---|---|---|---|---|---|
| | **Brown Butte** | **Double Mtn** | **North Harper North** | **Snively** | **South Alkali** | **Mean** |
| Basal veg (cut off at ground) | 2.8 | 1.5 | 7.2 | 5.6 | 1.7 | 2.8 |
| Bare ground | 50.2 | 52.7 | 55.9 | 46.0 | 45.1 | 50.2 |
| Biological crust | 0.5 | 0.0 | 2.5 | 4.9 | 0.4 | 0.5 |
| Rock/gravel ( ≥ 2mm ) | 0.1 | 0.1 | 0.0 | 0.9 | 0.2 | 0.1 |
| Litter ( < 2mm), including scats | 39.3 | 45.2 | 32.8 | 36.0 | 48.0 | 39.3 |
| completely dead shrub, attached | 1.5 | 0.3 | 1.2 | 0.1 | 0.0 | 1.5 |
| Wood ( ≥ 2mm), not attached, must be wood, from shrub/tree | 0.7 | 1.3 | 0.4 | 0.0 | 0.4 | 0.7 |

The loose, sandy substrate characterizing *A. mulfordiae* habitat readily leaves evidence of physical disturbances. Disturbances recorded in 2015 varied by site (Table 10). Snively experienced the most disturbance, which was composed primarily by footprints of researchers; in 2014 the site had the highest disturbance by cattle prints but none were found in 2015. North Harper North had high cover of cattle feces (older than 1 yr). Brown Butte also experienced moderate levels of disturbance, with much of it composed of human footprints (researchers), and animal burrows. The transect at Brown Butte is very open and exposed on a steep incline where evidence of disturbance could last for many years. Double Mountain and South Alkali experienced the least disturbance in 2015, mostly composed of animal burrows for Double Mountain and insect burrows for South Alkali (Table 10). Individual disturbance categories with the highest abundance included researcher footprints, cattle feces, and animal burrows. 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 only 3 plants (the same in 2014), which was much greater than the 35 affected in 2012. Insect damage and disease was relatively not abundant occurring on only 1 plant.

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 2015

| | Total % Cover | | | | | |
|---|---|---|---|---|---|---|
| **Disturbance Category** | **Brown Butte** | **Double Mtn** | **North Harper North** | **Snively** | **South Alkali** | **Total Cover** |
| anthill | 0 | 0 | 1 | 0 | 0.5 | 1.5 |
| burrow | 7.5 | 3.5 | 0 | 1 | 0 | 12 |
| cattle feces-recent (<1 yr) | 0 | 0.5 | 0 | 0 | 0 | 0.5 |
| cattle feces-older (>1 yr) | 0 | 0 | 12 | 0.5 | 1 | 13.5 |
| cattle prints | 0 | 0 | 0 | 0 | 2 | 2 |
| deer feces | 0 | 0 | 1.5 | 0 | 0 | 1.5 |
| deer prints | 0 | 0.5 | 0 | 0 | 0 | 0.5 |
| human footprints (researcher) | 6.5 | 1.5 | 0 | 28 | 0.5 | 36.5 |
| insect burrow (diameter < 1 cm) | 0 | 2 | 1.5 | 3 | 2.5 | 9 |
| pronghorn feces | 0 | 0 | 0 | 0 | 3 | 3 |
| rabbit feces | 0 | 0 | 1 | 0 | 0 | 1 |
| unknown animal prints | 1 | 0 | 0 | 0 | 0 | 1 |
| Total ground disturbance | 15 | 8 | 17 | 32.5 | 9.5 | |

# CONCLUSIONS

In recent years we have observed a decline in *A. mulfordiae* at all of our study sites, however, in 2015 we noted an increase in the number of plants from 2014 values. In 2014, the density of *A. mulfordiae* was the lowest since 2008, with very great declines observed between 2012 and 2013. While the increase seen in 2015 could be promising, especially in comparison to the low numbers observed in 2014, total number of plants remains low in comparison to those seen in 2008-2010. We did see very high numbers of new plants at North Harper South which accounted for the highest count at this site over the course of this study. While we still observed mortality from 2014 to 2015, we also noted many new plants in 2015. 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. Monitoring in 2016 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 2015, 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 species. Future monitoring is necessary to determine if additional management actions are needed.

In 2014 and 2015 we found no significant difference between plants within caged/uncaged plots, though these treatments were significant in 2013. Plants within caged and uncaged plots have shown great variability over the years, and even when these have been noted as significant difference 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 led to plant mortality at many of the sites.

Invasive species were ubiquitous in *A. mulfordiae* sampling plots, and have increased in recent years. Between 2010 and 2015, plant community composition has varied, however, most sites have transitioned from a native-dominated community to one dominated by exotic species. In 2015, 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 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. Winter from 2014-2015 was wetter than previous years and more similar to long-term normals which could explain the number of new plants noted in 2015. In these cold-desert ecosystems, most precipitation occurs during winter and early spring. Climate change projections suggest increasing temperatures especially in summer months throughout the Pacific Northwest (Mote and Salathé 2014). While forecasts for precipitation are more variable, they include enhanced seasonal changes (Mote and Salathé 2014). 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. mulforidae*.

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 and the slight increase in plants noted in 2015, 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. 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. *Astragaulus 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. Salanthé. 2010. Future climate in the Pacific Northwest. *Climate 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.

The PRISM Climate Group, Oregon State University. 2006. United States Average Monthly temperature or Annual Precipitation, 1971-2000. Corvallis, OR, USA. Available at: http://prismmap.nacse.org/nn/index.phtml. Accessed 15 January 2015.

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 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant # | X-coord | Y-coord | Diam (cm) | longest stem (cm) | #Infl. | | Insect | Deer / Cattle | Notes | |
| | | | | | | | | | | |
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# APPENDIX B. GPS COORDINATES FOR ALL PLOT AND TRANSECT LOCATIONS

Set Datum to "NAD83"

Set Position Format to "hddd.ddddd"

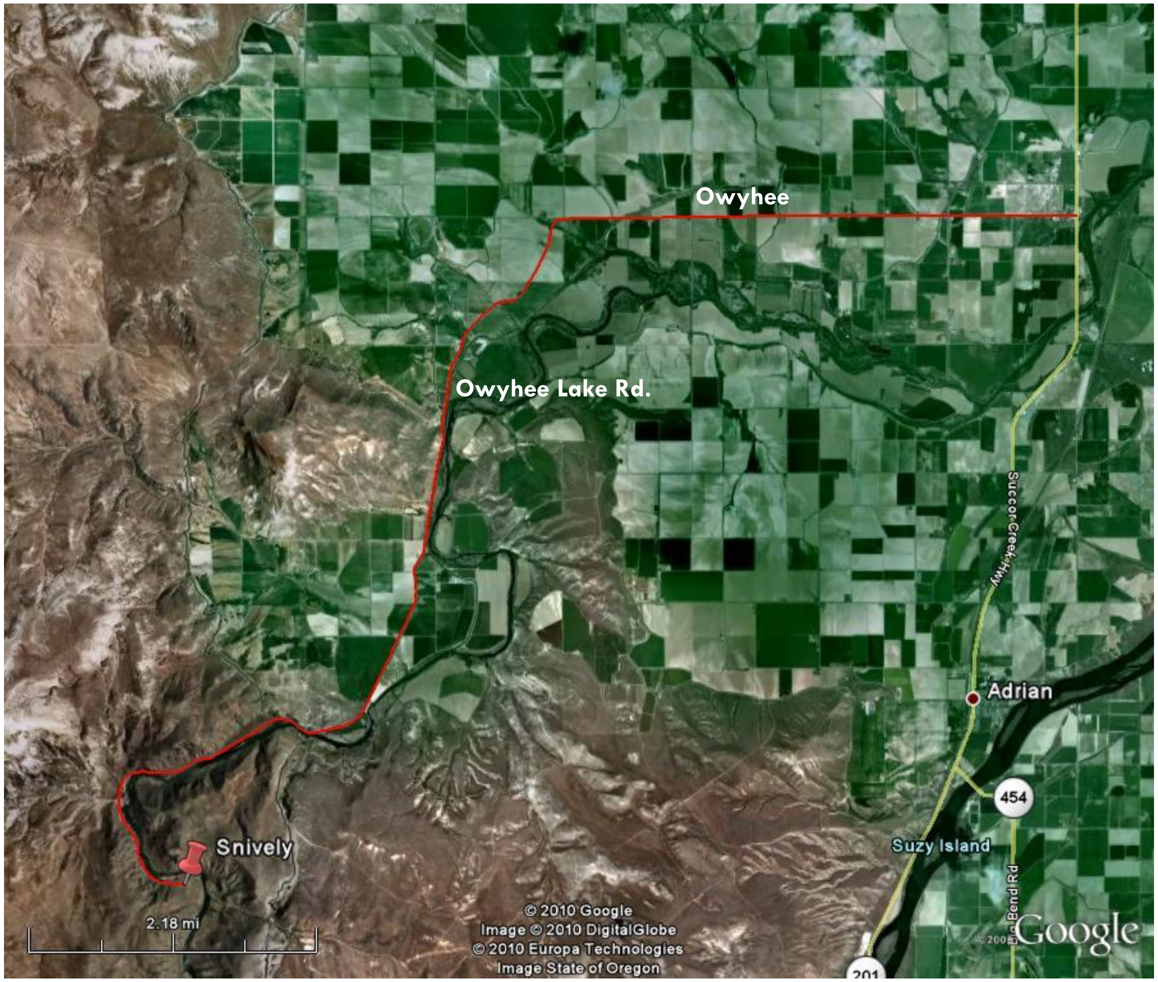
| Site | Sub-site | Plot # | Treatment | LAT | LONG | Notes 2012 | Notes 2013 | Notes 2014 | Notes 2015 |
|---|---|---|---|---|---|---|---|---|---|
| Brown Butte | | End | Transect | 43.73173 | -117.12424 | | | | |
| Brown Butte | | Start | Transect | 43.73190 | -117.12421 | | | | |
| Brown Butte | | 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 | | | |
| NorthHarper | South | 667 | Caged | 43.86389 | -117.23113 | | Plot missing | | |
| NorthHarper | South | 669 | Caged | 43.86382 | -117.23115 | | Plot missing | | |
| NorthHarper | South | 670 | Caged | 43.86317 | -117.23102 | | | | |
| NorthHarper | South | 672 | Caged | 43.86305 | -117.23102 | Plot missing | Plot missing | | |
| NorthHarper | 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 |
| NorthHarper | South | 666 | Uncaged | 43.86392 | -117.23116 | | | | |
| NorthHarper | South | 671 | Uncaged | 43.86308 | -117.23099 | | | | |
| NorthHarper | South | 674 | Uncaged | 43.86293 | -117.23082 | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| NorthHarper | 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**



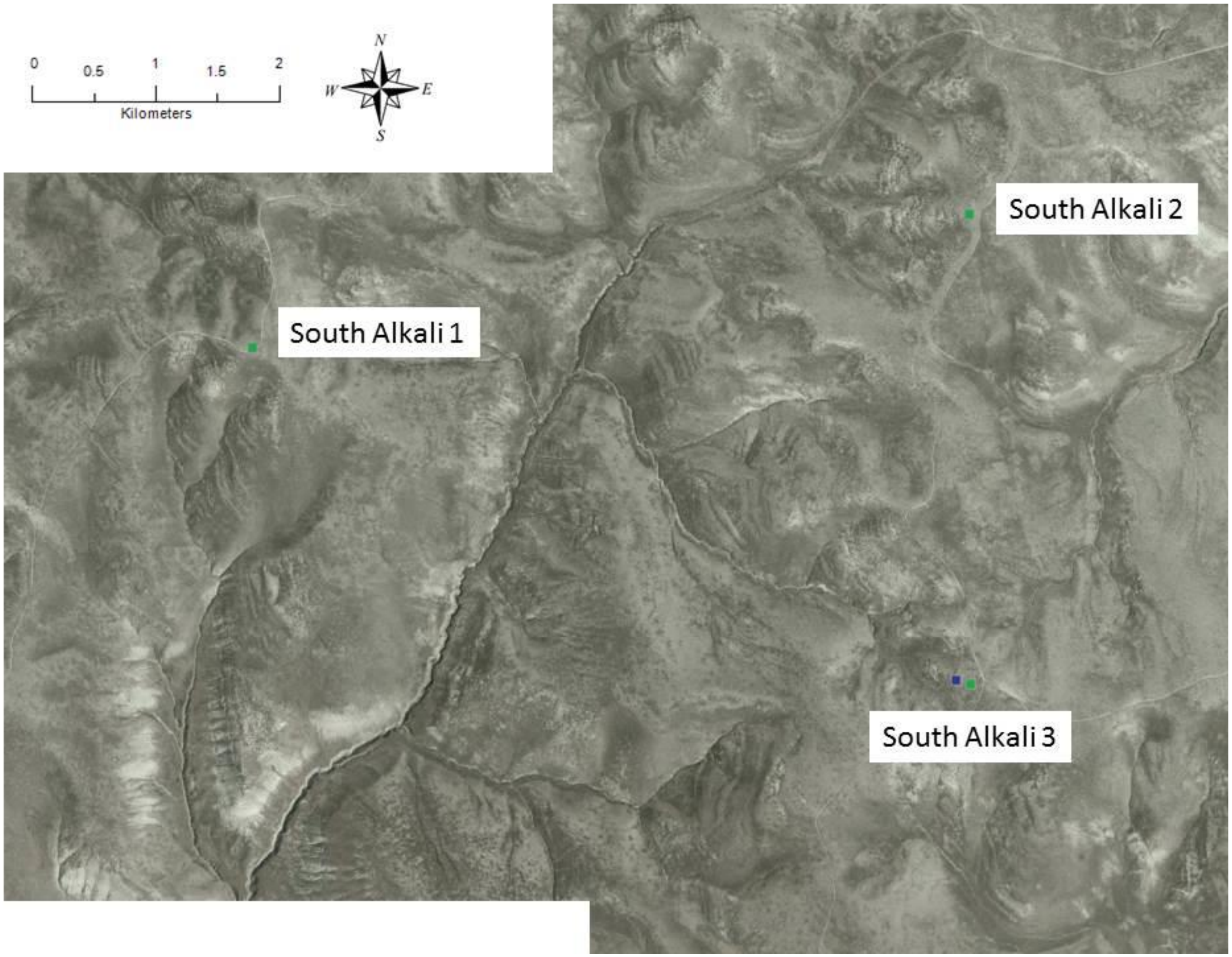

Driving route to Snively from State Route 201. Written driving directions can be found in Appendix C.

**Overview of the Snively field site.**

**Detailed map of the Snively field site.**

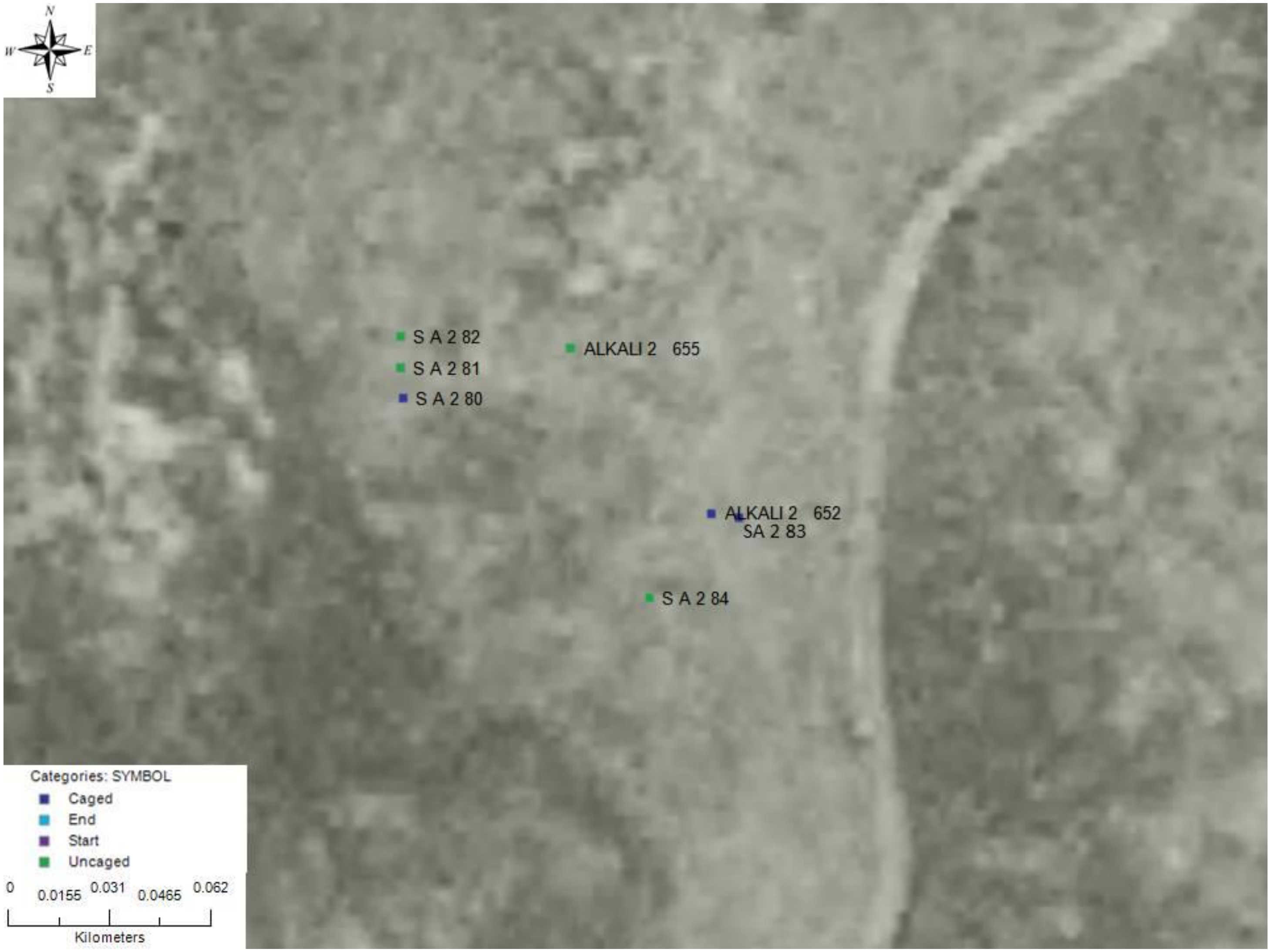

Driving route to South Alkali 1, 2, and 3. From Jordan Waterhole, it is advisable to drive clockwise around the loop, visiting S. Alkali 1 first. The road basically stays on top of a ridgeline all the way around this valley. Follow the 7.5" USGS topo map and written driving directions (Appendix C) carefully, 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**



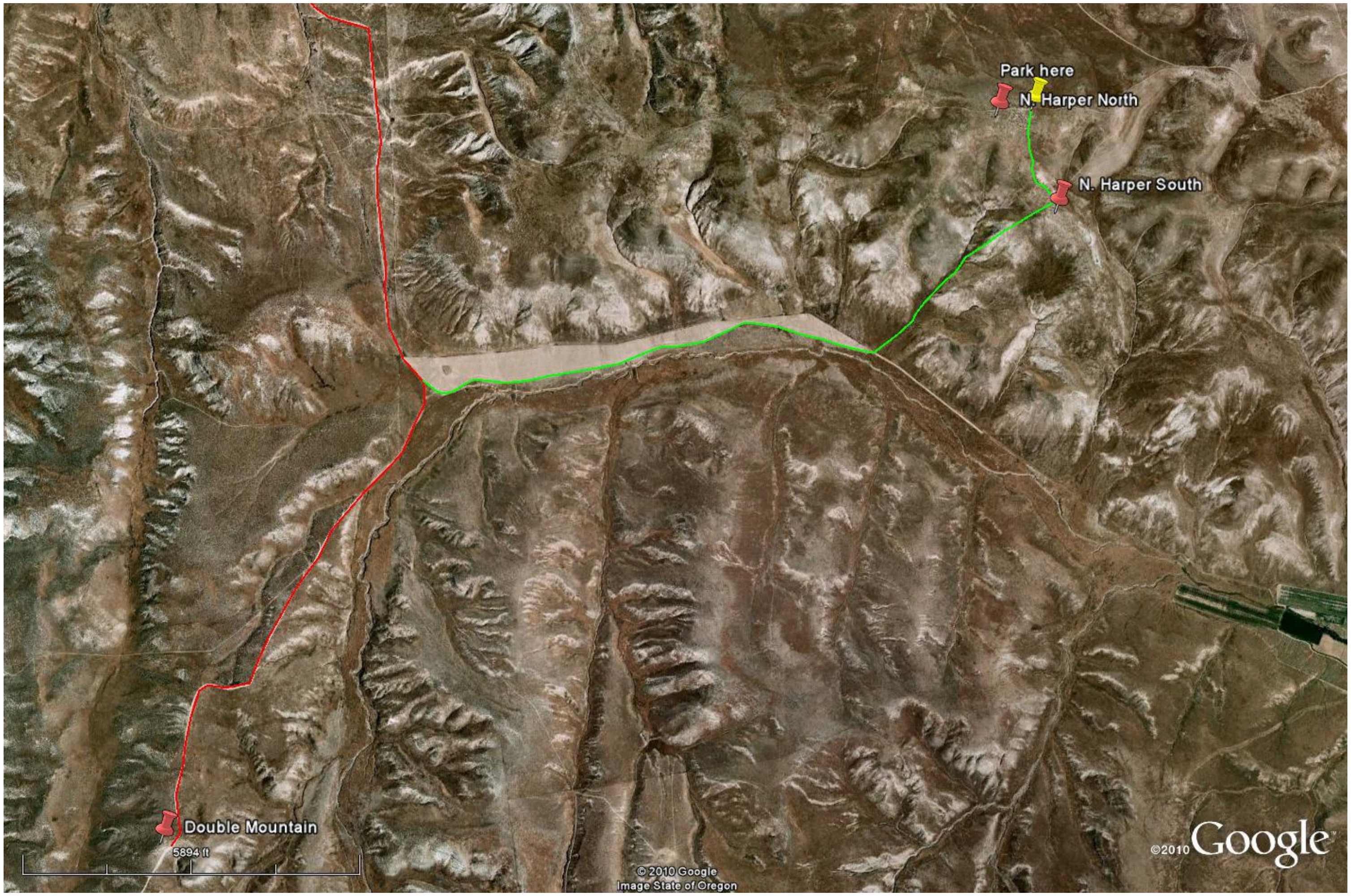
## South Alkali #1, Detailed Map

## South Alkali #2, Detailed Map



**South Alkali #3, Detailed Map**

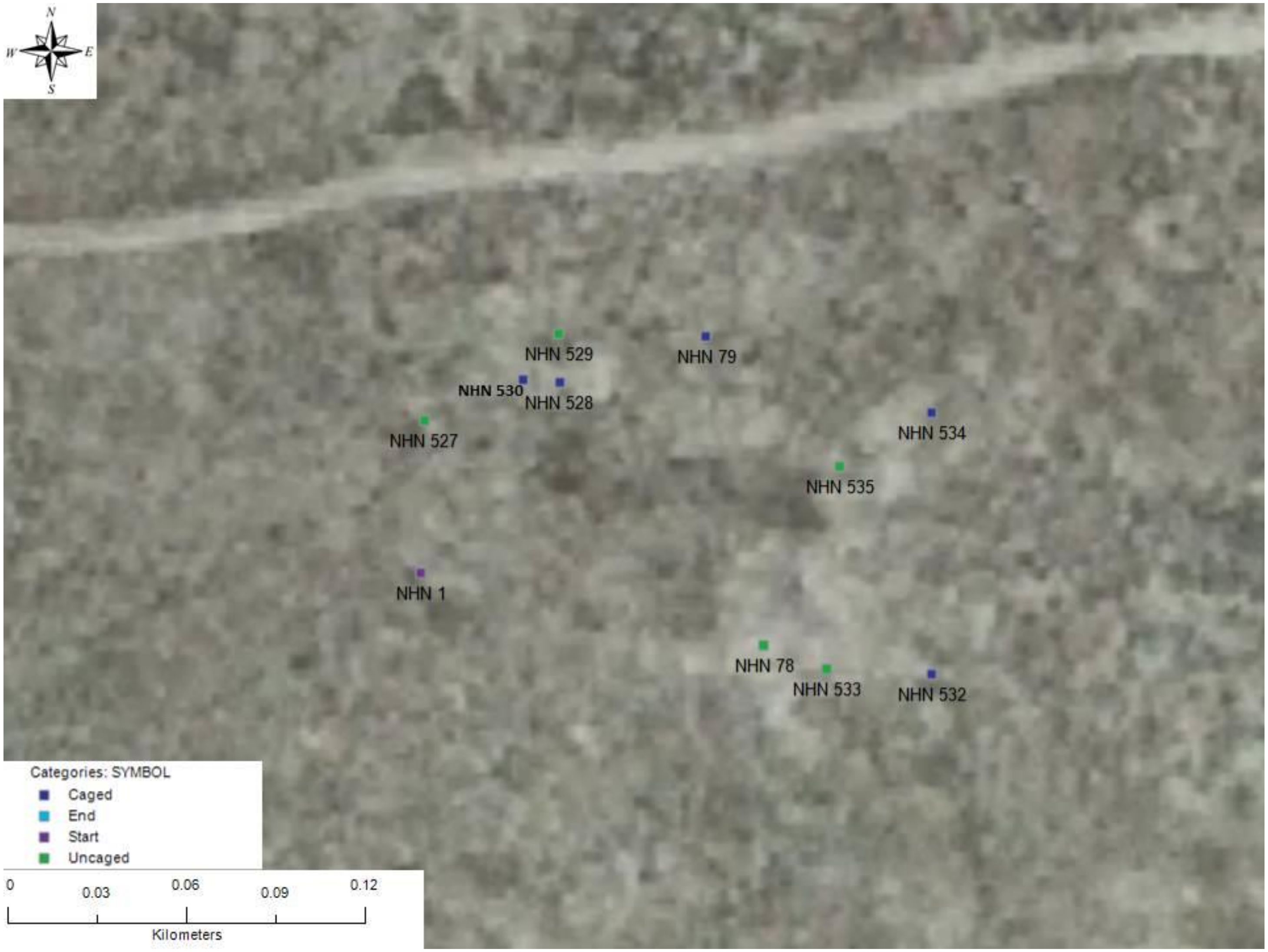
## Driving Route to North Harper



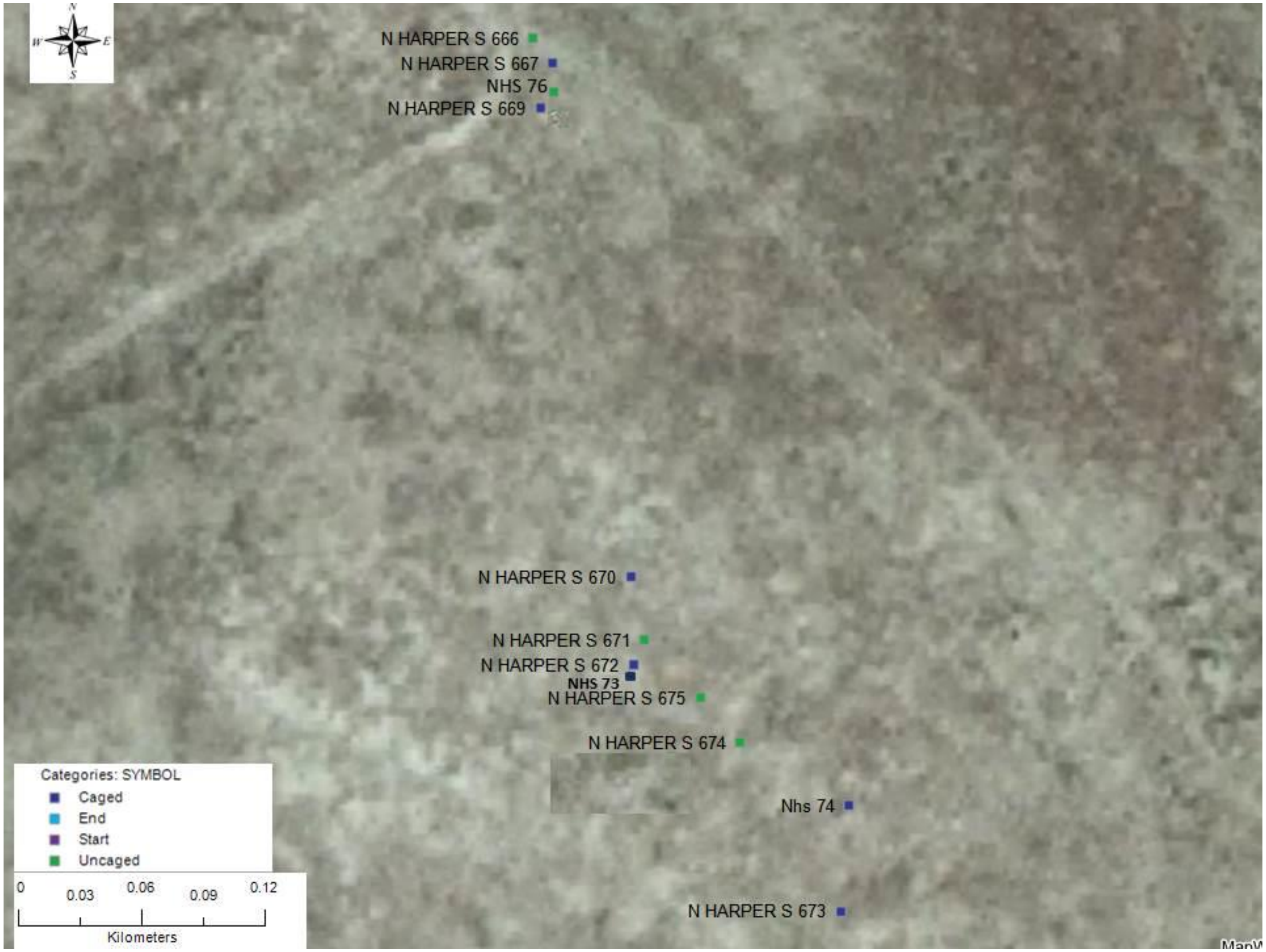

Driving directions to North Harper. Highway 20 is north on Russell Road. Follow the 7.5" USGS topo quad and written driving directions carefully (Appendix C).

### Overview of North Harper Field Sites

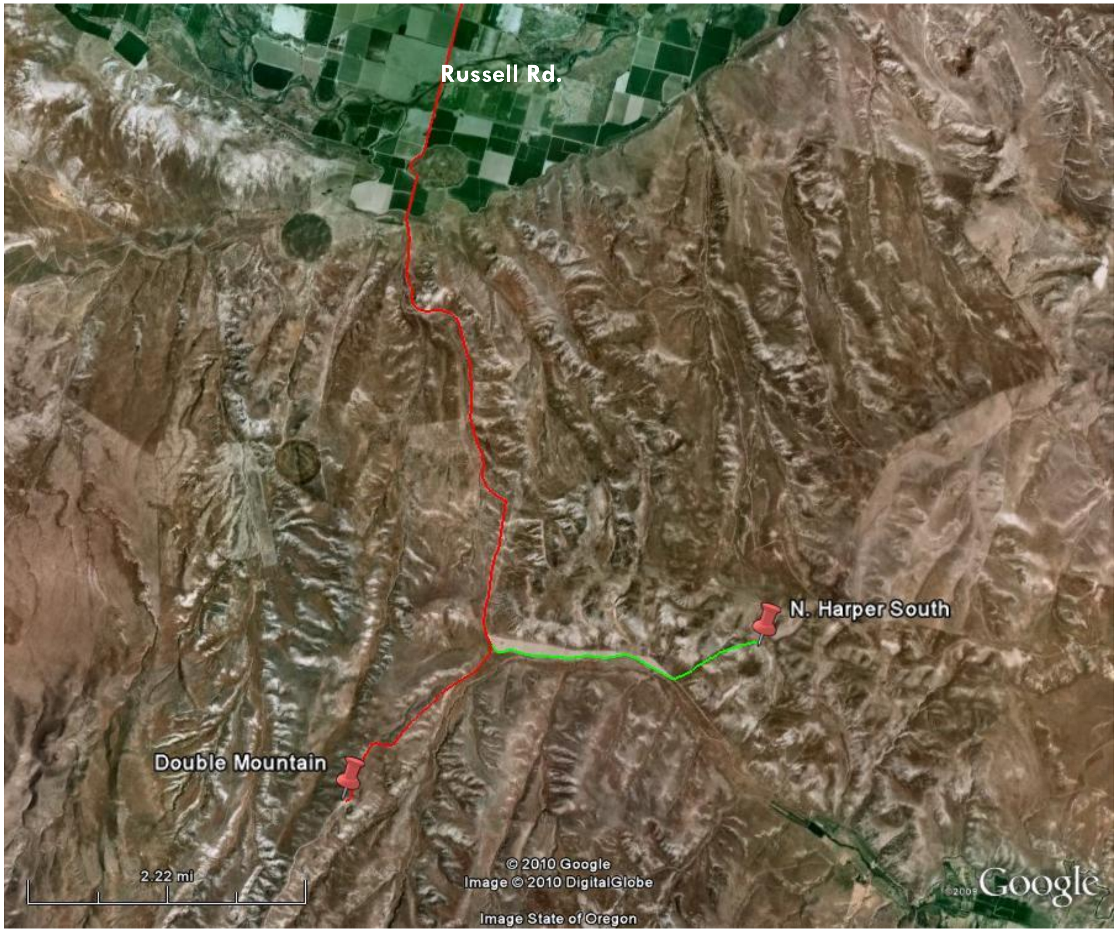
## North Harper North, Detailed Map



## North Harper South, Detailed Map

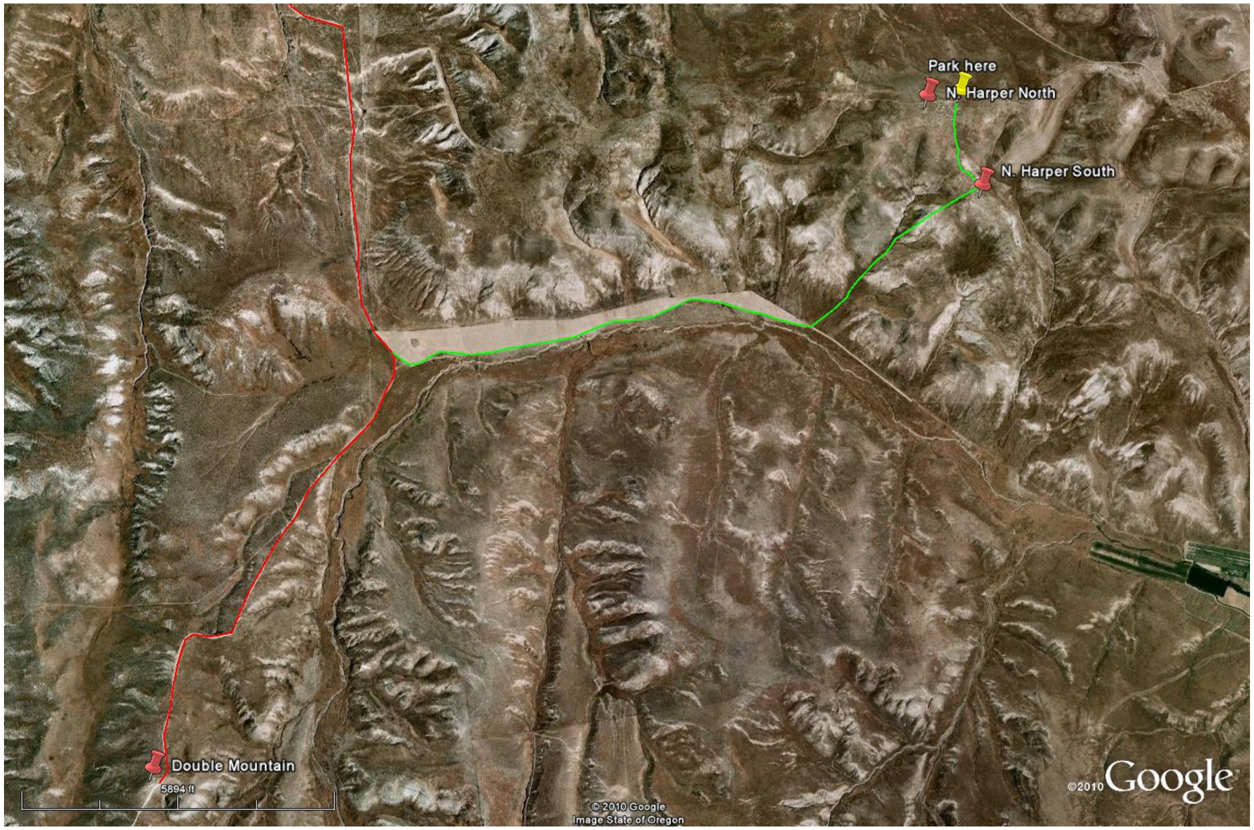


## Driving Route to Double Mountain



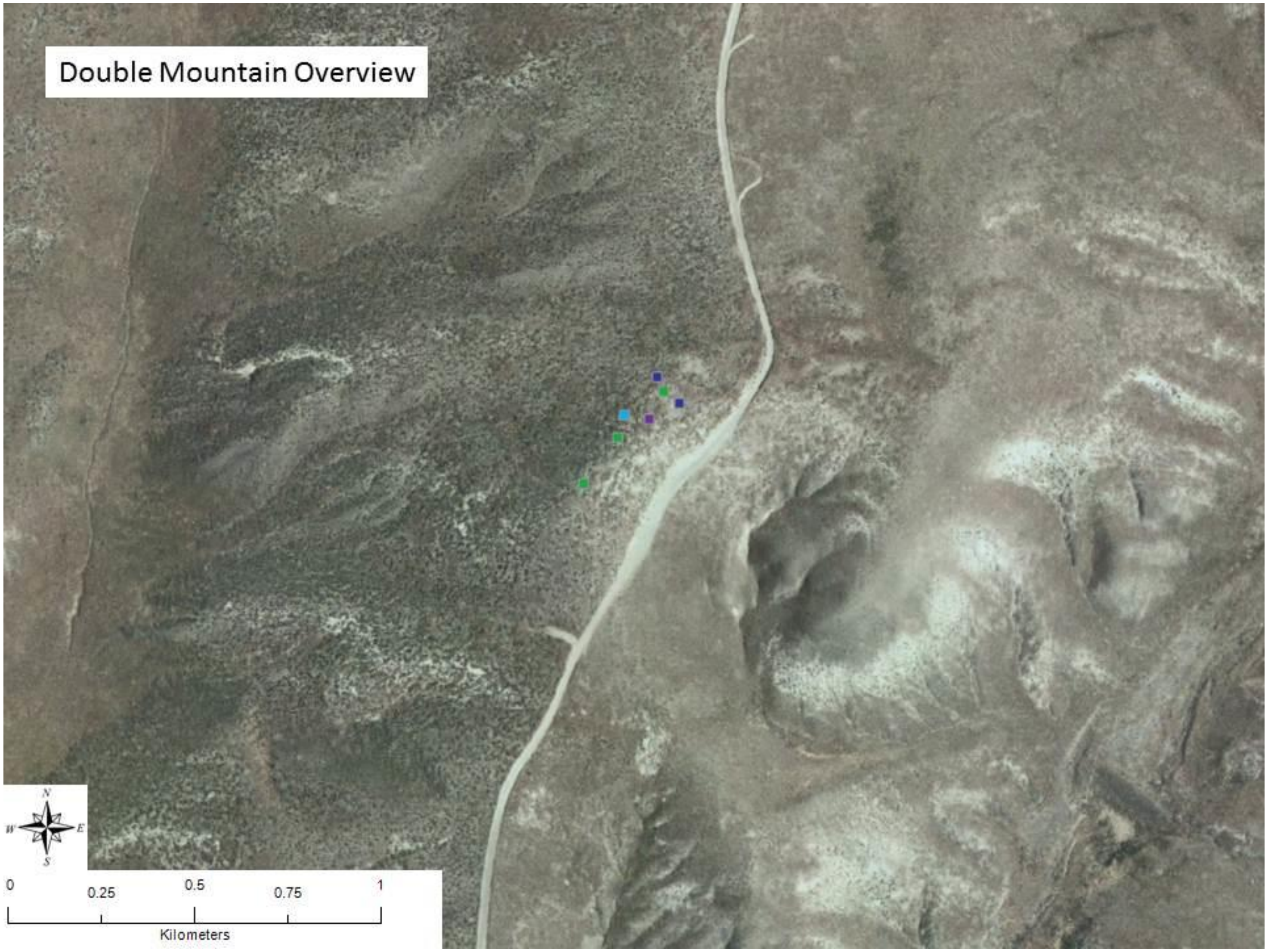

Driving route to Double Mountain (red) and alternative route to North Harper South (green). Highway 20 is north on Russell Road. Follow the 7.5" USGS topo quad and written driving directions carefully (Appendix C).

**Driving Route to Double Mountain (Zoom)**



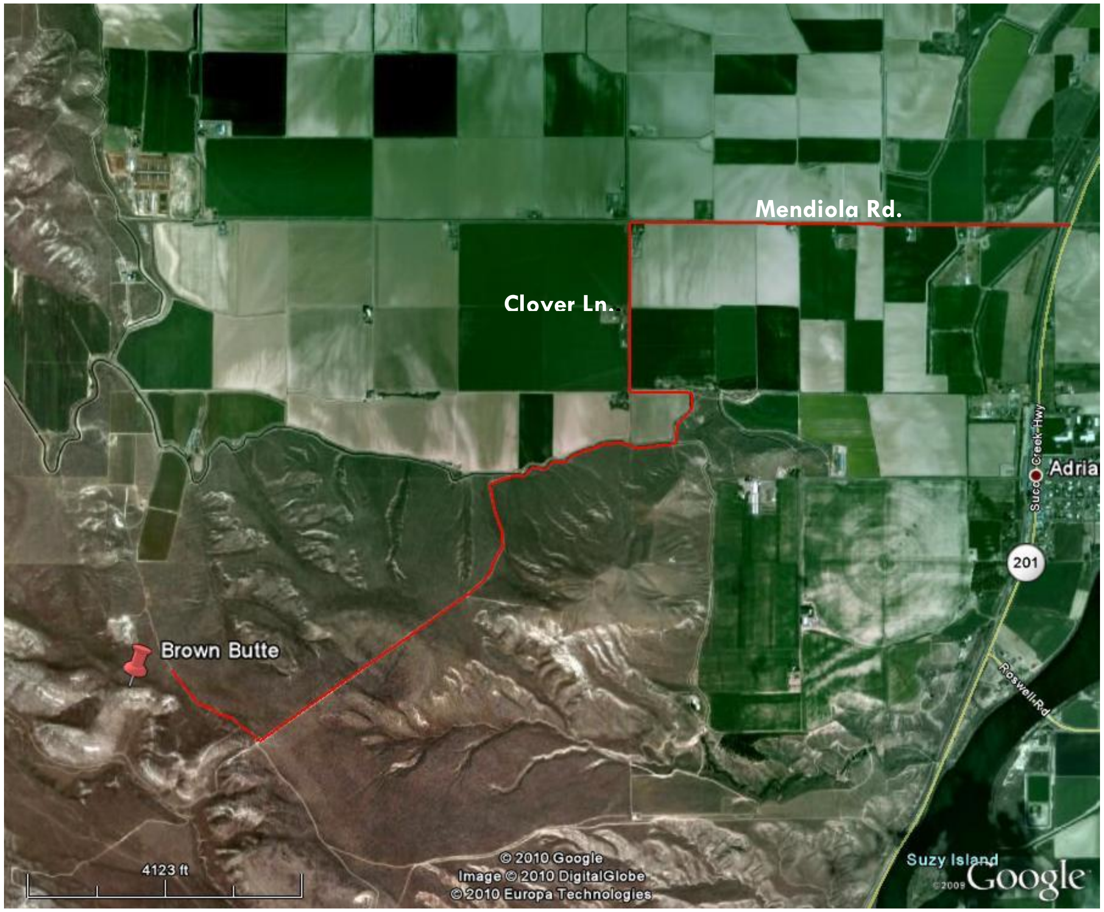

Driving route to Double Mountain (red) and alternate route to North Harper South and North (green). Highway 20 is north on Russell Rd. Follow the 7.5" USGS topo quad and written driving directions carefully (Appendix C).

**Overview of the Double Mountain Field Site**



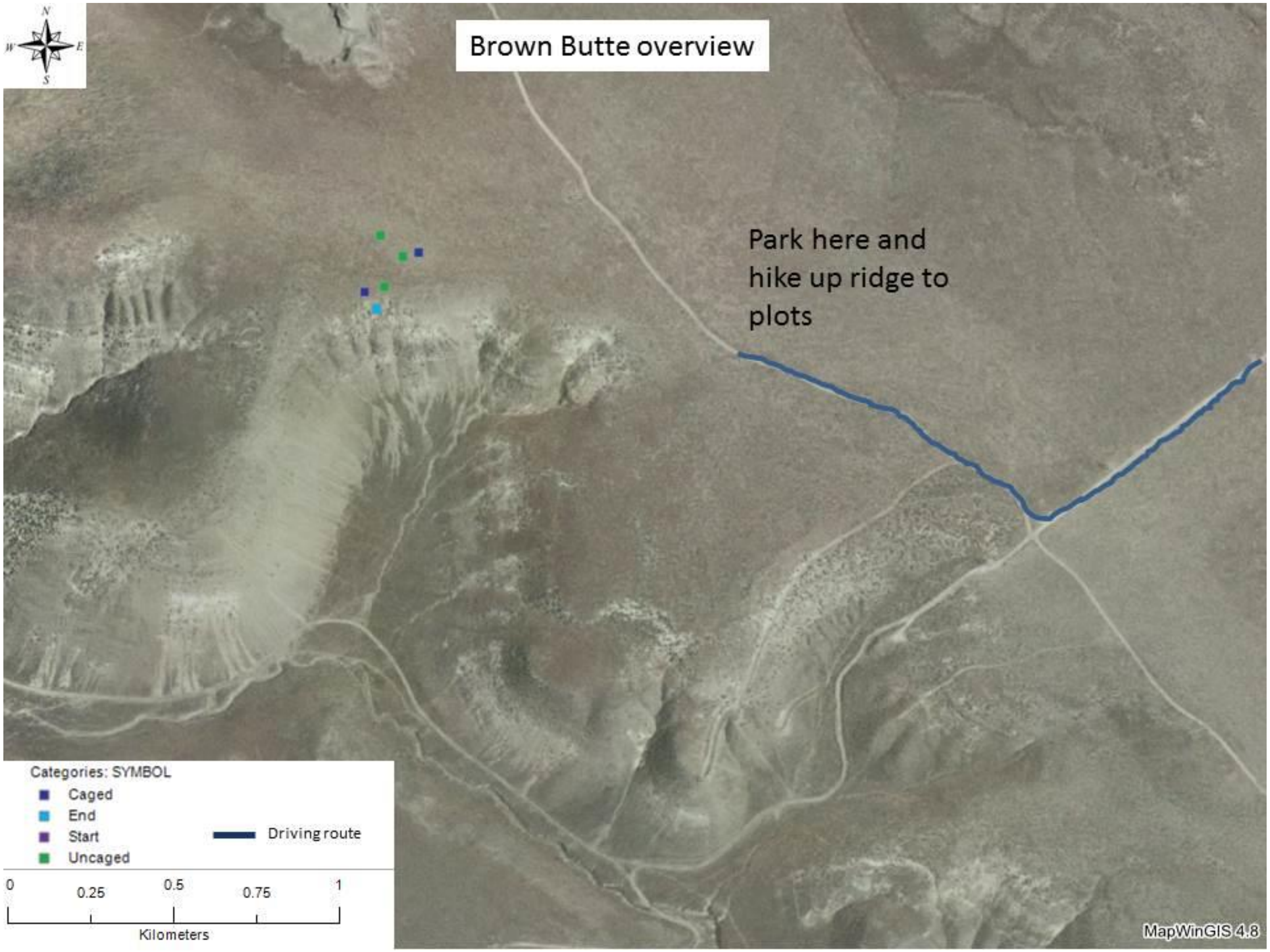
## Detailed Map of the Double Mountain Field Site

**Driving Route to Brown Butte**

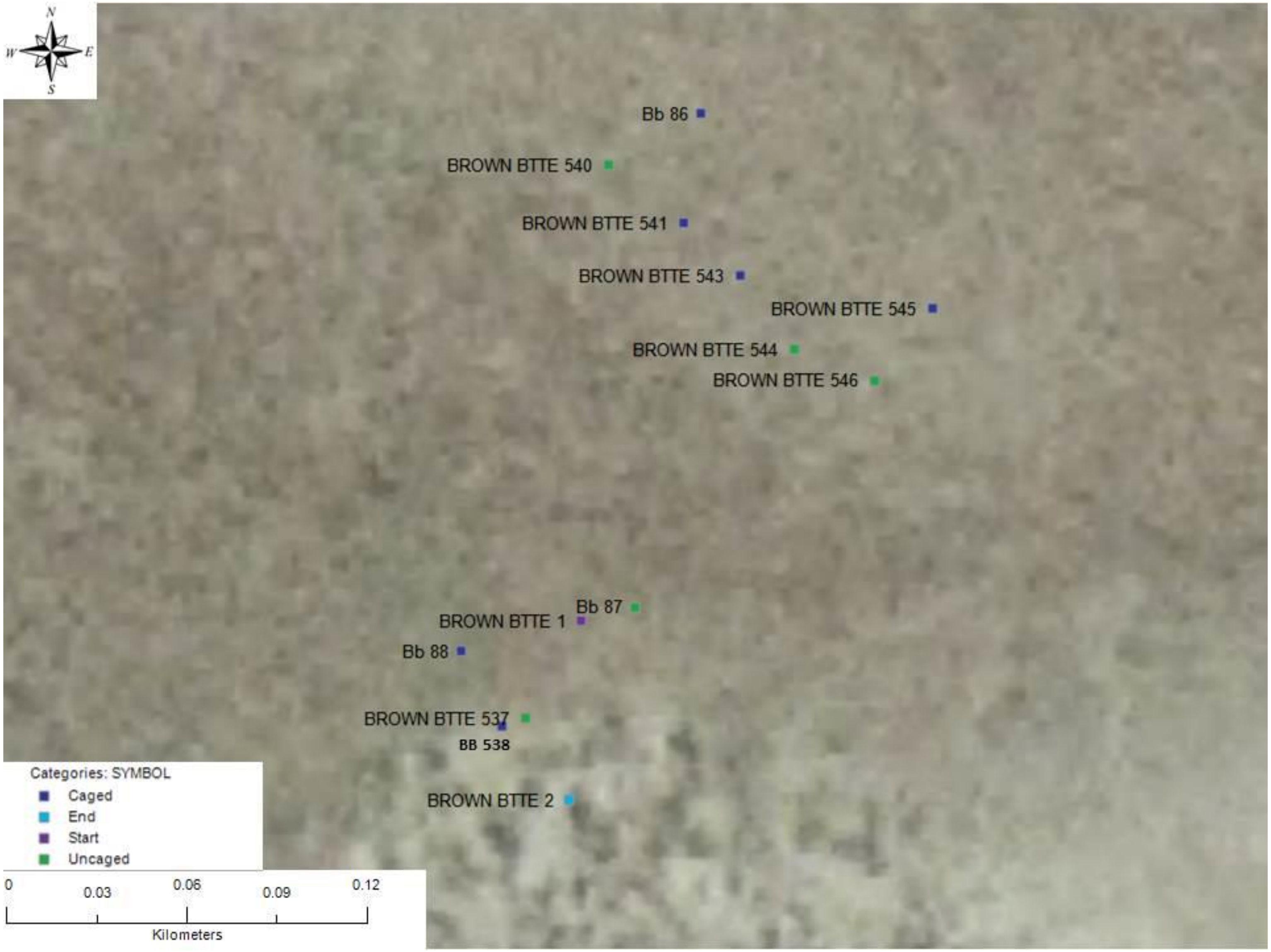



Driving route to Brown Butte sampling site from State Route 201. See Appendix C for written directions. After Clover Lane, follow the written directions carefully.

## Overview of Brown Butte



## Detailed Map of Brown Butte



**<u>Directions</u>** – 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 6/15 ECG

**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 might be more safe 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.

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.

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. 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** (from BLM office in Vale) Double Mountain quad

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, 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. Take a sharp left on Janeta ave, a sharp right on Jefferson Ave, and another sharp left on Owyhee Ave. Follow briefly 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 (3.2ish) and follow road until you can park and hike uphill to plots.

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

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, would recommend parking below where it is flat and hiking into both sites.**

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)

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.

## 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? |
|---|---|---|---|---|---|---|---|
| **Brown Butte** | caged | 86 | | y | | | |
| | caged | 88 | | y | | | |
| | caged | 538 | | | y | y | y |
| | caged | 541 | | | y | y | y |
| | caged | 543 | | | y | y | y |
| | caged | 545 | | | 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 | | | |
| | caged | 679 | | | | | |
| | caged | 680 | | | y | y | y |
| | caged | 683 | | | y | y | y |
| | uncaged | 268 | | y | | y | y |
| | uncaged | 272 | | y | y | y | y |
| | uncaged | 678 | | | | | |
| **North Harper North** | caged | 528 | | | y | y | y |
| | caged | 530 | | | y | y | y |
| | caged | 532 | | | | y | y |
| | caged | 534 | | | | | |
| | caged | 79 | | y | | | |
| | uncaged | 78 | | y | | y | y |
| | uncaged | 527 | | | | y | y |
| | uncaged | 529 | | | | y | |
| | uncaged | 533 | | | | y | y |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | uncaged | 535 | | | | | |
| **North Harper South** | caged | 73 | | y | | y | |
| | caged | 667 | | | y | y | y |
| | caged | 669 | | | y | y | |
| | caged | 670 | | | | | |
| | caged | 672 | y | | | y | y |
| | caged | 74 | | y | | | |
| | uncaged | 75 | | y | | | |
| | uncaged | 76 (new tag 576) | | y | | y | y |
| | uncaged | 666 | | | | | |
| | uncaged | 671 | | | | y | |
| | uncaged | 674 | | | | y | y |
| | uncaged | 675 | y | | | y | y |
| **Snively** | caged | 69 | | y | | | |
| | caged | 71 | | y | | | y |
| | caged | 72 | | y | | | |
| | caged | 547 | | | y | y | y |
| | caged | 553 | | | | | |
| | uncaged | 70 | | y | | | |
| | uncaged | 550 | | | | | |
| | uncaged | 552 | | | | | |
| | uncaged | 554 | | | | y | y |
| **South Alkali 1** | caged | 646 | | | | | |
| | caged | 649 | | | | | |
| | caged | 650 | | | | | |
| | uncaged | 647 | | | | | |
| | uncaged | 648 | | | | | |
| | 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 | | | |
| **South Alkali 3** | caged | 659 | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | caged | 660 | | | y | y | |
| | caged | 663 | | | | | |
| | caged | 665 | | | y | y | |
| | uncaged | 85 | | y | | | |
| | uncaged | 658 | | | | y | |
| | uncaged | 662 | | | | y | |
| | uncaged | 664 | | | | | |

## APPENDIX D. AVERAGE PERCENT COVER OF ALL VASCULAR PLANT SPECIES AND GROUND COVER CATEGORIES RECORDED AT THE FIVE TRANSECTS SAMPLED IN 2015. 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 | 1.5 | 4.1 | 0.0 | 0.0 | 0.0 |
| ALYDES | *Alyssum desertorum* | desert madwort | F | I | 0.0 | 0.0 | 0.1 | 0.1 | 0.5 |
| ASTMUL | *Astragalus mulfordiae* | Mulford's milkvetch | F | N | 0.5 | 0.0 | 0.8 | 0.5 | 1.6 |
| ASTPUR | *Astragalus purshii* | woollypod milkvetch | F | N | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BALSAG | *Balsamorhiza sagittata* | arrowleaf balsamroot | F | N | 0.0 | 1.8 | 4.9 | 0.4 | 1.1 |
| BROTEC | *Bromus tectorum* | cheatgrass | G | I | 37.9 | 51.1 | 27.8 | 35.9 | 21.8 |
| UNKCARY | *Caryophyllaceae* | Pink Family | F | | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 |
| CHADOU | *Chaenactis douglasii* | Douglas' dustymaiden | F | N | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| CHAMAC | *Chamaesyce maculata* | Small spotted sandmat | F | I | 0.5 | 0.0 | 0.0 | 0.2 | 0.4 |
| CHRVIS | *Chrysothamnus viscidiflorus* | green rabbitbrush | S | N | 3.8 | 10.1 | 5.9 | 4.3 | 4.1 |
| COMUMB | *Comandra umbellata* | bastard toadflax | F | N | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| CREACU | *Crepis acuminata* | tapertip hawksbeard | F | N | 0.0 | 0.0 | 0.2 | 0.0 | 0.3 |
| DESPIN | *Descurainia pinnata* | western tansymustard | F | N | 0.2 | 0.5 | 0.1 | 0.2 | 0.1 |
| ELYELYE | *Elymus elymoides ssp. elymoides* | squirreltail | G | N | 0.0 | 0.3 | 0.5 | 0.0 | 0.3 |
| UNKEPILO1 | *Epilobium sp. 1* | | F | | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| UNKEPILO2 | *Epilobium sp. 2* | | F | | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| ERIOG | *Eriogonum sp.* | buckwheat | F | N | 0.0 | 0.0 | 0.0 | 2.3 | 0.0 |
| ERIPUM | *Erigeron pumilus* | shaggy fleabane | F | N | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 |
| ERISPAW | *Eriastrum sparsiflorum var. wilcoxii* | Wilcox's woollystar | F | N | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |

Appendix D. continued

| Code | Current Name | Common name | Habit | Nativity | Brown Butte | Double Mtn | North Harper North | Snively | South Alkali |
|---|---|---|---|---|---|---|---|---|---|
| EROCIC | *Erodium cicutarium* | redstem stork's bill | F | I | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| FRIPUD | *Fritillaria pudica* | yellow fritillary | F | N | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| GRASPI | *Grayia spinosa* | spiny hopsage | S | N | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| HESCOMC | *Hesperostipa comata ssp. comata* | needle-and-thread grass | G | N | 2.6 | 0.4 | 7.5 | 6.1 | 0.0 |
| LACSER | *Lactuca serriola* | prickly lettuce | F | I | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LINPUN | *Linanthus pungens* | granite prickly phlox | F | N | 0.0 | 0.0 | 1.9 | 0.0 | 0.0 |
| MACCAN | *Machaeranthera canescens* | hoary tansyaster | F | N | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 |
| OENPAL | *Oenothera pallida* | pale evening primrose | F | N | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 |
| OPUPOL | *Opuntia polyacantha* | plains prickly pear | F | N | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 |
| PASSMI | *Pascopyrum smithii* | western wheatgrass | G | N | 0.0 | 3.0 | 0.0 | 0.4 | 0.1 |
| PENACU | *Penstemon acuminatus* | sharpleaf penstemon | F | N | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| PHAHET | *Phacelia heterophylla* | varileaf phacelia | F | N | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| PHALIN | *Phacelia linearis* | threadleaf phacelia | F | N | 0.0 | 0.0 | 0.2 | 0.1 | 0.1 |
| POABUL | *Poa bulbosa* | bulbous bluegrass | G | I | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 |
| POASEC | *Poa secunda* | Sandberg bluegrass | G | N | 0.4 | 0.2 | 4.4 | 0.1 | 2.1 |
| SALTRA | *Salsola tragus* | prickly Russian thistle | F | I | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| SISALT | *Sisymbrium altissimum* | tall tumblemustard | F | I | 0.1 | 0.2 | 0.1 | 0.2 | 0.0 |
| SPHGRO | *Sphaeralcea grossulariifolia* | gooseberryleaf globemallow | F | N | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| TRADUB | *Tragopogon dubius* | yellow salsify | F | I | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| VULPIA | *Vulpia spp.* | fescue | G | I | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 |

# APPENDIX E.  STATISTICAL RESULTS

Table 11.  Two factor analysis of variance (ANOVA) table for the mean diameter (cm) of *A. mulfordiae* in **2015 only,** by site.  Predictors with a *p*-value < 0.05 are in bold.

| | Df | SS | MS | F value | *P* value |
|---|---|---|---|---|---|
| Site | 7 | 3624.7 | 517.81 | 4.018 | **0.0007622*** |
| Residuals | 85 | 10954.1 | 128.87 | | |