Missoula's Conservation Lands Management Report

2019 Research and Monitoring Activities Summary

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1. Executive Summary

The research and monitoring (R&M) program of Missoula's Conservation Lands Management (CLM) division is responsible for monitoring the conditions and trends of recreational and natural resources on City-owned conservation lands. Staff in the R&M program work to improve land management techniques as well as our understanding of local ecology and the public use of conservation lands. This document provides an overview of R&M activities during the 2019 season. For some projects, more detailed individual reports are available upon request, as indicated in the Table of Contents.

In 2019, R&M staff worked on a variety of monitoring and research projects. Monitoring projects included revisiting long-term monitoring plots installed in Missoula's most intact grasslands. Monitoring of elk use of Mount Jumbo during the winter closure continued in its sixth year, while we revisited elk monitoring plots established in the South Hills for the first time. We also continued a user exit survey begun by University students to characterize recreational use at the South Hills Spur property. By early summer, we completed a comprehensive inventory of infrastructure at all trailheads and access points across the entire Conservation Lands system.

In addition to monitoring natural and recreational resources on Conservation Lands, the R&M program designs and implements its own research studies. In 2019, we report on six years of data collection in a study determining effective, integrated approaches to control persistent spotted knapweed populations. We also report on third-year results from studies on the impacts of deer browse on recruitment of riparian vegetation and the effectiveness of broadcast seeding efforts. Finally, we report on the preliminary results in a study initiated in 2018 aimed at determining best practices to restore grasslands invaded by exotic annual grasses.

Table of Contents

2. Monitoring

2.1 Vegetation

2.1.1 Long-term Baseline Monitoring

Introduction

In 2013, the CLM research team initiated a long-term monitoring program intended to track the condition and trend of grasslands communities on Mt. Jumbo, the North Hills, and Mt. Sentinel. The monitoring program consists of a network of permanently located plots that will serve as a platform to monitor long-term changes in the diversity and abundance of vascular plants and other biota in Missoula's grassland habitats. Plots were established in both "pristine" and "degraded" grassland habitats to serve as reference communities when developing management strategies to restore disturbed or invaded grasslands. Plots are revisited every three years on a staggered basis so that all pristine plots are read one year and degraded plots in another. In 2019, we revisited pristine plots for the second time since establishment in 2013.

Methods

Long-term monitoring plot locations were initially determined using a Vegetation Condition map developed by Missoula County Weed District. Using condition categories defined as "Pristine" (less than 15% non-native cover) and "Inundated" (greater than 75% non-native cover), we installed 8 plots in pristine habitats in 2013, and 12 plots in inundated habitats in 2015. Plots were selected by generating random points in each community, and visiting these points to reject any that did not meet criteria (i.e., too close to a trail or wrong vegetation condition).

We sample plots using a modified version of protocols developed by the National Park Service's Inventory and Monitoring Network (James et al. 2009). Pristine vegetation plots are 0.125 hectares in size, composed of two parallel 50-meter transects spaced 25 meters apart. Inundated plots are half the size, composed of a single 50 meter transect because they are less floristically diverse overall. Along each transect, we sample five nested quadrats spaced 10 meters apart. Nested quadrats range in size from 0.01 square meters to 20 square meters. We record all species present, identifying the smallest quadrat where each species occurs up to the 20 m^2

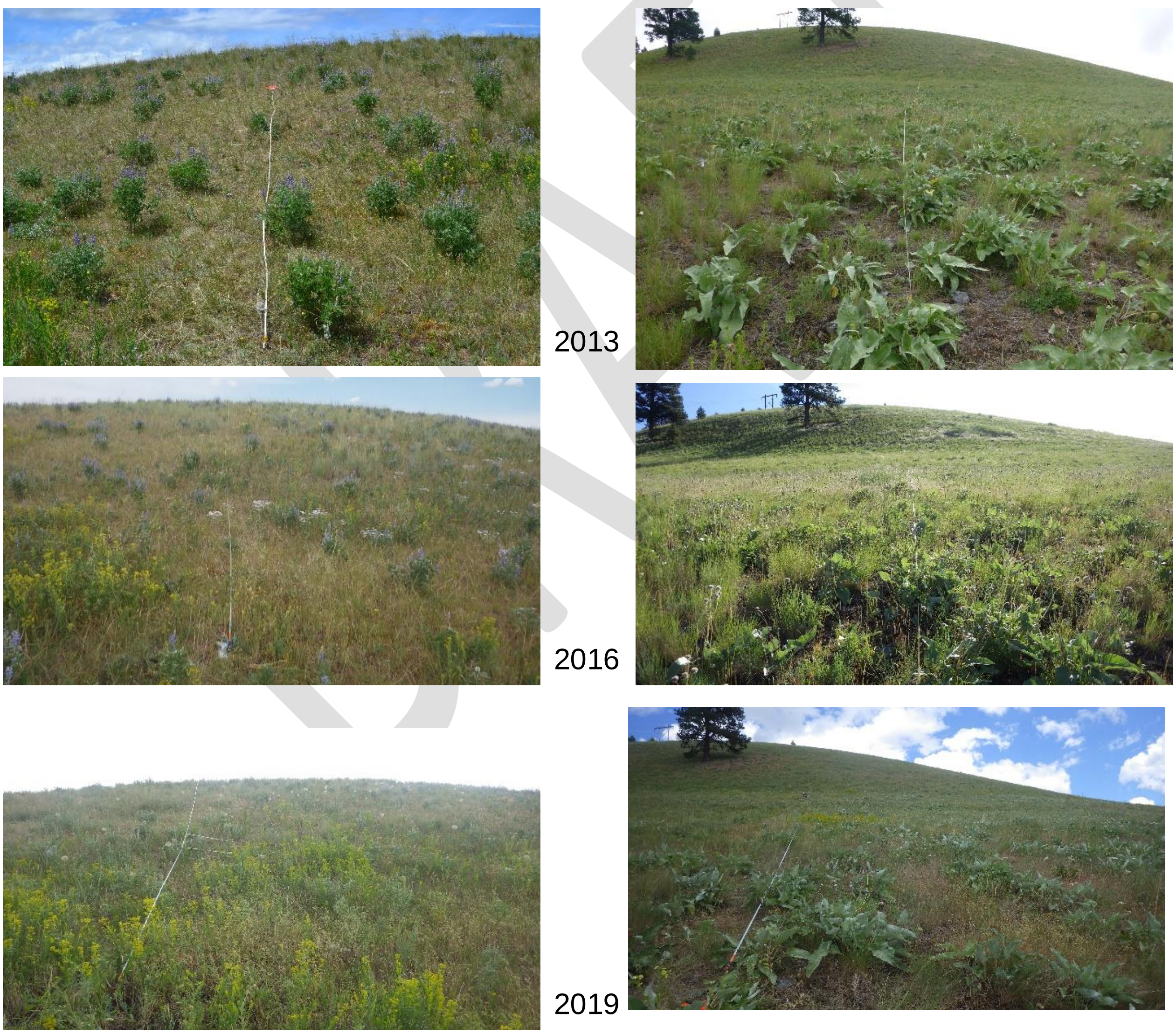
Functional Group	North Hills 1	North Hills 2	Jumbo Saddle East	Jumbo Saddle West	Jumbo Saddle South	Jumbo Summit West	Jumbo Summit East	Mt. Sentinel	**Overall**
E.A. Grass	2.92	1.92	8.90	0.87	0.48	0.39	1.61	-0.14	**2.12**
E.P. Forb	5.55	0.69	0.59	1.44	4.31	1.56	2.67	4.28	**2.63**
N.A. Forb	0.64	1.17	-0.03	0.07	0.19	2.95	1.43	0.50	**0.86**
N.P. Forb	4.80	15.75	1.90	8.43	5.09	6.59	5.86	1.93	**6.29**
E.P. Grass	0.09	-0.08	-0.72	0.04	0.04	0.03	-0.01	3.14	**0.32**
N.P. Grass	13.63	3.13	7.50	7.50	5.68	11.88	5.63	18.20	**9.14**
Shrubs		-1.48	0.14					-0.11	**-0.48**
Trees					-1.29		-3.54		**-2.41**

Table 1. Shows the six-year trend in functional group cover (rows) for each site (column). Abbreviations E. and N. stand for "Exotic" and "Native", abbreviations A. and P. stand for "Annual" and "Perennial". The values in each cell are the calculated slopes of the trend line that best fits the average functional group covers for the three sampling years. Green shaded cells indicate a trend towards greater native vegetation whereas red shaded cell indicate a trend towards greater exotic vegetation.

plot. We also estimate surface covers (litter, moss, gravel, etc.) and cover by plant functional group (annual grass, perennial forb, etc) at the 1m^2 level.

Results

Having now collected data in three sampling years, we are able to begin exploring trends in vegetation community composition at the pristine sites. In this report, we will focus on broad trends in functional groups, shown in the table above, and discuss some species-specific examples. Overall, most sites saw an increase in exotic annual grasses and exotic perennial forbs (see Table 1). The Mt. Sentinel site was the only site where exotic annual grasses have decreased in cover over the sampling periods. The Jumbo Saddle East site experienced the greatest increase in exotic annual grasses (slope of 8.9) and the North Hills 1 site increased the most in exotic perennial forbs (slope of 5.55). At the same time, all sites also increased in native perennial forb and grass cover since 2013 with the highest increase in native forbs at the North Hills 2 site and the highest increase in native grass at the Mt. Sentinel site.



Photographs of baseline monitoring sites at North Hills 1 (left) and Mt. Jumbo Saddle East (right). Photos are vertically chronological starting with 2013 (top) and ending with 2019 (bottom).

Both photographs and species frequency data help to further explore these apparent trends in functional group cover. The series of photographs above show the North Hills 1 site (on the left) and the Mt. Jumbo Saddle East site (on the right) in the three sampling years with 2013 on the top, 2016 in the middle, and 2019 the last. At the North Hills site encroachment and expansion of leafy spurge (*Euphorbia esula*) into the monitoring plot is evident in the lower left corner of the photograph frames. At the Mt. Jumbo site, gaps between the arrowleaf balsamroot (*Balsamorhiza sagittata*) and bunchgrasses that are visible in 2013 are gradually filled in by 2019 with exotic annual grasses, principally Japanese brome (*Bromus japonica*) and cheatgrass (*B. tectorum*).

Management Implications

The baseline monitoring plots are meant to convey information on the long-term composition of grassland communities. Thus, we are careful not to react too drastically to apparent trends. That said, the observed trends in increased exotic species cover deserves more scrutiny. As we develop priorities for invasive species management activities for the coming year, further analysis into areas of particular concern should be considered, including:

- Exotic annual grasses at the Jumbo Saddle East site, and
- Exotic perennial forbs at the North Hills 1, Jumbo Saddle South, and Mt. Sentinel sites

Options for managing exotic winter annual grasses like cheatgrass and Japanese brome are limited, but recent research on the herbicide Esplanade® show some promise especially in areas with significant existing native perennial vegetation. Consideration of Esplanade® as a potentially viable and desired management tool for Missoula's Conservation Lands will continue to incorporate results of ongoing research, including our own research on this topic (see Section 3.1.4 in this report).

The observed trends in exotic perennial forbs may also lead to specific management actions in specific areas. In general, results from baseline monitoring plots will help inform both specific vegetation management actions conducted annually, and multi-year invasive management planning and prioritization.

2.2 Wildlife

2.2.1 *Mount Jumbo Elk Spotters Program*

Introduction

Each winter a herd of 50-100 elk migrate from the Rattlesnake Wilderness and Recreation Area to the slopes of Mount Jumbo in the Missoula Valley. Protecting this herd of elk has been a management priority of the Missoula community since efforts to preserve habitat on Mt. Jumbo started in the 1990s. The first seasonal closure to restrict human and elk contact on Mt. Jumbo was implemented in 1996. Since then, local land managers have sought to increase their knowledge of how elk use Mt. Jumbo to better inform and adapt their management activities.


Mount Jumbo in Winter Photo by [illegible]

The Elk Spotters program is one aspect of a monitoring plan to understand the status and trend of elk use of Mt. Jumbo. Starting in 2013, members of the Missoula community have voluntarily collected data on the presence and abundance of elk through the winter months. This data helps to support annual decisions about the seasonal closure and informs our understanding of longer-term trends in elk behavior.

Methods

The Elk Spotters program is driven entirely by the voluntary efforts of citizen scientists who keep a log of the number and location of elk throughout the winter season. Each participant in the program is given a copy of a map of Mt. Jumbo and datasheets for recording observations. Elk Spotters use the datasheets to record daily observations of the location and number of elk they see. Participants are encouraged to record a "0" if no elk are visible and a "W" if their view of Mt. Jumbo is obscured due to weather.

Results

Elk were first reported on Mt. Jumbo on November 9th, 2018, nearly one month before the mountain closed to public use on December 1st. Through the months of December and January, 40-50 elk could be seen on a fairly regular basis. By February, winter turned notably colder and snowier. In fact, the February of 2019 was Missoula's 3rd coldest and 3rd snowiest on record. On February 28, a small avalanche, likely triggered by elk, occurred on the same day as a fatal avalanche in 2014. Mt. Jumbo was placed under an Urban Avalanche Warning for much of March.

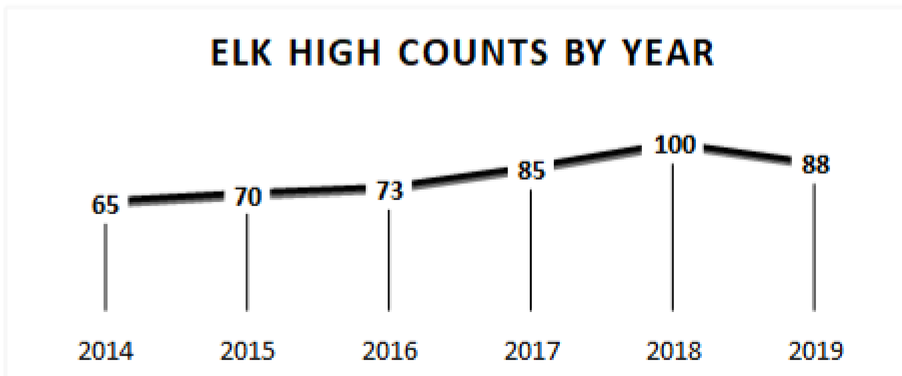


Figure 1. The 2018-2019 winter marked the first year since Elk Spotter data has been collected that the high count of elk has decreased.

February 28th, 2019 avalanche
Photo by Clancy Jandreau

The highest number of elk were observed on April 11th when participants counted 88 elk grazing on the slopes of Mt. Jumbo. The south zone of Mt. Jumbo opened just 4 days later on April 15th; and by the 24th, the elk left the South Zone.

Management Implications

Over the past 6 winters, elk have arrived on Mt. Jumbo an average of 10 days before Mt. Jumbo closes to public use on December 1st. Elk have departed the South Zone of Mt. Jumbo an average of 26 days after the South Zone is regularly set to open on March 15th. The result has been the ad hoc extension the South Zone closure for 5 of the past 6 winters. These facts have prompted land managers to consider whether the March 15th date is an appropriate time to reopen Mt. Jumbo to public use, or whether a permanent extension of the closure should be considered.

2.2.2 South Hills Spur Elk Population Monitoring

Introduction

The South Hills Spur (SHS) property, located at the mouth of Pattee Creek, is the most recent City property to open for public use. The property offers excellent recreational opportunities as well as wildlife habitat. Development of the property is guided by the SHS Recreation Management Plan, which aims to ensure that recreational opportunities are balanced with conservation goals. The SHS Recreation Management Plan identifies a lack of information that currently exists on the North Sapphire elk herd's use of the property. Thus in 2018, Missoula Parks and Recreation initiated an effort to better understand the basic distribution and habitat utilization of elk on this property. Following protocols developed for elk monitoring on Mount Jumbo, we established a network of plots across the SHS property to search for elk pellets. Combined with continued elk observation records, these plots will serve as a framework to monitor the potential impacts of winter recreation on elk use of the SHS property.

Methods

Following the protocol previously developed for the Mount Jumbo elk monitoring program, quantification of fecal pellet groups is used as an index for elk occupancy, distribution, and relative use. Fecal pellet group densities are measured at plots systematically placed across the SHS property. Plots consist of four subplots, each 3-meters in radius and located in the four cardinal directions from a center point. Data is generally collected in a two person team. Teams navigate to an established plot center and use meter sticks and compasses to delineate subplots before searching for and counting groups of elk pellets in each subplot. After each subplot is counted, any pellets within the subplot are removed so that the it is cleared for the next sampling period.

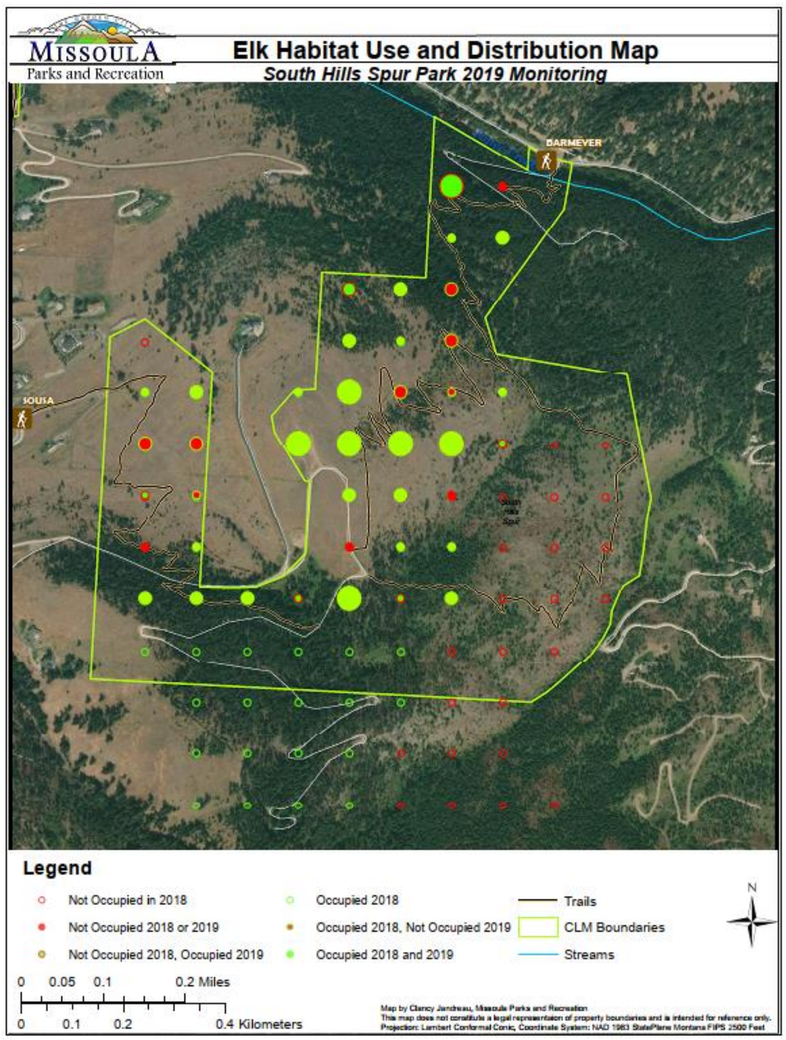


Figure 2. Map of the sampled elk pellet plots on the South Hills Spur property. Larger dots indicate a large difference between 2018 and 2019 pellet densities.

Results

Pellet counts were first conducted in 2018 across the SHS and adjacent property to the south. Of the 84 plots sampled in 2018, 60% contained recent elk pellets, concentrated on the grassy knob at the top of the property and in forest to the south. The distribution of elk occupancy had significant overlap with the newly created trails.

In 2019, we focused our sampling on plots where 2018 elk occupancy overlapped with current trails (see solid dots in Figure 2). We surveyed 41 plots in total and observed elk occupancy in 73%, compared to 75% of the same plots in 2018. Spatially, areas where elk occupied in 2018 but not in 2019 (red dots with green outline in Figure 2) are clustered along the Barmeyer trail at mid-slope and near the Sousa trail at mid-slope; however, whether and how the recreational use of the trails impacted elk use is not certain. Elk use on top of the knob does not appear to have been negatively impacted by recreationists and actually increased, according to observed pellet densities, since 2018 (see large solid green dots in Figure 2).

Management Implications

Based on 2018 data, the grasslands on the top and the east slope of the property were identified as having the most intense elk use in areas with publicly open trials. Data collected in 2019 does not indicate that recreation during the 2018-2019 winter decreased elk use in these areas; however, that does not mean that winter recreation had no impact on elk use. We do not know how much recreational activity occurred during the 2018-2019 winter (trail counters were not set up in the area until August of 2019). We will have a better idea of how much recreational activity the area receives this winter with the trail counters that are now established. Both the recreational use of the area and its potential impact on the North Sapphire elk herd may change significantly if public acquisition up the flanks of Mt. Dean Stone continue, and should be monitored accordingly.

2.3 Recreation

2.3.1 South Hills Spur Recreational Use Survey

Introduction

When the Barmeyer loop trail opened in 2018, the popularity of the new trail quickly outpaced anticipated demand, leading to parking issues, user conflicts, and user displacement, among other concerns. These challenges prompted a partnership between the University of Montana and Missoula Parks and Recreation to investigate recreational use of the South Hills Spur property. Key objectives for the investigation included understanding who is using the trail, what activities they are pursuing, why they choose this trail, and the potential for user conflicts on the trail. In the fall of 2018, University students surveyed 206 recreationists at the Barmeyer trailhead and conducted some initial trail use counts. In the summer of 2019, MPR staff surveyed 227 recreationists at the Barmeyer and Sousa trailheads and conducted additional trail use counts. A full report of the 2019 findings is available upon request. In this document, we summarize broad trends in the data.

Methods

Surveys were conducted by intercepting recreationists as they exited either the Barmeyer or Sousa trailhead during the months of August and September 2019. Research staff administered surveys in three-hour shifts on weekdays and six-hour shifts on weekends, randomized by day, site, and weekday start time (9am, 12pm, or 4pm). During the survey shifts, researchers also manually tallied the number of recreationists and dogs entering and exiting the trailhead, organized by recreation type (i.e., hikers, runners, and bikers) and by leash status (i.e., no dogs, leashed dogs, unleashed dogs). Since August 12th 2019, infrared trail counters have been established in three locations along the trail and continuously count trail use each hour.

Results

The table below shows the average number of users counted by the infrared trail counters for the period of August 12th to September 30th, 2019 separated by trailhead and weekday versus weekend. Trail counts are non-directional, thus because the vast majority of users start and end their trip at the same location (confirmed by survey data), most users are double counted by the trail counters. Therefore, an estimate of the daily traffic at each site can be calculated by dividing the daily total by two. On average, an estimated 65 recreationists use the Barmeyer trail each weekday and 94 each weekend day. Only 15 recreationists use the Sousa trail each weekday and 22 on the weekend days.

TRAILHEAD	WEEKDAY TOTAL	ESTIMATED DAILY WEEKDAY TRAFFIC	WEEKEND TOTAL	ESTIMATED DAILY WEEKEND TRAFFIC
BARMEYER	131.4	65	189.2	94
SOUSA	31.7	15	44.3	22

The most common type of user observed at the Barmeyer trailhead was a hiker without any dogs, accounting for 54% of all use at that site. Another 26% of use was accounted for by hikers with leashed dogs and hikers with unleashed dogs made up another 10%. Only 10% of use at the Barmeyer trailhead consisted of runners/joggers or bikers of any kind. Use at the Sousa trailhead meanwhile was more diverse. The most common type of user observed at the Sousa trailhead was a hiker with unleashed dogs, accounting for 28% of all use at the site. The additional hikers were evenly split between those with leashed dogs and those without dogs, each containing 23% of overall use. Bikers, all without dogs, accounted for 21% of the use at the Sousa trailhead and runners just 5%.

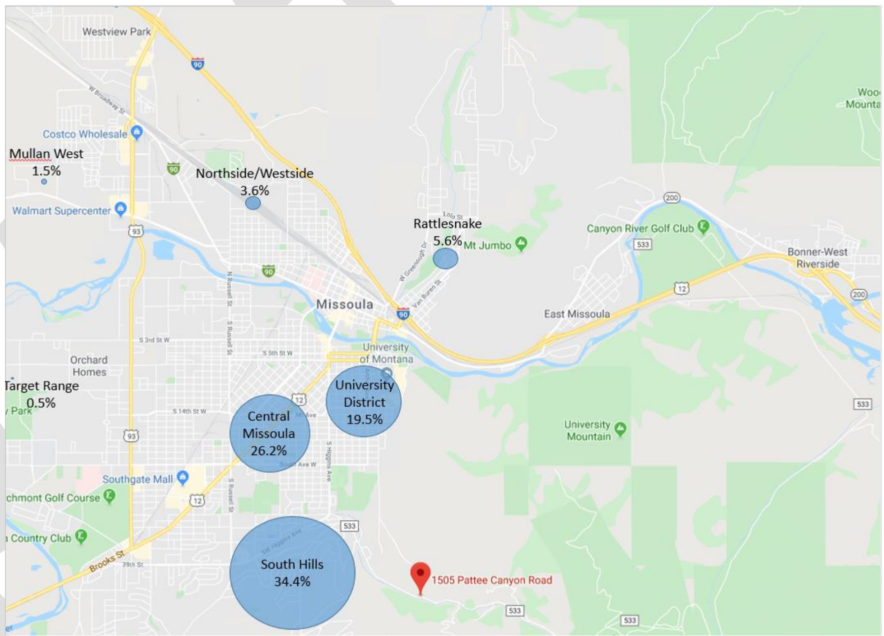


Figure 3. Map of locations where survey respondents reported residing. Larger blue dots indicate more respondents residing at that location.

Notable findings of the administered survey include:

- 85% of respondents reported that they were residents of the City of Missoula, while only 5% reported county residency

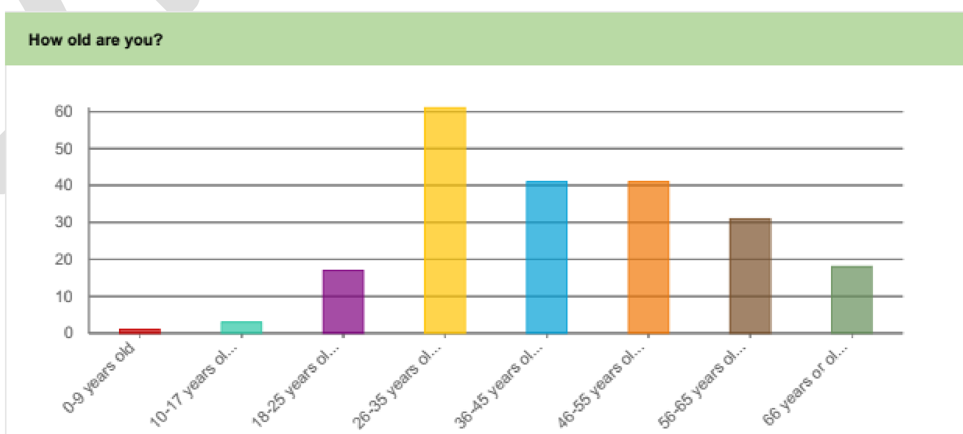


Figure 4. Bar graph of the reported age classes of survey respondents at the Barmeyer and Sousa trailhead.

- Nearly 1/3 of respondents reported residing in South Hills, *up from 22% in 2018*

- The most common age class reported by respondents was 26-35 years old, yet the average age class mid-point was 44, *up slightly from 43 in 2018*.

- ¼ of respondents were first time trail users, yet only 5% of respondents reported "this trail is new" as their reason for hiking the trail, *a decrease of more than 30 percentage points since 2018*

- 94% of respondents reported finding parking immediately upon arriving at the trailhead

- More than 2/3 of hikers reported they are comfortable sharing the trail with bikers, *up 16 percentage points since 2018*

- 92.8% of hikers reported bikers have no or only a slight impact on their experiences; *"no impact" was up by 24 points and "high impact" was down by 20 percentage points since 2018.*

For more detail information on these survey results see the full South Hills Spur Recreation Report available by request.

Management Implications

Unfortunately, we do not know how many trail users were using the trail during the first few months that it opened in the summer of 2018 when trail conflicts were high. However, indications from this survey and from other anecdotes suggest that the potential for conflict has subsided considerably. Survey results demonstrate that there is a high level of local use by residents of the South Hills, that less people are traveling to the area just to experience a new trail, and that the vast majority of users find parking immediately upon arriving at the trailhead. Potential conflict with mountain bikers also appears to have decreased. When University students first conducted their survey, mountain bikers were not yet allowed on the trail and thus survey respondents were asked to predict how bikes might impact their experiences. In 2019, after nearly a year with multiple uses open on the trail, respondents had the opportunity to report their actual experiences with bikers. Yet, overall comfort with bikes remained high (76.6% of hikers reported being comfortable sharing trail with bikers) and the percentage of respondents reporting that bikers have a high impact on their experience decreased by 20 points. Biking also remains a relatively small proportion of the total use at the SHS property (only 4% at the Barmeyer trailhead and 21% at the Sousa trailhead). Thus, hikers' levels of comfort with bikers may change if we see a substantial increase in biking at this property. For now, these indicators align fairly well with the goals outlined in the SHS Management Plan and suggest that the recreational infrastructure built thus far is meeting the current recreational demand.

2.3.2 Conservation Lands Trailhead Inventory

Introduction

The 2018 Missoula County Open Space Bond was approved by Missoula County residents during the November 2018 General Election. The bond measure included up to $0.5 million for improving Trails and Trailheads across Missoula's Open Space and Conservation Lands System. Trails and trailheads were last inventoried in 2015. documenting 63 trailheads and 54 miles of trail. Of those documented, only one primary, no secondary, and half of local access trailhead met standards established in the 2010 Conservation Lands Management Plan. The majority of the trailheads in the Conservation Lands System were developed over a 30 year period and many contain inconsistent signage, inaccurate trail maps and in many cases do not comply with current trailhead standards and/or City ordinances. In an effort to provide consistency between these City trailheads, Conservation Lands Management staff conducted an updated inventory of all Conservation Land trailheads and access points in the spring of 2019. Data from this inventory will provide the information needed to complete a comprehensive upgrade of all Primary, Secondary and Local access points, including standardizing all rules and regulations signage, providing bear-resistant trash cans where needed, upgrading all trail maps, and providing informational kiosks at all Primary Access points.

Methods

Staff visited all access points to document the condition of all infrastructure, GPS the site, and take a picture of all signs. Access points were defined as any sanctioned entry point into a Conservation Lands property. This includes formalized trailheads, neighborhood access points, and points where existing trails cross into City property from adjacent property such as U.S. Forest Service or University land.

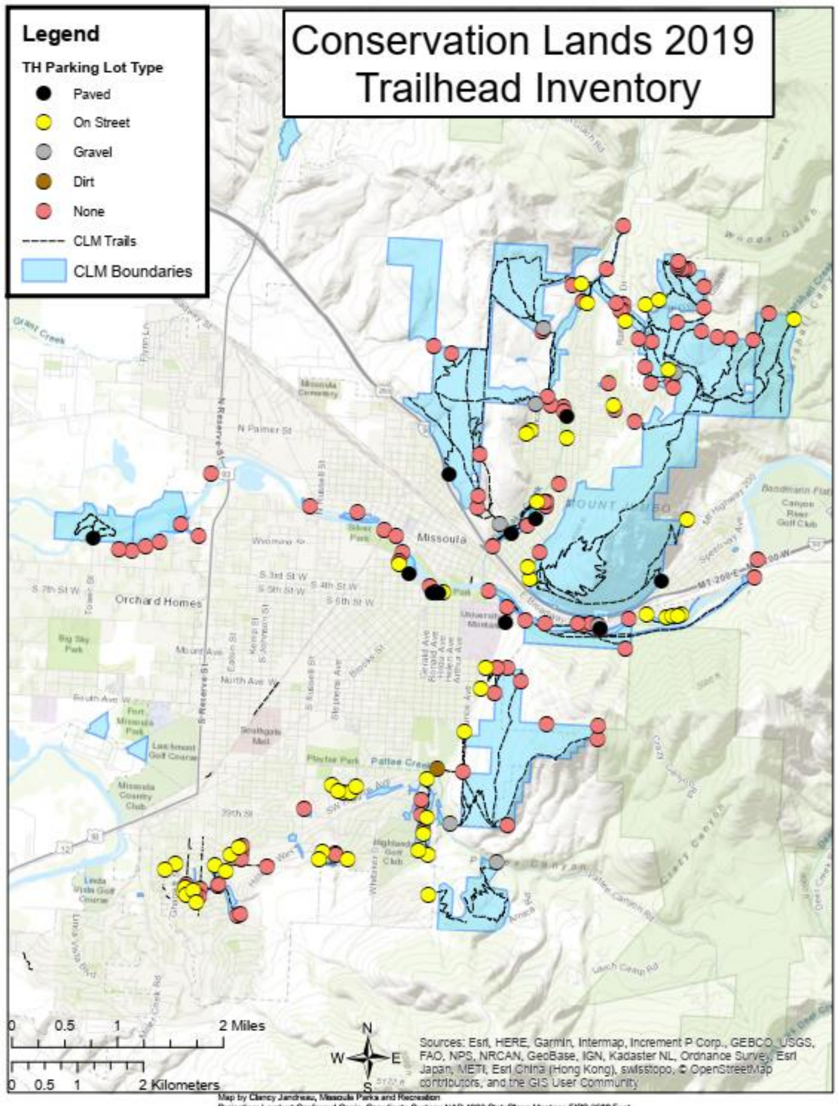


Figure 5. Map of all 171 access points inventoried across the Conservation Lands system. Black dots represent access points with paved parking lots, gray with gravel lots, brown with dirt lots, yellow with on-street parking, and red with no parking.

Results

Staff documented a total of 171 trailheads and access points. Mount Jumbo contained the most access points with 31; Mount Sentinel had 15, and the Rattlesnake Greenway had 14. Specific infrastructure documented at these sites include:

- 11 paved, 7 gravel, and 1 dirt parking lot
- 13 bike racks
- 394 trailhead signs
- 3 Kiosks
- 45 trash cans
- 39 mutt-mitts

- 16 lend-a-leash's, and
- 31 gates

More detailed information about the condition of infrastructure will be available in the full Trailhead Inventory Report, which is expected to be completed in the Spring of 2020.

Management Implications

Conservation Land Management staff are currently in the process of analyzing the inventory data to assess the specific inventory needs across the trailhead system. The result will lead to a full account of necessary materials to upgrade and standardize all City-maintained access points. Ultimately, the goal is to create a system that is more intuitive for trail users, and more efficient for Conservation Lands Management staff to maintain.

3. Research

3.1 Internal Research

3.1.1 Integrated Life Cycle Control of Spotted Knapweed

Introduction

Knapweed is not generally a target of CLM's herbicide weed control program. Previous reliance on broadcast spraying of Tordon and Milestone was largely abandoned because knapweed is so widespread, and able to regenerate from its seed bank after spraying and re-invading the site. Failure to remove knapweed during the first spray can lock managers into a 3-5 year spray cycle to control the weed (Rice et al. 1997, Ortega and Peterson 2011). Repeated spraying has also been shown to damage the health of native plant populations (Crone et al. 2009).

Instead, CLM has invested in biologically based efforts to control knapweed, including using insect biocontrols, handpulling, and implementing sheep grazing. CLM has released tens of thousands of biocontrol insects of at least five species, and at least eight species of insects are established on Mt Jumbo. Seedhead biocontrols have been shown to decrease spotted knapweed seed production by 50-70% (Olson et al. 1997, Benzel et al. 2009). Biocontrols are considered cost effective because they establish and spread on the landscape to provide a long lasting "natural control", although many insects do not cause outright mortality of plants. Sheep grazing during bolt or flowering stage in combination with insects can reduce seed production by 90-99% (Mosley et al. 2012), but sheep grazing also does not cause outright mortality of knapweed plants.

CLM did not monitor knapweed populations throughout the duration of the grazing program, but photographic evidence suggests spotted knapweed declined in abundance at the Mt Jumbo Saddle (study site for this project) between 2004-2014 (see Figure 6). Sheep have grazed this site from 2007-2018. Although there is some reason to suspect that drought and root-dwelling biocontrols were contributing factors for this decline, we believe recruitment limitation was the mechanism of the population crash, brought on by sheep grazing and seedhead biocontrols reducing seed production for the last decade.

Given the apparent success of these biocontrol efforts, we wondered how to best capitalize on gains made through additional integrated management. The primary management questions driving this project are: *What is an appropriate exit strategy from grazing*? *Will gains disappear if we stop grazing? How can we best take advantage of gains made?* Our research hypothesis for the project is spraying *once* after long-term grazing will improve knapweed control by taking advantage of depressed seed banks and killing remaining adult knapweed compared to grazing or spraying alone. Desired outcomes of the best treatment include *1)* longer term control of knapweed*, 2)* less secondary invasion by annual grasses and other non-native plants, and *3)* less impact on susceptible natives. Results will be evaluated to see which treatment was most successful in meeting these three desired outcomes, if any.

Figure 6. 2004 photo of knapweed on the Jumbo saddle, taken while knapweed is in bloom (purple coloration). This is one of dozens of photos of the area that show high levels of knapweed in 2004.

2014 photo of the same location, taken while knapweed is in bloom, appearing to show a landscape level decline in knapweed cover.

Methods

Treatments were applied on 10 paired 5x5m plots, in grazed and ungrazed pastures. Our 4 treatments were: 1) Never Grazed & Not Sprayed (NG+NS); 2) Never Grazed & Sprayed (NG+S); 3) Grazed and Not Sprayed (G+NS); 4) Grazed and Sprayed (G+S). We surveyed all plots before the last graze in summer 2014 and sprayed half the plots in October 2014 with 5 oz/acre Milestone. We enclosed grazed plots with fencing in 2015 (to simulate the end of grazing, as grazing continues on site) and visited plots each summer thereafter to collect data. On our plots we collect information on the cover and density of knapweed as well as select native and exotic grasses and forbs. Density is measured by the following demographic groups: seedlings, non-flowering adults, and flowering adults.

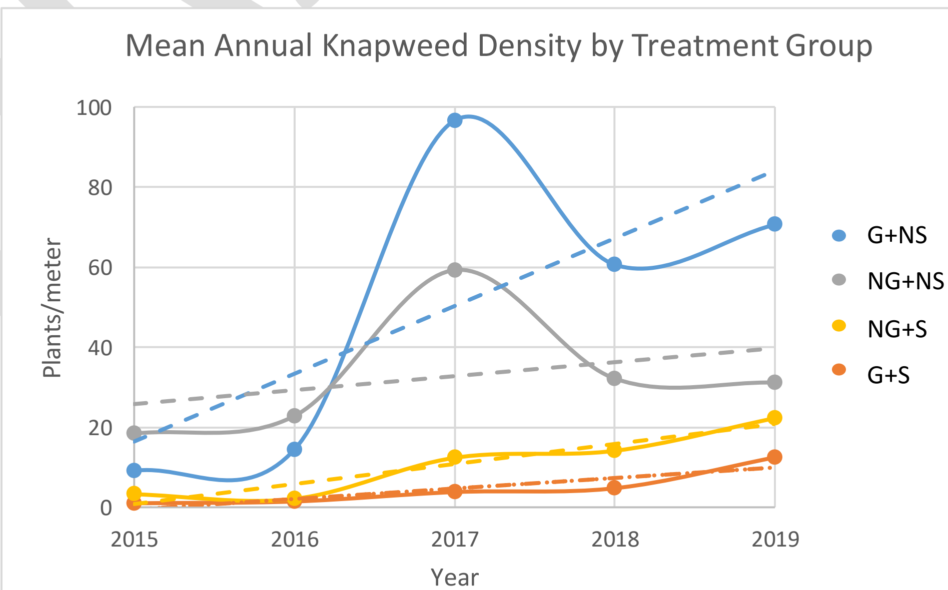


Figure 7. Graph of the mean knapweed densities observed for each treatment group in each year after plots were sprayed in 2014. Lines indicate the linear trends that best fit the change in densities across years.

Results

Our first stated metric of a successful treatment is the long-term control of knapweed. If grazing has indeed reduced the knapweed seed bank in plots with a history of grazing, we would expect to see a slower recovery of knapweed in G+S plots over time as compared to NG+S plots. In 2019, the average density of knapweed in G+S plots was 11.45 plants/meter, which is 10.9% higher than pretreatment levels measured in 2014. For NG+S plots, the average knapweed density observed was 21.25 plants/meter, which is 36.8% lower than in 2014 (see Figure 7). These results indicate that knapweed has recovered to its pretreatment levels in grazed plots but not in never grazed plots; however, the overall pretreatment density of knapweed was much less in grazed plots in 2014 (average of about 10 plants/meter) than in not grazed plots (average of about 30 plants/meter). Overall, the G+S group has the lowest knapweed density in 2019 and the slowest rate of change in knapweed density over the 5 year period of any group (see Table 2). Meanwhile, the G+NS group has the highest overall knapweed density and saw the highest rate of change in density. Looking just at sprayed plots, knapweed density in plots that do not have a history of grazing are increasing nearly twice as fast as plots with successive grazing (compare slopes of 5.0 and 2.62 for NG+S and G+S plots respectively).

Treatment Group	$\bar{x}_{19}$	m	R^2
Grazed + Not Sprayed	70.6	19.92	0.51
Not Grazed + Not Sprayed	31.15	3.49	0.12
Not Grazed + Sprayed	22.25	5.0	0.90
Grazed + Sprayed	12.45	2.62	0.81

Table 2. Selected knapweed density metrics for each treatment group. $\bar{x}_{19}$ is the observed mean knapweed density in 2019; m is the slope of the trendline shown in figure 7; and R^2 is a measure of how well the trendline fits the data, where value closer to 1 indicate better fit.

There also appears to be treatment effects on our other measures of success. Regarding secondary invasion by annual grasses, grazed plots seem to be faring better than not grazed plots. After being sprayed, both grazed and ungrazed plots saw a spike in annual grass cover in 2016; however, by 2019 annual grass cover in grazed plots has fallen back to within 7% of its level before being sprayed whereas, annual grass cover in ungrazed plots remains 346% greater than before being sprayed. At the same time, perennial forbs have recovered in NG+S plots at a rate that is 5 times greater than perennial forbs in G+S plots.

Management Implications

Community composition dynamics following disturbances are complicated and this research is proving to be no exception. Five years in, results on our stated measures of success, including long-term knapweed control, reduced secondary invasion, and reduced impacts to native perennial forbs are mixed. More detailed analyses are still in progress to test the various possible interactions and main effects, yet there are some conclusions that are becoming more clear. First, there is evidence that suggests successive years of grazing has contributed to a suppressed knapweed population. Second, whether a one-time application of herbicide is an effective exit strategy for grazing really depends on what level of control is desired. Data from 2019 shows that 5 years after treatment knapweed density in grazed and sprayed plots have recovered to their 2014, pretreatment levels. Yet, compared to areas both grazed and sprayed, there is nearly 6 times more knapweed in grazed areas that were not sprayed, 3 times more knapweed in areas not grazed or sprayed, and 2 times more knapweed in areas not grazing that were sprayed. Knapweed densities in sprayed plots are catching up to unsprayed plots much faster in never grazed areas than in grazed areas. Thus, it is clear that simply ending the grazing program without any additional treatment would result in a large rebound of knapweed in those formally grazed areas.

3.1.2 Impacts of Deer Browse on Riparian Recruitment and Restoration

Introduction

In Missoula, there have been periodic discussions about controlling urban deer populations for the purposes of reducing conflict between humans and deer (i.e., traffic safety, mountain lions, deer browse of landscaping, etc.). In these discussions, there has been less attention payed to the impact of deer on natural ecosystems and especially the woody herbaceous dominated riparian areas. Both observations of restoration efforts and anecdotal evidence suggest that deer browse may be limiting recruitment of important riparian vegetation in cottonwood floodplains. However, currently there is little information available on the relative density of deer in the urban area or how deer browse is affecting natural regeneration of woody vegetation in our riparian parks. This study intends to increase our understanding of urban deer dynamics by relating deer population densities and browse intensities with vegetation structure, diversity, and change in riparian forest types. This monitoring program will assist with the development of site-specific best management practices to restore and enhance native riparian habitats. Our primary research questions include: *1)* how does woody and herbaceous vegetation diversity, vigor, and abundance respond to the cessation of browse pressure and *2)* will the cessation of browse allow woody vegetation to reach heights above typical browse limits.

Methods

The aim of this study is to both characterize vegetation dynamics as well as deer populations in important riparian habitats and determine how both may be related. Two primary methods address these goals. Vegetation will be measured over a multi-year sampling effort inside and outside of established deer browse exclosure fences. Exclosures were established in late summer of 2017 at five different sites across the Missoula valley including along Grant Creek (Charolette Marbut Nature Reserve), Rattlesnake Creek (Greenough and Tom Green Parks), Patty Creek (Takima-Kokaski Natural Area), and the Clark Fork River (Clark Fork Islands). The exclosures are designed to prevent browsing by deer on all the vegetation within the plot. Exclosures measure 11 meters long by 3 meters wide and are constructed with 7 foot tall orchard fencing. Two 10-meter transects, one within the exclosure and one outside, were also established. Vegetation characteristics are measured in 10 1-meter square quadrats (sized 0.5 x 2m) along each transect. Measured parameters include the cover class, stem count, average height, and average browse rating for each tree or shrub in a quadrat and the cover class of all non-woody herbaceous species present in the quadrat. Browse intensity is determined based on a rating scale were 0 indicates no browse, 1 is light with less than 50% of the current year's growth browsed, 2 is mild with over 50% browsed, 3 is moderate with two to three year old growth browsed, and 4 is heavy where browse has caused an arrested growth form of the plant.

Deer populations are characterized using wildlife cameras set up at each site. The cameras are set to capture as much of the area of the un-exclosed transect as possible. Following the methods of Rowcliffe et al. (2008), the cameras are used as a phototrap to estimate deer densities at each site. If you can assume deer move at a constant rate throughout the day and can estimate this rate, the density of deer at each site can be estimated based on trapping rates, i.e., the number of photographs recorded per unit time. Although deer likely don't move at a constant rate and exhibit considerable variability in movement rates, the method still allows for relative densities to be calculated and compared across parks and related to key vegetation parameters.

Results

Data collection in 2019 marked the third year in our sampling efforts. Changes in selected woody vegetation metrics across that time are shown in Figure 8. Since exclosures were establish in 2017, woody vegetation inside those exclosures have increased in cover by 107%, decreased in number of stems by 49%, decreased in browse rating by 94%, and increased in height by 97%. Woody vegetation outside exclosures meanwhile remained relatively constant in percent cover, browse rating, and height but experienced a similar decrease in recorded stems. On average, woody vegetation in exclosures have increased in cover by 3.6% and grown 10.9

centimeters each year that browse has been excluded. In 2017 ,there were no stems above 2 meters, the typical browse height limit. In 2019, we recorded 3 stems above 2 meters and 5 stems at 2 meters. Data from wildlife cameras indicate Takima-Kokaski Park receives the highest deer pressure with an estimated population of 28 individual deer and Greenough Park the lowest with an estimated population of just 6 deer. Despite attempts to sample across multiple seasons, camera capture data for Greenough Park has remained persistently low. This is puzzling given that Greenough Park consistently rates the second highest in woody browse. Overall, browse ratings correlate strongly with average woody species heights at each park (see Figure 9), but the variation in deer density among parks only predicts about 41% of the variation in browse rating probably due in part to this discrepancy at Greenough Park.

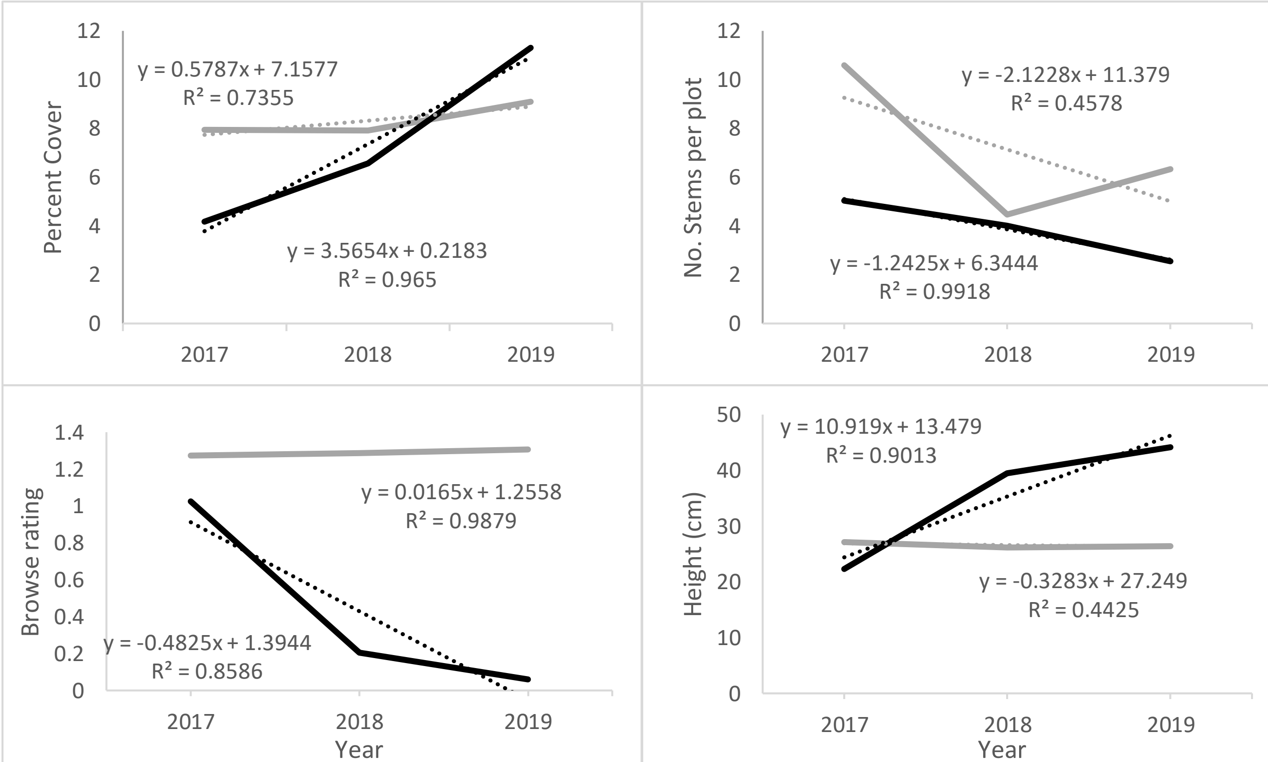


Figure 8. Effects of browse exclusion on cover, stem counts, browse rating, and height of woody vegetation in exclosed (black lines) and control (gray lines) treatment groups.

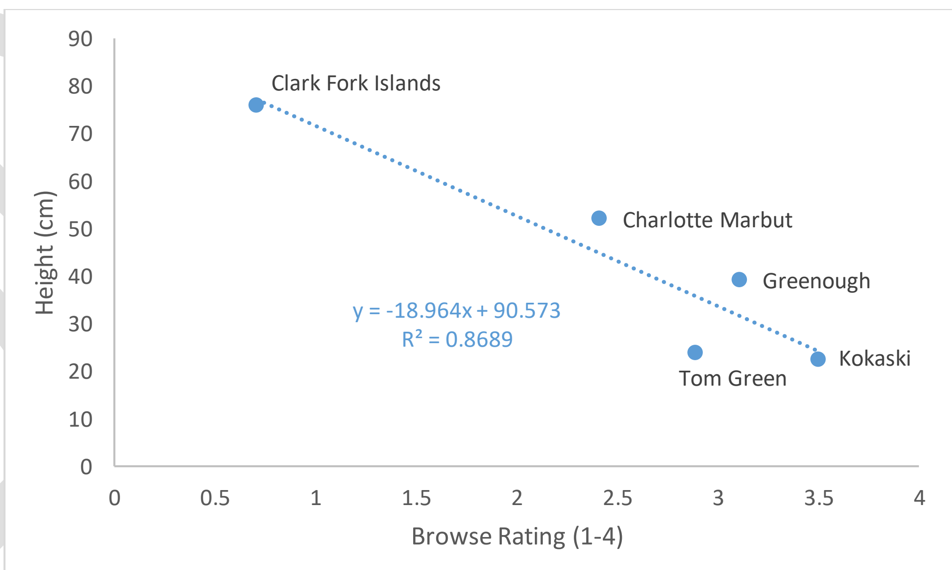


Figure 9. Correlation between average height of woody vegetation and browse rating at each site. The R^2 value indicates that browse rating explains 86.9% of the observed variation in woody species heights across these 5 parks.

Management Implications

One of the objectives of this research is to determine how long deer browse needs to be excluded from an area to allow the woody vegetation to reach heights above the typical browse limit. Data from this study suggests that the answer to this question will depend on characteristics of each site, principally the amount of existing woody vegetation and the severity of deer browse. In areas with low to moderate deer browse and significant existing woody vegetation in the understory, such as in Greenough and Charlotte Marbut Parks, the existing vegetation will respond well and quickly to the cessation of deer browse pressure. In these areas, simply establishing fencing to prevent deer browse and rotating the fenced area after several years would likely be an effective restoration option. In areas with heavy browse and little existing understory vegetation such as in Takima-Kokaski Park, the woody vegetation response is much slower. In these areas, more active restoration efforts, such as woody species plantings, may be necessary to achieve the desired level of native woody vegetation.

3.1.3 Effectiveness of Broadcast Seeding Efforts on Conservation Lands

Introduction

Each year, significant funds and labor are invested in seeding grasslands within the Conservation Lands system that have depauperate native plant communities; including recently disturbed sites, long-term restoration projects, areas of recent herbicide application, and degraded habitats. The success of these broadcast seeding efforts is not well understood in terms of either establishment or persistence of seeded species. In 2017, the CLM research program began a monitoring effort to begin to understand more about the effectiveness of broadcast seeding. The monitoring program calls for multi-year observation of seeded species to determine which species germinate and whether they persist for several years. We will also study differences, if any, between different seeding timings including fall only, fall and spring, or spring only.

Figure 10. Map of the targeted areas for broadcast seeding in 2017 with locations of established monitoring plots.

Methods

Seeding effectiveness is measured by monitoring the frequency of seeded species establishment in grassland plots using methods developed by Vogel and Masters (2001). The method uses a frequency grid made up of 25 squares, each 15 centimeters by 15 centimeters (6 in x 6 in). Frequency is measured by determining the number of grids that contain germinated seeded species. This measurement is repeated four times per plot.

Three sites on the North Hills, which we are calling Froehlich, Peace Basin, and Orange Street Trailhead were selected for monitoring. The Froehlich site is a triangular-shaped seeded area bounded by the Ray Froehlich trail to the west, an old fence line to the south, and the city view trail to the east (see Figure 10). This area was sprayed for leafy spurge and dalmation toadflax in the summer of 2017.

The Peace Basin site is a seeding zone located north of the boundary between the City and Jeannette Rankin Peace Center properties. Seed was broadcasted to areas of bare soil around the mid-slope between the property fence line and a southwest-running ridgeline (see Figure 10).

The Orange Street Trailhead area is directly East and uphill from the parking area at the base of the I-90 on/off ramp. This area was seeded in the spring of 2018 and 2019, serving as our spring only treatment group.

Plots for the monitoring project were established by following behind CLM crew members as they broadcast seeded target areas. Plots were placed in areas with significant bare ground or disturbance to accommodate four iterations of a frequency grid. A total of 30 plots were established. Six plots at the Froehlich and Peace Basin sites were randomly selected to receive an additional spring seed in the spring on 2018. All plots at the Orange Street Trailhead site were only seeded in the spring.

Results

Broadcast seed plots on the North Hills have been monitored for two springs now. In both 2018 and 2019, plots that only received seed in the spring had the greatest overall germination frequency (see Figure 11) although analysis shows no significant difference among groups in either year (χ^2, d.f. = 2, P >0.1). Overall, only 13.6% of quadrats contained germinants in 2018, and only 10.9% in 2019. Looking at individual species, most germination in any group is grasses species. At spring only sites, we only found two penstemon (*Penstemon* wilcoxii) germinants over the two years. Across all plots, Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Agropyron spicatum*), and Sandberg's bluegrass (*Poa secunda*) are the only three species to achieve greater than an estimated one plant per square meter (see Table 3). No seeded forb species met this threshold.

Species	Common Name	D
Festuca idahoensis	Idaho fescue	10.42
Agropyron spicatum	bluebunch wheatgrass	5.51
Poa secunda	Sandberg's bluegrass	4.52
Arabis holboellii	Holboell's rock cress	0.92
Achillea millefolium	yarrow	0.88
Balsamorhiza saggittata*	arrowleaf balsamroot*	0.83
Gaillardia aristata	blanketflower	0.73
Penstemon procerus	Little flower penstemon	0.70
Koeleria macrantha	june grass	0.59
Penstemon wilcoxii	Wilcox's penstemon	0.57

Table 3.List of all species scientific names, common names, and estimated densities (D) found successfully germinating across all sites and years.
* arrowleaf balsamroot was only included in fall seedings.

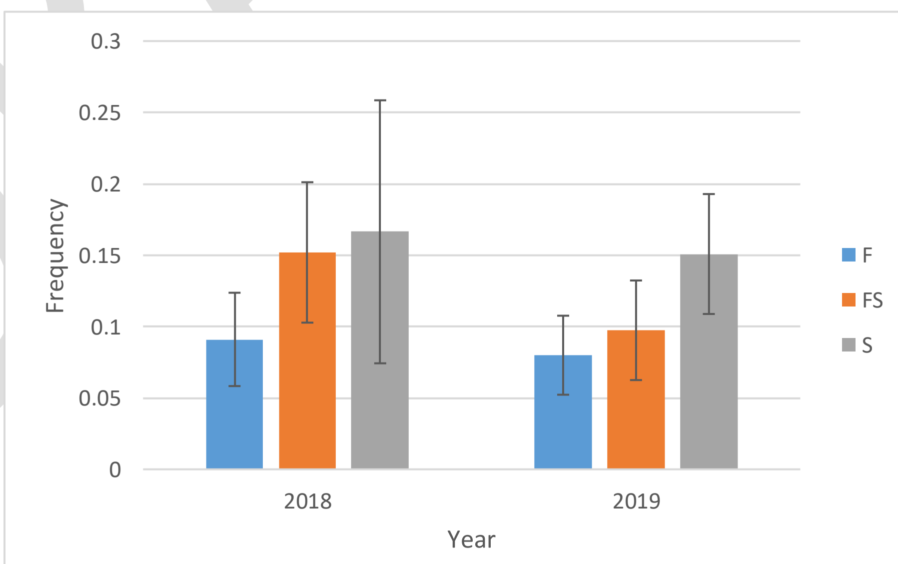


Figure 11. Mean (± STD) frequency of germination for Fall (F), Fall and Spring (FS), and Spring only (S) plots in 2018 and 2019.

Management Implications

Although we have not yet shown statistically significant differences between seeding timings in this study, there are known limitations to seeding in the fall. Seed predation from resident rodents during the winter dormant season is known to impact seed survival. It is reasonable to suppose that a well-timed spring seeding following good soil moisture would limit the time seeds were available to granivores and lead to higher success. However, the seeds of arrowleaf balsamroot require a cold stratification in order to germinate and one of the primary goals of the North Hills seeding effort is to increase the amount of arrowleaf balsamroot, which has been impacted from years of historic herbicide application. **One option is to experiment with cold stratification in the greenhouse setting before seeding in the spring.**

3.1.4 Restoration of Ventenata Infested Grasslands

Introduction

Ventenata (*Ventenata dubia*) is an invasive winter annual grass that has been introduced to the arid and semiarid grasslands of the Pacific Northwest. It was discovered on Missoula Conservation Lands in 2016. In 2017, a preliminary effort was conducted to locate and intensively map areas where ventenata has established. Mapping efforts continued in 2018 at the same time that conversations regarding management of ventenata infestations increased in Missoula and across the state. In Montana, ventenata was added to the state noxious weed list in 2019 as a priority 2A noxious weed. Across the Pacific Northwest, land managers are scrambling to find effective management tools to control the rapid spread of this invasive grass. Recent studies have suggested the herbicide indaziflam (Esplanade ©, Bayer) could prove to be a potent tool in the management of invasive winter annual grasses including cheatgrass (*Bromus tectorum*) and ventenata (Sebastian et al. 2016). On Missoula's conservation lands, ventenata is a relative newcomer, prioritized for management due to concern over its demonstrated ability to spread, while cheatgrass is pervasive but not currently a management priority. Application rates of Esplanade are supposedly non-lethal to resident perennial plants, but have been shown to reduce recruitment by killing dicot and monocot germinants for two or more years (Sebastian 2017). In areas with few native perennials and in high use natural areas, this can be problematic if the site becomes bare ground for an extended time and susceptible to secondary invasion. Effective restoration protocols following application of Esplanade are largely unknown. In order to increase our knowledge of restoration options, we initiated two studies in the fall of 2018 to test different restoration strategies; one study tests planting strategies and another tests seeding strategies. Here we present preliminary results from the planting study.

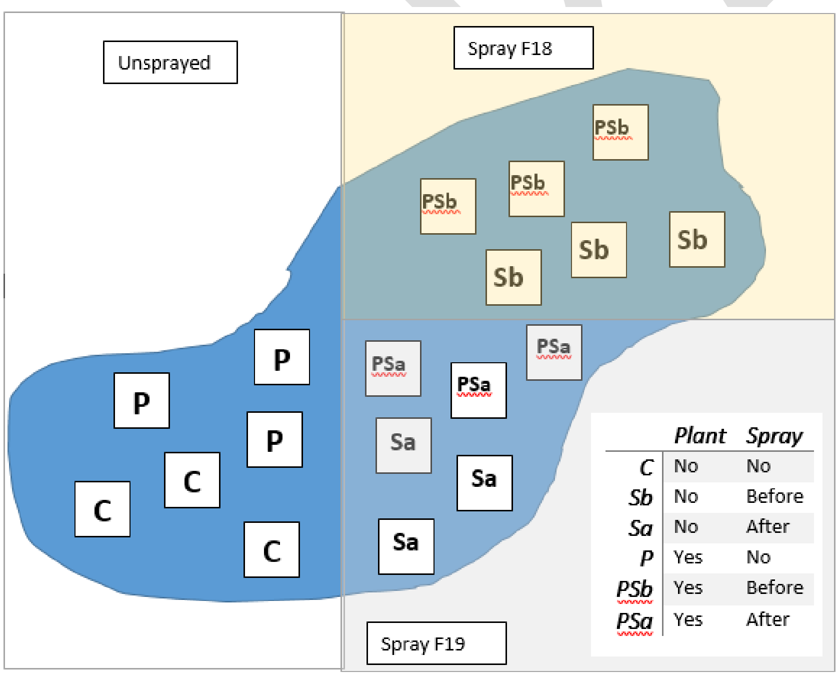


Figure 12. Schematic of the planting study experimental design and plot layout. The blue polygon represents a patch of dense ventenata. Treatment combinations are listed in the legend at the bottom right.

Methods

The objective of our planting study is to determine effective restoration strategies following the application of Esplanade in areas where few native perennials remain and ventenata and other winter annual grass cover is very dense but the overall patch is still relatively small. In the fall of 2018, we selected three sites with ventenata infestations that best fit these criteria; in the rattlesnake powerline corridor, on Mt. Jumbo, and on Mt. Sentinel. At each site, we established plots in a spilt-spilt-block design with 3 replications per treatment combination. A total of six treatment combinations were derived from two planting treatments and three herbicide treatments. In the spring of 2019, half the plots were planted with plugs of native species and the other half were left unplanted. Herbicide treatments consist of pre-emergent application of Esplanade at 5oz/acre in the fall of 2018 (before planting), in the fall of 2019 (after planting,) or no herbicide application (see Figure 12). Plots are 0.25 square meters in size. In each plot, we will track the survival and vigor of planted species, and we will measure the cover of planted species, functional groups, and ventenata each summer.

Results

By the summer of 2019, the only treatments that had been completed were the plant and spray before treatments. Thus, to simplify, we only report results from these plots and exclude the spray after plots for now. Before treatment, all plots had an average ventenata cover of 65.6% in 2018 (see Figure 13). In 2019, sprayed plots had an average of 13% ventenata cover while unsprayed had 36% cover. This represents just 63% control on ventenata. Analysis of variance indicates a significant spray treatment effect on ventenata cover (P=0.001, df=1), but no plant treatment effect or interaction effect.

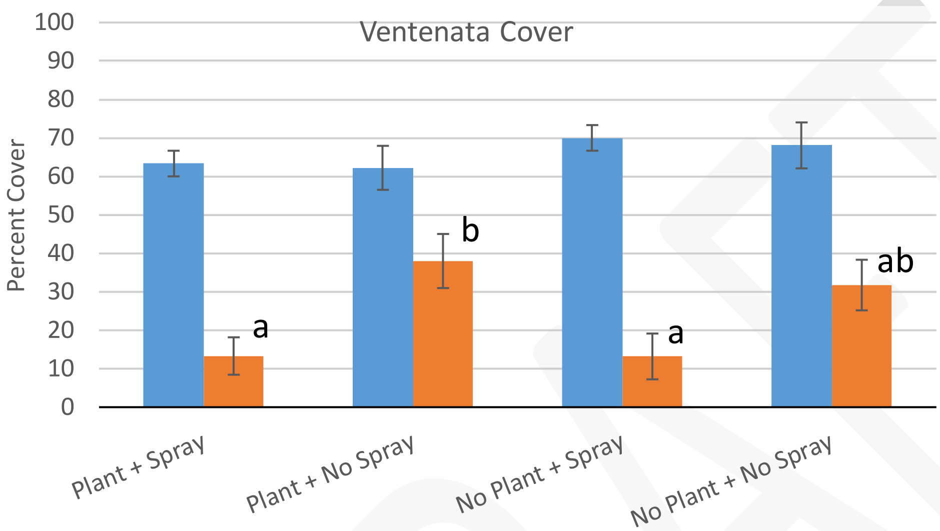


Figure 13. Shows mean Ventenata dubia cover ± standard errors for each treatment group. Blue bars represent pre-treatment data and orange bars represent post-treatment data.

Perennial grass cover also showed post-treatment differences (see Figure 14). Before treatment, all plots averaged just 3% cover of perennial grass. After treatment, perennial grass cover was significantly more in plots that were sprayed (P=0.006, df=1) or planted (P=0.01, df=1), but there was no interaction effect. Thus the effects of planting and spraying on perennial grass cover are additive for the Plant and Spray groups at least for this first year. For now, the effect of spraying appears to be greater than the effect of planting on perennial grass cover.

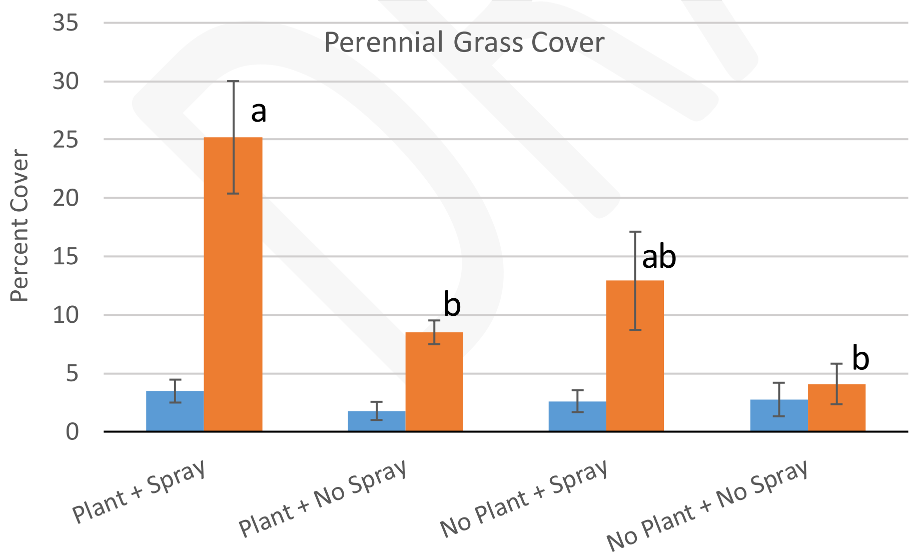


Figure 14. Shows mean perennial grass cover ± standard errors for each treatment group. Blue bars represent pre-treatment data and orange bars represent post-treatment data.

Meanwhile, the health of the planted species does not appear to be affected by herbicide application before planting. No measures of plant health, including height, vigor, and survival showed any significant differences between sprayed and unsprayed plots. Survival of planted species, for example was 87% and 89% for sprayed and unsprayed plots, respectively.

Management Implications

The results presented here are quite preliminary as we are still early in this study. In this first year, we only achieved 63% control on ventenata with Esplanade®. This is less than expected according to other studies, but we would also expect control to increase in year two. Thus far, our planted species do not appear to be affected by the herbicide. If that holds true, we would also expect to see planted species in sprayed areas begin to gain a competitive advantage over planted species in unsprayed areas. One of the questions that we hope to answer with this study design is whether it is better to spray before planting thereby giving the planted species immediate access to available resources, or to spray after planting thereby giving planted species a chance to get more established before potentially harming them with an herbicide application. We expect to have a better understanding of that question after we collect data this summer.