MERLIN RANCH

2016 Rangeland Health

Monitoring

Written By:

RANCH ADVISORY PARTNERS

EXECUTIVE SUMMARY

The Merlin Ranch monitoring effort was initiated in 2006 to track changes in rangeland health and provide information for improving grazing management decision-making. A total of 15 permanent rangeland health transects have since been established, with one of them having been newly established in 2016. In total, three monitoring sites were visited in 2016, and this document presents the findings from this effort.

The sites assessed revealed mixed results, but the trends appeared generally upward. Improvements in management since monitoring was initiated in 2006 have resulted in general reductions in bare ground, increases in litter cover, and improvements in decomposition rates. These improvements in the water and mineral cycles have led to widespread shifts in species composition, some of which were favorable (such as increases in the abundance of needleandthread and western wheatgrass) and others which were not (such as increases in cheatgrass and Japanese brome). However, improvements in the water cycle generally result in increases in both desired and undesired rangeland plant species, so these changes were indicative of shifts in the plant communities in response to basic improvements in rangeland health. Ongoing shifts in species composition should be expected over time.

2016 was, overall, a fairly good moisture year, but much of this moisture came late in autumn, and the summer was hot and dry. This resulted in slightly lower than normal levels of production and early dormancy at some sites, but plant vigor in general remained high despite this stress.

Pastures on the Merlin Ranch are particularly sensitive to early season grazing. Thus, strategies that defer spring grazing for one to two years have benefited the ranch as a whole. Further, pasture subdivisions have facilitated implementation of shorter grazing durations, longer recovery periods, and altered season of use. These strategies have been integral to the successful improvement of rangeland health across the ranch over the past decade and should be maintained.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 2
TABLE OF CONTENTS 3
INTRODUCTION & PURPOSE 4
SUMMARY OF FINDINGS & MANAGEMENT RECOMMENDATIONS 6
SUMMARY OF METHODS & DATA INTERPRETATION 8
TRANSECT PHOTOS & DATA 10
  MRT11 – 3 Section 10
  MRT23 – Lawrence 16
  MRT27 – Big Pasture 21
NUTRIENT ANALYSIS 26
APPENDIX A: DETAILED MONITORING METHODS 28
LITERATURE CITED 34
ABOUT THE AUTHORS 35

INTRODUCTION & PURPOSE

This document presents the findings from three rangeland health monitoring transects on the Merlin Ranch assessed in August 2016. Two of the transects were previously established, one in 2007 and one in 2011, and one was established in 2016. Merlin began a monitoring effort in 2006 to track changes in land health through time. Table 1 to the right displays the transects monitored by year. Using permanently marked study sites within pastures, data gathered through the years provides a permanent record of changes on the land. Data presented will show how the land has responded to changes in management, changes in precipitation, and natural phenomena such as grasshopper outbreaks. The data will also serve as the basis for making management recommendations to improve land health and overall performance of pastures.

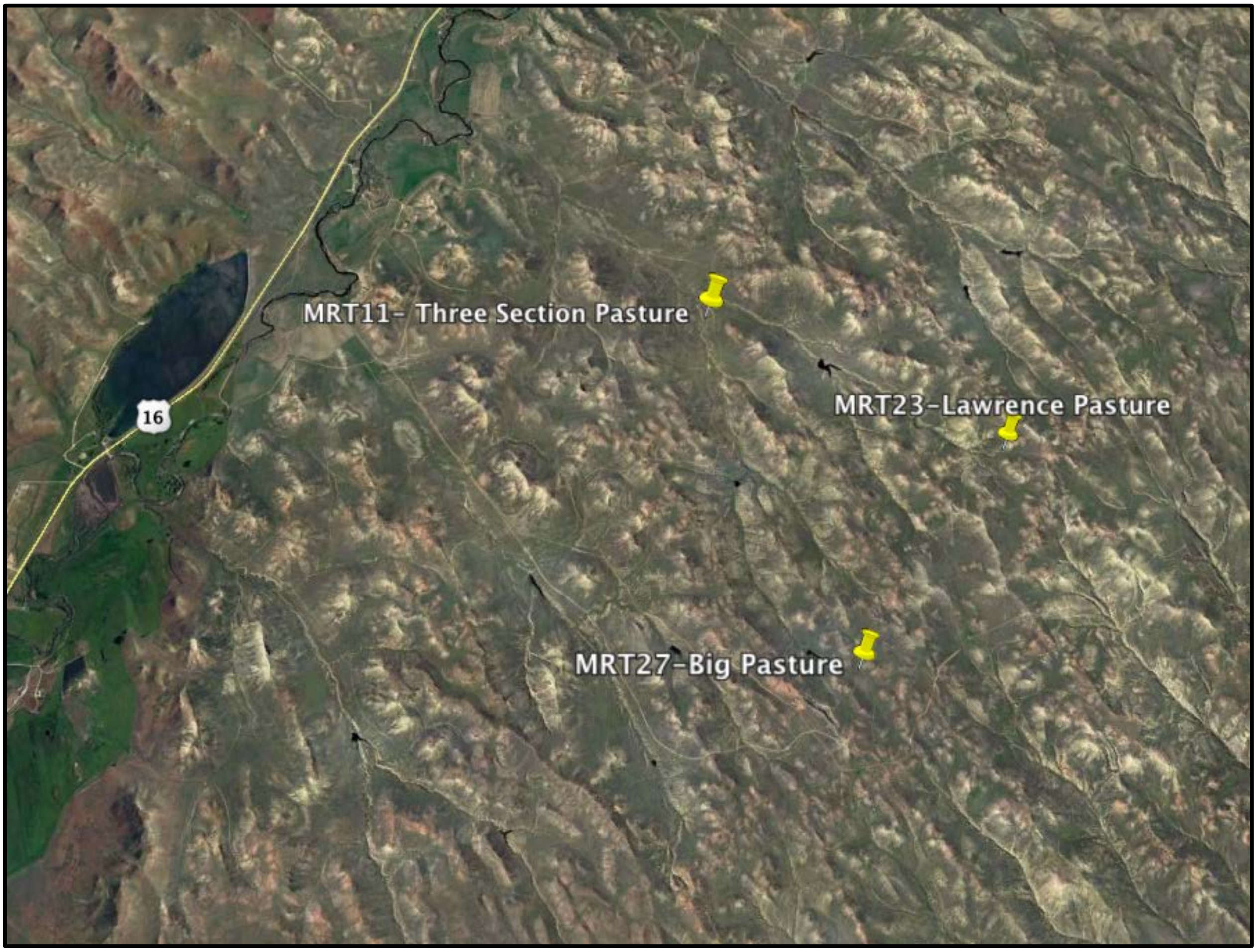
TABLE 1: Merlin Ranch Transects by Year
**indicates year transect was established*

2005 Hall Homestead* Hall Pasture*	2012 Tipperary Three Section Lower Hepp
2006 Hall Homestead Hall Pasture	2013 Hall Homestead Pigpen Lawrence Trap*
2007 Three Section* Tipperary* Hall Pasture	2014 Hall Pasture Lawrence Lower Pasture
2008 Lower Pasture* M&M #1* Pigpen*	2015 Hepp* Upper Hell's Canyon* Petrified Forest*
2009 Hall Homestead Tipperary	2016 Three Section Lawrence Big Pasture *
2010 Hall Pasture Three Section Lower Hepp*	
2011 Lower Pasture M&M#1 Lawrence*	

Much discussion will be made concerning the function of four fundamental ecosystem processes. These are the water cycle, mineral cycle, energy flow, and successional process. These are reviewed graphically in the Methods section displayed later in this document. Management may influence the function of these processes by altering such variables as stocking rate, stock density, grazing duration, recovery times between grazings, utilization rate, and timing of grazings. Data presented in this report will show how these variables interact with function of ecosystem processes, and how management may improve their interaction for the improvement of pasture performance, wildlife habitat, and profitability.

Findings will be presented with a combination of qualitative rangeland health indicators and quantitative data. Quantitative data will be used to track changes on the land as they occur through time. Qualitative indicators will provide a snapshot of land health on the day the site was sampled. Both are used to inform the management recommendations contained herein.

A map of the transect locations is provided below.


MRT11- Three Section Pasture
MRT23-Lawrence Pasture
MRT27-Big Pasture
16

SUMMARY OF FINDINGS & MANAGEMENT RECOMMENDATIONS

A short summary of the findings from the 2016 monitoring effort is provided here. See the individual site discussions for more detail.

MRT11 – 3 Section

This transect was established in 2007 in the middle of the Three Section Pasture. In the spring of 2009, the pasture was treated for sagebrush using a Lawson Renovator, which created two large treated swaths through the monitoring site. Since 2007, this site has experienced obvious improvements in the water and mineral cycles, which have resulted in ongoing shifts in species composition – some of which are desired and some undesired. Improvements in the water cycle led not only to increases in desired species like needleandthread and western wheatgrass, but also to increases in undesired species like cheatgrass. This, however, is a common initial response on rangelands to improved water and mineral cycling. The abundance of cheatgrass can be expected to decline over time as rangeland health continues to improve.

2016 marked the first year in which this pasture was split into two smaller units resulting in a reduced grazing duration (1 week per unit), lengthened recovery period and increased stock density. This was a good move on management's part. The increased stock density should further support the mineral cycle while also stimulating the successional process by creating additional germination sites for desired plants. Any opportunities to provide periodic springtime rest in this pasture will further help support the establishment and expansion of the desired grasses and forbs.

MRT23 – Lawrence

This transect was established in 2011 in an area with diverse topography and vegetation. By 2016, this site had experienced notable improvements in the water cycle resulting in some desired shifts in species composition as well as an influx in Japanese brome and cheatgrass. The mineral cycle was functional, but still slower than desired the successional process lagging a bit. This pasture is a small pasture that was grazed during the summer in both 2015 and 2016. Cows had left this pasture shortly before monitoring occurred in 2016, and utilization rates were high at around 60%, resulting in slight reductions in ecological function. However, there was nothing to indicate the pasture would not bounce back with rest and some better growing season moisture.

Management's strategy of grazing this pasture later in the growing season is a good one. Given its size, the grazing durations may need to be adjusted slightly (1/2-day increments) depending on the moisture year and forage production at the time of grazing.

Unfortunately, the Lawrence monitoring site was also established in the wet spring of 2011 atop a two-track road that went un-noticed in that year. Use of this road by people and animals appears to be influencing ground cover. This monitoring site should be moved.

MRT27 – Big Pasture

This transect was established in 2016 to track changes in the Big Pasture where management is considering additional water development and pasture subdivision into smaller units. The site showed a decent level of rangeland health with functional water and mineral cycles that both showed room for improvement. Plant species composition was moderate with an overabundance of cheatgrass and a plethora of mid-seral species, while abundance was lacking somewhat on the desired grasses and forbs.

The Big Pasture has traditionally been grazed in the summer (either early or late) with a follow-up grazing even in the early fall. The combination of early summer and early fall grazing appears to have had a detrimental effect on plant species composition. Later use in the fall and summer would be ideal, keeping grazing durations short. The prospect of adding water and dividing this pasture into smaller units would help management control grazing distribution, timing and duration to improve rangeland health over time.

SUMMARY OF METHODS & DATA INTERPRETATION

Six different monitoring methods were used to gather data and information at this monitoring site:

- Photographs
- Line-point intercept method
- Line-intercept method
- Belt transect method
- Most abundant plant by weight
- Qualitative indicators of rangeland health

Each of these is reviewed in detail in the Methods section of this document. This portion serves to highlight means of examining the data being presented.

Photographs were taken of each transect site, including one looking down the transect line's outstretched tape measure, while another looks down at a 4.8 square foot quadrat placed at the transect's 10-foot mark.

The ***line-point intercept*** method was used to gather ground cover data. Ground cover data includes all things covering the soil surface, such as bare soil, litter (dead plant material lying on the soil surface), live plant cover, rocks, gravel (particle sizes between 3 cm and 6 cm), and coarse woody debris (larger chunks of litter with a diameter of at least 7 cm). Ideally, the amount of bare ground at each site is low. Excess bare ground may suggest increased chance for soil erosion, or increased opportunity for growth by invasive plant species. Further, the percent live plant cover should be relatively high, indicating the presence of abundant, living plants with large plant bases covering the soil surface.

In contrast to the line-point intercept method, the ***line-intercept method*** measures canopy cover. This method was applied only to shrubs and used to assess the relative contributions of various shrub species to the canopy. The line intercept method was only used to assess the proportion of the plant canopy composed by shrubs. Comparisons of data across years will provide information on the expansion or contraction of shrubs at a site.

The ***belt transect method*** measures the density of shrubs per unit area. In this case, shrub density was measured per 1000 square feet. The resulting data, in combination with the line intercept data will illustrate shifts in the shrub community over time.

The ***most abundant plant species by weight*** compliments the community composition data provided by the point-intercept method. Using the 4.8 square-foot quadrat, the top five most abundant plant species by weight are estimated every 20 feet along the transect line. This method provides a picture of species composition by productive contribution.

Lastly, various qualitative ***indicators of rangeland health*** will be discussed. These qualitative indicators provide information on the health of rangelands and associated wildlife habitat. They include, but are not limited to, signs of erosion, distribution of litter across the soil surface, signs of recruitment of desired plant species, and rates of dung break-down. Many of these indicators are often linked to the Ecological Site for the area. Each Ecological Site should have an associated Ecological Site Description (ESD), denoting its expected level of ground cover, plant productivity, and plant species composition. For example, a site might be expected to have between X% and Y% bare ground, and if data revealed those parameters were met, then certain conclusions can be drawn regarding the condition of the site. Ecological Site information can be found using the Natural Resources Conservation Service's (NRCS)

Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm). For the purposed of this report, qualitative indicators of rangeland health will be presented in the format displayed in a “Bullseye Rangeland Health Target” that uses the colors of the Olympics to denote functionality of each. See Appendix A for more detail on all rangeland health monitoring methods.

TRANSECT PHOTOS & DATA

MRT11 – 3 Section

Overview

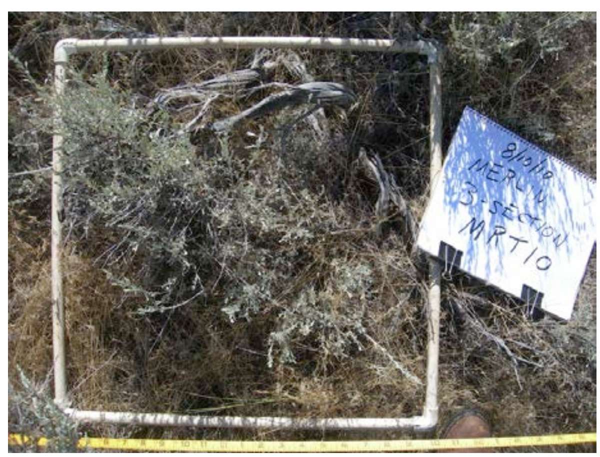
This site was established in 2007 and lies nearly in the middle of the Three Section Pasture. The pasture consists of large draws, rolling hills, and bottomland. Much of the pasture occurs in shallow loamy soils. This site was chosen due to its abundance of plant growth and species diversity relative to other reaches of the pasture. The pasture was treated with a Lawson Renovator in spring 2009, and the machine made two large swaths across the transect length.

Site Photos & Data

Transect View: Photo taken August 17, 2007

Quadrat View: Photo taken August 17, 2007

Transect View: Photo taken August 10, 2010



Quadrat View: Photo taken August 10, 2010

Transect View: Photo taken August 23, 2012

Quadrat View: Photo taken August 23, 2012

Transect View: Photo taken August 2, 2016

Quadrat View: Photo taken August 2, 2016

PLANT SPECIES FOUND IN TRANSECT AREA

2007	2010	2012	2016	
26	***27***	***15***	***19***	***Total count***
X	X	X	X	Cheatgrass
X	X	X	X	Western wheatgrass
X	X	X		Green needlegrass
X	X	X	X	Japanese brome
X	X		X	Sandberg bluegrass
X	X	X		Prairie junegrass
X	X	X	X	Needleandthread
X	X			Bluebunch wheatgrass
X	X		X	Blue grama
	X			Sixweeksgrass
X	X	X	X	WY big sagebrush
X	X	X	X	Fringed sage
	X			Greasewood
X	X			Rubber rabbitbrush
X	X			Mustard species
X	X	X	X	Scarlet globemallow
X	X		X	Salsify
X	X	X	X	Pricklypear cactus

PLANT SPECIES CONTINUED

2007	2010	2012	2016	
X	X	X	X	Western yarrow
	X			Vetch species
	X		X	Peppergrass
	X			Sego lily
X	X	X	X	Broom snakeweed
X	X			Dandelion
	X			Plains goldenaster
	X			Curlycup gumweed
3	X	X	1	Unknown perennial forb
X		X		Tanysmustard
		X		Four-wing saltbush
X				Lepidium
X			X	Hood's phlox
X				Stickseed
			X	Threadleaf sedge
			X	Winterfat
			X	Wooly plantain

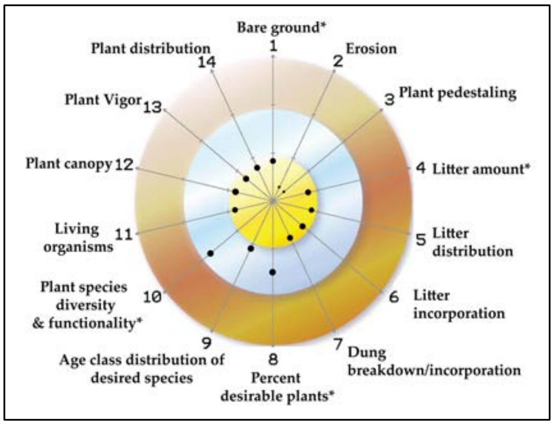
RELATIVE BASAL PLANT COVER BY SPECIES
(TOP 7 SPECIES)

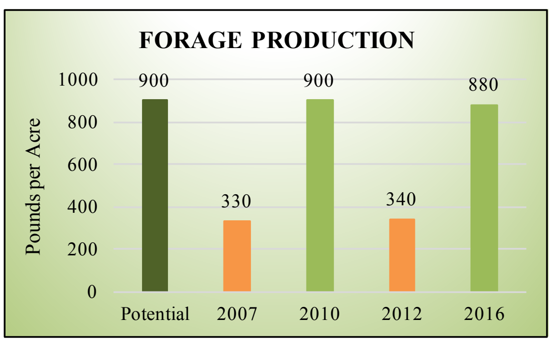
2007		2010		2012		2016	
Western wheatgrass	34%	Western wheatgrass	47%	Western wheatgrass	71%	Western wheatgrass	32%
WY big sagebrush	13%	Needleandthread	12%	WY big sagebrush	10%	Needleandthread	23%
Blue grama	10%	WY big sagebrush	11%	Prairie junegrass	8%	WY big sagebrush	22%
Sandberg bluegrass	8%	Western yarrow	8%	Green needlegrass	4%	Blue grama	12%
Kentucky bluegrass	7%	Prairie Junegrass	7%	Needleandthread	3%	Sandberg bluegrass	4%
Needleandthread	5%	Sandberg bluegrass	5%	Western yarrow	2%	Scarlet globemallow	3%
Prairie junegrass	5%	Scarlet globemallow	3%	Scarlet globemallow	1%	Western yarrow	2%

PLANT SPECIES COMP. BY WEIGHT RANKING
(TOP 5 SPECIES)

2007		2010		2012		2016	
WY big sagebrush	33%	WY big sagebrush	33%	WY big sagebrush	31%	WY big sagebrush	32%
Japanese brome	15%	Cheatgrass	15%	Western wheatgrass	23%	Western wheatgrass	23%
Green needlegrass	11%	Japanese brome	15%	Japanese brome	14%	Cheatgrass	19%
Cheatgrass	10%	Western Wheatgrass	12%	Cheatgrass	10%	Needleandthread	12%
Sandberg bluegrass	9%	Prairie junegrass	10%	Needleandthread	7%	Japanese brome	6%

BULLSEYE RANGELAND HEALTH TARGE





GROUND COVER

2007	2010	2012	2016	
16%	8%	1%	0%	Bare
79%	88%	98%	97%	Litter
5%	4%	1%	3%	Live

RELATIVE BASAL PLANT SPACING (in)

2007	2010	2012	2016
2.3	2.6	1.7	3.4

SHRUB DATA

Big Sagebrush

2007	2010	2012	2016	
Line Intercept				
43	41	41	55	***# of plants encountered***
				Age Class Distribution
0%	0%	0%	0%	seedling
0%	8%	0%	0%	young
100%	77%	95%	96%	mature
0%	15%	5%	4%	decadent
27	20	18	15	***Average plant height (in)***
29%	24%	27%	27%	***% canopy intercept***
Belt Transect				
152	135		129	***Density per 1000 sq ft***

Data Interpretation

A look at the ***Site Photos*** reveals the effects of the Lawson Renovator to the right of the transect line, where the machine made a swath through the site removing much of the big sagebrush and opening this area for increases in herbaceous production. Herbaceous production in the 2016 transect view photo appears lower than in previous years, particularly 2010. The quadrat view photos show fairly strong ground cover through the years and changes in the sagebrush morphology over time.

The ***Relative Basal Cover by Species*** data provide a look at which perennial species are dominating the soil surface. This offers a look at perennial plant species composition at the level of the soil surface, which, over time, is useful for monitoring shifts in the plant community. This site has shown steady improvements in the perennial plant species composition since its establishment in 2007. Western wheatgrass, an expected dominant perennial grass for this ecological site, has maintained its relative basal cover through time. Big sagebrush declined slightly following the Lawson Renovator treatment, and then rebounded substantially between 2012 and 2016. Perhaps most importantly, however, are the shifts in perennial species composition away from mid-seral species like prairie junegrass, Kentucky bluegrass and Sandberg bluegrass toward later seral species like needleandthread, green needlegrass and perennial forbs like scarlet globemallow. The relative basal cover of needleandthread has varied notably over the years (5% in 2007, 12% in 2010, 3% in 2012, and 23% in 2016) as the water and mineral cycle have improved and competition with other species has shifted. Green needlegrass, another very desirable species, appeared for the first time in 2012, but was absent in 2016. Similarly, blue grama, present at 10% basal cover in 2007, disappeared from this list by 2010 and did not reappear again until 2016, when it accounted for 12% of the basal cover. The reasons for these changes are not precise, but rather indicative of ongoing change at this site. In general, the trend in perennial species composition has been positive since 2007.

The ***Relative Basal Plant Spacing***, a measure of the average distance between perennial plants on the soil surface, has changed over time as well. Between 2010 and 2012 it moved in a desired direction toward tighter perennial plant spacing on the soil surface, but increased notably from 1.7 inches in 2012 to 3.4 inches in 2016. This may reflect the increase in needleandthread abundance relative to other non-bunchgrass species like western wheatgrass, which declined in relative abundance between 2012 and 2016. Sometimes an initial increase in relative basal plant spacing may be seen when sites are shifting toward a greater abundance of perennial bunchgrasses. More data are required to fully determine the trend in this metric.

The ***Predominant Species Composition by Weight*** chart shows the top five most productive species by weight at the site and offers another perspective on plant species composition. A comparison of findings for this metric between 2007 and 2016 shows several positive changes. In 2007, green needlegrass was the only truly desired species (aside from Wyoming big sagebrush) making a notable productive contribution to this site. The rest of the productive composition was accounted for by early and mid-seral species (Japanese brome, cheatgrass, and Sandberg bluegrass). However, over time, this composition has improved so that by 2016 Wyoming big sagebrush, western wheatgrass and needleandthread were among the top five most productive species at the site. During this time Japanese brome, also declined. These were all very positive changes. The continued presence of both cheatgrass and Japanese brome in this list of top five most productive species by weight speaks to their ongoing abundances overall, which was not desired. However, the shifts in species composition here suggest this site is moving in a desired direction and reductions in cheatgrass and Japanese brome may be expected over time if the trend continues.

The ***Ground Cover*** table shows that since 2002 bare ground has steadily declined to 0% while litter cover has steadily improved, indications of substantial improvements in the water cycle. The live cover readings for this site have been decent over time. Importantly, live cover results for sites with elevated rangeland health generally range from 5% - 10%. Thus, a low live cover reading does not mean that living plants were absent from the site. Rather, it is a reflection of the dominance of plants like western wheatgrass and cheatgrass that do not form broad basal areas.

The ***Shrub Data*** shows a slight increase in the number of plants encountered at this site over time, likely a reflection of the community's response to the Lawson treatment. However, the age class data reveal little in the way of recruitment taking place with most plants mature and a few decadent since 2012. This is consistent with trends in the sagebrush community observed throughout Merlin Ranch over the years. Interestingly, the number of sagebrush plants encountered on the treatment line has surpassed pre-treatment levels, and the percent canopy intercept was roughly the same. This suggests that, for sagebrush, the life span of a Lawson Renovator treatment in this area is roughly nine years. By contrast, the treatment, as well as good grazing management, continues to help improve herbaceous plant species composition substantially.

Forage Production in 2016 was up from 2012 and just slightly below the potential for the site, which was good to see. Notably, despite the fact that 2016 was a decent moisture year overall, June and July were particularly dry, which affected production. The 880 pounds per acre for 2016 was a strong finding.

The ***Bullseye*** provides an overview of rangeland condition at a specific point in time based on a visual assessment of qualitative indicators of rangeland health. Bare ground at this site was low, and no signs of erosion or plant pedestaling were observed. The amount of litter was decent (in part due to the abundance of cheatgrass and Japanese brome) and well distributed. Together, these indicators suggest a mostly effective water cycle.

As mentioned above, litter was abundant and well distributed. It was also incorporating quite well, adding organic material to the soil. Dung breakdown appeared fairly rapid with some older cowpies present, but few young ones to be found. Together, these indicators suggest that the mineral cycle was fairly rapid.

A total of 19 plant species were observed in 2016, down slightly from the 27 observed in 2010 and 26 observed in 2013. This represented a moderate level of species richness for this site and was indicative of ongoing change in species composition. The percent of species was moderate with an abundance of early and mid-seral species dominating the plant list. That said, several desired species including western wheatgrass, needleandthread, blue grama, winterfat, and scarlet globemallow were present. Cheatgrass and Japanese brome were the only outright undesired species. A shift toward a greater number of later seral grasses and forbs (like green needlegrass, bluebunch wheatgrass, Cusick's bluegrass, and perennial forbs) would be ideal over time.

Among the plant community at large, obvious age classes were present on the needleandthread, which indicated active succession. Few younger age classes were present in the big sagebrush community. Plant species diversity and functionality was lower than desired with the perennial bunchgrasses and forbs lacking abundance while cheatgrass and Japanese brome were overabundant. Together, these indicators suggest that the successional process was active, but lagging behind some of the other ecological processes.

This site clearly provided useful habitat for a variety of organisms including deer, antelope, raptors, rodents, songbirds and insects.

The plant canopy was high and still photosynthetically active, despite the dry summer. Plant vigor was also high with needleandthread having gone to seed, western wheatgrass still green and growing, and leaders on the sagebrush pushing 4-6 inches. Plant distribution was fairly uniform across the soil surface. These indicators suggest that the flow of energy through the system was effective.

Management Recommendations

The Three Section Pasture has historically been grazed for 2-3 weeks in the spring followed occasionally by a short graze in the fall. 2016 represented the first year in which this pasture was split into two smaller units, which brought the grazing duration down to one week in each unit. This was a good move that should help lengthen recovery periods and minimize durations during that sensitive spring growth period for plants. Management has considered splitting this pasture one more time if possible. This would be recommended to further increase stock density, shorten grazing durations, and add flexibility to the season of use. Any opportunity to provide springtime rest in this pasture will help support the establishment and expansion of desired perennial bunchgrasses, which are particularly sensitive to early season grazing. When using this pasture in the spring, grazing durations should be kept short and utilization rates light to moderate.

Early Warning Indicators

Grazing managers require a feedback mechanism to determine if management actions are being properly implemented. That mechanism comes in the form of early-warning indicators. Such indicators are the earliest signs that course corrections are required, and may be contrasted to late-warning indicators, which tend to require more time consuming and costly corrections.

If management practices move rangeland health in a positive direction, look first for maintained high plant vigor even in dry years. Next, look for shifts in species composition that favor greater species richness and abundance in the desired perennial bunchgrasses like needleandthread and green needlegrass, as well as declines in undesired species like cheatgrass and Japanese brome.

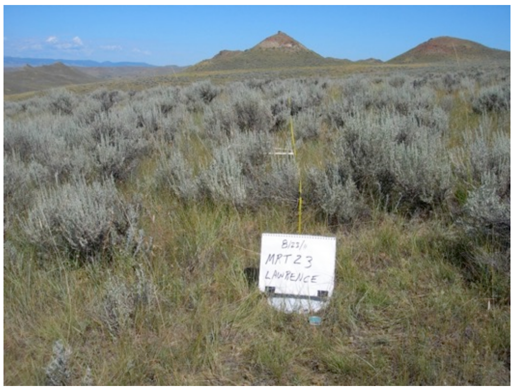
If management practices move rangeland health in a negative direction, look first for reductions in plant vigor, suggesting that utilization rates are too high and/or grazing durations too long. Next, look for increases in bare ground. Finally, look for shifts in species composition that favor undesired and mid-seral species like cheatgrass, Japanese brome, Kentucky bluegrass, Sandberg bluegrass, prairie junegrass, and sixweeksgrass.

MRT23 – Lawrence

Overview

This transect was established in 2011 in an open bowl of the Lawrence Pasture not far from the pasture boundary fence and close to stockwater. This portion of the pasture contained mixed plant cover, including steeper slopes, small flats, areas with light sagebrush cover, and areas with dense sagebrush. This transect was specifically chosen to lie in an area that contained a mix of grasses, forbs, and shrubs.

Site Photos & Data



Transect View: Photo taken August 10, 2011

Quadrat View: Photo taken August 10, 2011

Transect View: Photo taken August 13, 2014

Quadrat View: Photo taken August 13, 2014

Transect View: Photo taken August 2, 2016

Quadrat View: Photo taken August 2, 2016

PLANT SPECIES FOUND IN TRANSECT AREA

2011	2014	2016	
27	*20*	*21*	***Total count***
X			Allium species
X	X	X	Big sagebrush
X	X	X	Blue grama
X	X	X	Bluebunch wheatgrass
X	X	X	Broom snakeweed
X	X	X	Cheatgrass
		X	Crested wheatgrass
X			Dandelion
	X		Flax
X	X	X	Fringed sage
X	X		Green needlegrass
	X	X	Hood's phlox
X	X	X	Japanese brome
		X	Long-leaf phlox
		X	Lupine
X			Mushroom
		X	Needleandthread
X			Needleleaf phlox
X	X	X	Peppergrass
X	X		Prairie junegrass
X	X	X	Pricklypear cactus
X	X	X	Salsify
X	X	X	Sandberg bluegrass
X	X	X	Scarlet globemallow
X			Sego lily
X			Showy fleabane
X			Second fleabane species
		X	Tansymustard
X	X		Threadleaf sedge
1	1	1	Unknown perennial forb
X			Vetch Species
X	X	X	Western wheatgrass
X	X	X	Western yarrow
X			Winterfat

SHRUB DATA

Big Sagebrush

2008	2014	2016	
Line Intercept			
45	39	33	***# of plants encountered***
			Age Class Distribution
0%	0%	0%	seedling
0%	0%	3%	young
82%	87%	88%	mature
18%	13%	9%	decadent
17	16.7	14	***Average plant height (in)***
25%	24%	18%	***% canopy intercept***
Belt Transect			
99	87	108	***Density per 1000 sq ft***

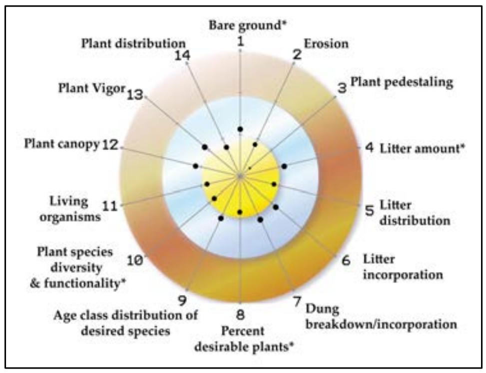
RELATIVE BASAL PLANT COVER BY SPECIES (TOP 7 SPECIES)

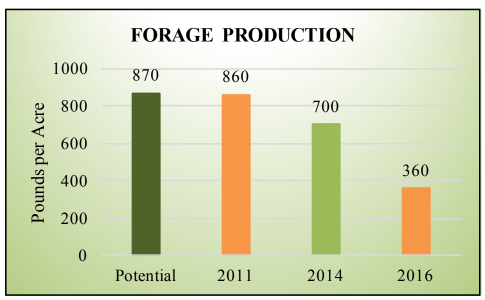
2011		2014		2016	
Western wheatgrass	33%	Western wheatgrass	52%	Western wheatgrass	39%
Green needlegrass	17%	Sandberg bluegrass	19%	Bluebunch wheatgrass	30%
Needleleaf phlox	12%	Big sagebrush	9%	Big sagebrush	17%
Sandberg bluegrass	11%	Hood's phlox	7%	Scarlet globemallow	4%
Big sagebrush	7%	Scarlet globemallow	4%	Hood's phlox	3%
Bluebunch wheatgrass	5%	Green needlegrass	2%	Blue grama	2%
Needleandthread	4%	Prairie junegrass	2%	Needleandthread	2%

PLANT SPECIES COMP. BY WEIGHT RANKING (TOP 5 SPECIES)

2011		2014		2016	
Big sagebrush	24%	Big sagebrush	23%	Western wheatgrass	28%
Green needlegrass	23%	Western wheatgrass	22%	Big sagebrush	20%
Western wheatgrass	13%	Green needlegrass	9%	Japanese brome	15%
Japanese brome	7%	Bluebunch wheatgrass	9%	Needleandthread	8%
Vetch species	6%	Japanese brome	9%	Cheatgrass	7%

BULLSEYE RANGELAND HEALTH TAI





GROUND COVER

2011	2014	2016	
8%	9%	5%	Bare
82%	87%	89%	Litter
10%	4%	6%	Live

RELATIVE BASAL PLANT SPACING (in)

2011	2014	2016
1.2	2.1	3.2

Data Interpretation

A look at the ***Site Photos*** reveals good plant canopy and ground cover in 2011 and 2014. This pasture was grazed in late July 2016, shortly before monitoring took place. The 2016 transect view photo shows overly high utilization rates, and as a result, less ground cover in the quadrat view photo. The heavier utilization rates will affect the plant species composition by weight figures described below.

The ***Relative Basal Cover by Species*** data provide a look at which perennial species are dominating the soil surface. This offers a look at perennial plant species composition at the level of the soil surface, which, over time, is useful for monitoring shifts within plant communities. Since this transect was established in 2011, western wheatgrass has maintained its relative dominance on the soil surface. This is to be expected for this site according to the Ecological Site Description. Ongoing shifts in relative perennial plant cover by species reflects continued changes at this site in response to change in management and slow improvements in the water and mineral cycles. Wyoming big sagebrush has steadily increased its relative basal abundance over time. Green needlegrass has steadily declined in basal abundance since 2011 and was absent from this list in 2016. At the same time, bluebunch wheatgrass, which was the sixth most basally abundant plant in 2011, disappeared from this list in 2014, but came roaring back in 2016 to account for 30% of the relative perennial cover on the soil surface. Needleandthread followed a similar, though less pronounced pattern, disappearing in 2014 and reappearing in 2016, though it only accounted for 2% of the relative basal cover. Overall, the list of species dominating the soil surface in 2016 was favorable, but ongoing shifts in relative abundance should be expected to continue.

The ***Relative Basal Plant Spacing***, a measure of the average distance between perennial plants on the soil surface, has steadily increased since 2011. This represents a trend in the wrong direction, but may also reflect positive changes in perennial plant species composition toward a greater abundance of perennial bunchgrasses, like bluebunch wheatgrass. Further years of data will reveal whether this trend continues in the same direction or reverses.

The ***Predominant Species Composition by Weight*** chart shows the top five most productive species by weight at the site and offers another perspective on plant species composition. A comparison of findings for this metric between 2011 and 2016 shows mixed results, but overall reflect improvements in the water cycle. On the one hand, desired species like green needlegrass and bluebunch wheatgrass disappeared from this list by 2016 (they likely were selected by cattle in the recent grazing event), while Japanese brome and cheatgrass increased their relative productive contributions. On the other hand, cheatgrass and Japanese brome often increase in abundance after initial improvements in the water cycle, and these changes were accompanied by increases in the desired needleandthread and western wheatgrass. Ongoing changes in the relative productive composition of the plant community should be expected.

The ***Ground Cover*** table shows that bare ground declined between 2014 and 2016 despite the high utilization rate in 2016, which was a good sign. Similarly, the amount of litter has improved steadily since 2011, though room for improvement still existed. The live cover reading in 2016 was 6%, another positive result. Altogether these findings indicate that the water cycle was improving and was moderately effective in 2016.

The ***Shrub Data*** show a steady decline in the number of plants encountered since 2011. The number of mature plants has remained relatively constant, while the number of decadent plants has declined, and the number of young plants increased. The increase in young plants may explain the increase in density per 1,000 square feet despite the reduction in percent canopy intercept and number of plants encountered along the transect line itself. These data suggest that slow turnover was taking place within the big sagebrush community.

Forage Production at this site dropped off sharply in 2016 reflecting the high utilization rates resulting from the grazing event that occurred shortly before it was monitored. The dry summer also meant that plants were not able to recover as much as they normally would under better conditions.

The ***Bullseye*** provides an overview of rangeland condition at a specific point in time based on a visual assessment of qualitative indicators of rangeland health. The amount of bare ground at this site was low, but still showed room for improvement. No sign of water erosion was present and only very minor signs of wind erosion in the form of minor plant pedestaling was observed. The amount of litter was decent, but also showed room for improvement and litter distribution was good. These findings indicate that the water cycle was functional, but not yet as effective as desired.

As mentioned above, litter cover was decent and well distributed. It was also incorporating moderately well showing itself to be in contact with the soil surface, but not mixing with the soil as desired. Dung breakdown rates appeared a bit slower than desired. Since the cows had recently come out of this pasture at the time of monitoring, fresh cowpies were abundant, but older ones were also observed. Together, these indicators suggest that the mineral cycle was moderately rapid.

A total of 21 plant species was observed in 2016, down from the original finding of 27 in 2011. In 2016, many forbs species that had previously been observed were absent, as was the desired green needlegrass. That said, overall species richness was decent and the percent of species that were desired was fairly high. Only cheatgrass and Japanese brome were undesired. Not many younger age classes were observed on the big sagebrush, which has been the trend on this ranch. Few younger age classes were observed on the perennial bunchgrasses as well. Plant species diversity and functionality was decent, with good abundance of perennial grasses like needleandthread, bluebunch wheatgrass, and western wheatgrass, but lower forb diversity. Together, these findings suggest that the successional process was lagging.

This site clearly provided useful habitat for a variety of organisms. Sign of deer, rabbits, birds and insects were observed.

The plant canopy was moderate, in part because cows had recently come out of this pasture and utilization rates were on the high side. Plant vigor was also moderate for similar reasons. The hot, dry summer meant many species were already going dormant at the time of grazing and therefore showed little recovery following the grazing event. That said, some of the grasses had produced seed and achieved a decent stature despite the dry year. The big sagebrush appeared to be struggling and leader lengths were somewhat short, though sign of deer in the area was abundant and this may have reflected browse pressure. Plant distribution was fairly uniform. Altogether, these observations indicate that the flow of energy through the system was moderate, but should recover quickly with better moisture and more moderate utilization rates.

Management Recommendations

The Lawrence Pasture is a small pasture. It was grazed for short durations (a week or less) in the summer of 2015 and then in late July of 2016. The timing of using this pasture later in the growing season is a good strategy that provides the desired bunchgrasses ample growth opportunity during the fast growth period in early spring and summer. Utilization rates in 2016 were at roughly 60%, which was a bit high. Management can make slight adjustments to the grazing duration (e.g. ½-day increments) at the time of grazing depending on forage availability and precipitation. The small size of this pasture makes small adjustments to durations very meaningful.

This monitoring site was established in the wet spring of 2011 in a good growth year. At that time, it was unknown that a two-track road crosses the transect line, at roughly the transect beginning point. The road is not visible in the transect view photos above, but it runs perpendicular to the transect line near where the photos are taken. Since this road is actively used (albeit not often) by both vehicles and livestock, this transect should be abandoned, and a new one should be established elsewhere in the pasture.

Early Warning Indicators

Grazing managers require a feedback mechanism to determine if management actions are being properly implemented. That mechanism comes in the form of early-warning indicators. Such indicators are the earliest signs that course corrections are required, and may be contrasted to late-warning indicators, which tend to require more time consuming and costly corrections.

If management practices move rangeland health in a positive direction, look first for maintained high plant vigor even in dry years. Next, look for reductions in bare ground and erosion. Finally, look for shifts in species composition toward a greater abundance of green needlegrass, needleandthread, and Cusick's bluegrass accompanied by reductions in cheatgrass and Japanese brome.

If management practices move rangeland health in a negative direction, look first for reductions in plant vigor, suggesting that utilization rates are too high and/or grazing durations too long. Next, look for increases in bare ground and erosion. Finally, look for shifts in species composition toward lower species richness and greater dominance by early to mid-seral species like cheatgrass, Japanese brome, Kentucky bluegrass, prairie junegrass and even blue grama mats.

MRT27 – Big Pasture

Overview

The Big Pasture is being considered for additional water development and associated subdivision using high tensile electric or polywire fencing. This transect was established in 2016 to track changes in rangeland health in response to changes in management. The transect lies in a fairly flat spot surrounded by hills and dominated by big sagebrush.

Site Photos & Data

Transect View: Photo taken August 2, 2016

Quadrat View: Photo taken August 2, 2016

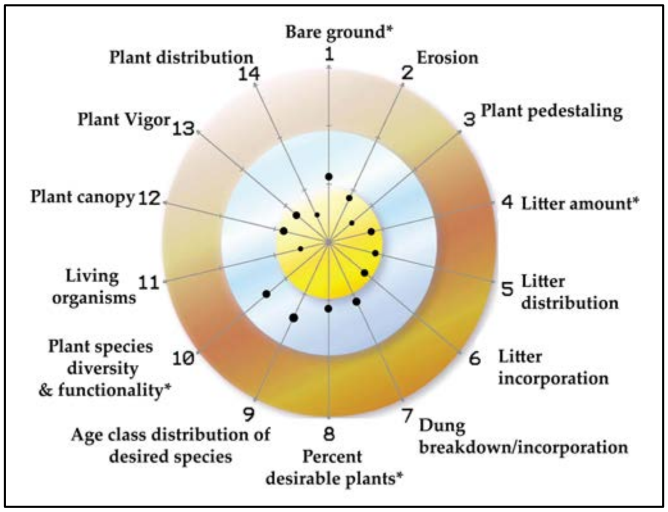
PLANT SPECIES FOUND IN TRANSECT AREA

2016	
21	***Total count***
X	Blue grama
X	Broom snakeweed
X	Cheatgrass
X	Cudweed sagewort
X	Fanweed
X	Fringed sage
X	Hood's phlox
X	Japanese brome
X	Needleandthread
X	Pennycress
X	Peppergrass
X	Pricklypear cactus
X	Sandberg bluegrass
X	Scarlet globemallow
X	Silver sagebrush
X	Threadleaf sedge
X	Vagrant lichen
X	Western wheatgrass
X	Western yarrow
X	Wooly plantain
X	Wyoming big sagebrush

RELATIVE BASAL PLANT SPACING BY TOP 7 SPECIES

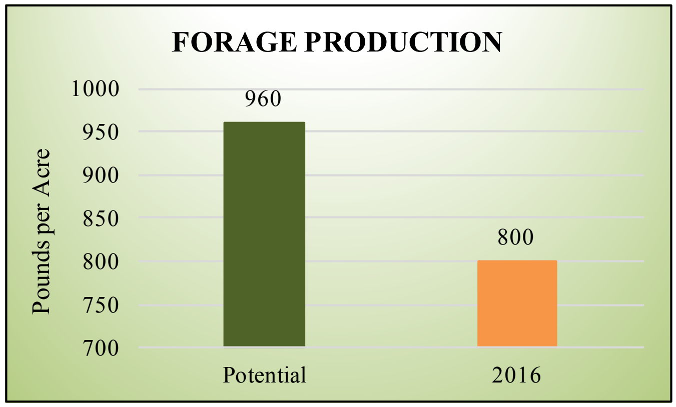
2016	
Western wheatgrass	55%
Sandberg bluegrass	14%
Wyoming big sagebrush	6%
Needleandthread	6%
Scarlet globemallow	6%
Prairie junegrass	4%
Blue grama	2%

BULLSEYE RANGELAND HEALTH TARGET



PLANT SPECIES COMP. BY WEIGHT RANKING (TOP 5 SPECIES)

2016	
Wyoming big sagebrush	30%
Western wheatgrass	16%
Needleandthread	15%
Cheatgrass	12%
Fringed sagewort	11%



SHRUB DATA

Big Sagebrush Data

2016	
Line Intercept	
30	***# of plants encountered***
	Age Class Distribution
0%	seedling
0%	young
90%	mature
10%	decadent
15.5	***Average plant height (in)***
22%	***% canopy intercept***
Belt Transect	
130	***Density per 1000 sq ft***

GROUND COVER

2016	
3%	Bare
95%	Litter
2%	Live

RELATIVE BASAL PLANT SPACING (in)

2016
2.4

Data Interpretation

A look at the ***Site Photos*** shows the abundance of Wyoming big sagebrush at this site. In the transect view photo, the herbaceous canopy appears moderate and largely dormant by early August. The quadrat view photo shows little bare ground and decent litter cover, but also highlights the low herbaceous stature at this site.

The ***Relative Basal Cover by Species*** data provide a look at which perennial species are dominating the soil surface. This offers a look at perennial plant species composition at the level of the soil surface, which, over time, is useful for monitoring shifts in relative plant dominance. In 2016, western wheatgrass was the most basally abundant plant, followed by Sandberg bluegrass, Wyoming big sagebrush, needleandthread, scarlet globemallow, prairie junegrass and blue grama. Overall this represents a decent composition of perennial species, but room for improvement is also apparent. The dominance of western wheatgrass is to be expected, as is the abundance of big sagebrush. Ideally, however, needleandthread will expand to replace Sandberg bluegrass, a less desired mid-seral species that tends to cure out early in the growing season even in good moisture years. Similarly, it would be ideal to see the prairie junegrass replaced by another high value grass like green needlegrass or bluebunch wheatgrass.

The ***Relative Basal Plant Spacing***, a measure of the average distance between perennial plants on the soil surface, was 2.4 inches in 2016. This was a moderate finding with room for improvement. Ideally, this number will fall over time with improvements in the water cycle and tightened spacing between perennial plants.

The ***Predominant Species Composition by Weight*** chart shows the top five most productive species by weight at the site and offers another perspective on plant species composition. As expected, silver sagebrush and western wheatgrass dominated this metric. Favorably, needleandthread was the third most productive plant by weight, but cheatgrass and fringed sage ranked fourth and fifth in this metric, which was not desirable. Ideally, green needlegrass, bluebunch wheatgrass and/or a forb like lupine will move in to replace the cheatgrass and fringed sagewort over time.

The ***Ground Cover*** table shows that bare ground was 3%, litter cover 95% and live cover 2%, all positive findings that indicated functionality in the water cycle.

The ***Shrub Data*** shows 30 big sagebrush plants were encountered along the transect line accounting for 22% of the canopy intercept. Ninety percent of these plants were mature and 10% decadent, conforming to the traditional pattern of slow decline in sagebrush communities witness across the ranch for several years.

Forage Production in was 160 pounds per acre below the potential, which was not bad given the hot, dry summer.

The ***Bullseye*** provides an overview of rangeland condition at a specific point in time based on a visual assessment of qualitative indicators of rangeland health. Bare ground at this site was not bad, but still showed room for improvement. No sign of water erosion and only signs of very minor wind erosion in the form of minor plant pedestaling were observed. The amount of litter was decent, but partly due to the abundance of cheatgrass, and fairly well distributed across the site. Together, these findings suggest that the water cycle was mostly effective.

As mentioned above, litter was abundant and well distributed. It was also in contact and mixing with the soils indicating decent incorporation. Dung breakdown appeared a bit slow with mostly older cowpies present. These findings indicate that the mineral cycle was moderately rapid.

A total of 21 plant species was observed in 2016 representing a decent level of species richness. The percent of species that were desirable was moderate overall with a fair number of mid-seral species, in addition to the undesired cheatgrass and Japanese brome, composing the list. Few age classes were observed on either the grasses or shrubs. Plant species diversity and functionality was moderate with both the desired grasses and perennial forbs lacking in abundance, and cheatgrass overly abundant. Together these indicators suggest that the successional process was lagging.

This site clearly provided useful habitat for a variety of organisms including deer, rodents, rabbits, and birds.

The plant canopy was moderate with most of the grasses having gone dormant due to the hot, dry summer. Plant vigor was lacking a bit. Few seedheads were seen on the needleandthread and none on the western wheatgrass, though leaders on the big sagebrush were pushing 3-5 inches. Plant distribution was even. These findings indicate that the flow of energy through the system was functional, but also stood to be improved with improvements in the water and mineral cycles.

Management Recommendations

The Big Pasture is traditionally grazed in the summer (either early summer or late summer) and sometimes grazed again in the fall. Management has utilized salt to create herd effects, but control over grazing distribution, stock density, and grazing durations is constrained by limited water (this large pasture has only two big tanks) and the overall size of the pasture. In an ideal scenario, management would like to develop additional water in this pasture and break it into smaller units using temporary or high tensile electric fence. This would substantially increase management's capacity to control grazing in ways that could improve rangeland health over time.

In the meantime, the findings above suggest that the combination of early summer and early fall grazing in this pasture may be having a detrimental effect on species composition. Thus, if this pasture is used again in the fall, management should try to wait until later fall after the autumn rains create a burst of growth in vegetation and keep durations short. Similarly, focus on an altered season of use to provide periodic early summer rest. Use of mineral or salt to help distribute cattle through the pasture is a good strategy worth continuing.

Early Warning Indicators

Grazing managers require a feedback mechanism to determine if management actions are being properly implemented. That mechanism comes in the form of early-warning indicators. Such indicators are the earliest signs that course corrections are required, and may be contrasted to late-warning indicators, which tend to require more time consuming and costly corrections.

If management practices move rangeland health in a positive direction, look first for maintained high plant vigor even in dry years. Next, look for reductions in bare ground and erosion. Finally, look for shifts in species composition toward less cheatgrass and more needleandthread, bluebunch wheatgrass, green needlegrass and perennial forbs.

If management practices move rangeland health in a negative direction, look first for reductions in plant vigor, suggesting that utilization rates are too high and/or grazing durations too long. Next, look for increases in bare ground and erosion. Finally, look for shifts in species composition toward lower species richness and greater dominance by early to mid-seral species like cheatgrass, Japanese brome, Kentucky bluegrass, prairie junegrass, and Sandberg bluegrass.

NUTRIENT ANALYSIS

At each of the three sites, a single plot of forage was clipped to determine above-ground productivity. Material taken from this clipping was saved and used to determine nutrient content of the plants. The sample was first sorted to remove species like sagebrush that cattle would not graze, and the samples were sent to Midwest Labs in Omaha, NE for nutrient analysis. The following table displays the dry-matter nutrient content of each of the samples in 2016.

Nutrient	Big Pasture	Lawrence	3 Section
Crude Protein (%)	6.86	7.55	7.11
Acid Detergent Fiber (%)	43.3	45.6	47.4
Total Digestible Nutrients (%)	53.1	50.6	48.5
Net energy-lactation (Mcal/lb)	0.54	0.51	0.49
Net energy-maintenance (Mcal/lb)	0.51	0.48	0.45
Net energy-gain (Mcal/lb)	0.28	0.26	0.24
Sulfur (%)	0.11	0.12	0.11
Phosphorus (%)	0.12	0.13	0.12
Potassium (%)	1.09	0.98	0.7
Magnesium (%)	0.1	0.09	0.11
Calcium (%)	0.48	0.55	0.51
Sodium (%)	none taken	none taken	none taken
Iron (ppm)	217	379	335
Manganese (ppm)	33.6	56.1	74.3
Copper (ppm)	3.9	4.2	3.5
Zinc (ppm)	22.4	20.8	28.1

A glance at the table above shows that none of the trace minerals occurred at toxic levels. As is typical in the Rocky Mountain West, some, particularly phosphorus, zinc, and copper, were low.

A comparison of the nutrients provided by each pasture against the needs of an 1100-pound lactating cow is provided in the table below. The plants were collected in early August in a year that was overall above average in precipitation, but experienced a hot, dry summer. The nutrient requirements for a 1100-pound lactating cow of average milking ability were drawn from Nutrient Requirements of Beef Cattle tables (NRC, 1984).

Nutrient Requirements vs. Nutrient Actuals

	Dry Matter	*Crude Protein*	*TDN*	*Ca*	*P*	*Ca:P Ratio*
1100-lb Lactating Cow	21.6#	2#	12.1#	27g	22g	1:1
Big Pasture	21.6#	1.5#	11.5#	47g	12g	4:1
Lawrence	21.6#	1.6#	10.9#	54g	13g	4:1
3 Section	21.6#	1.5#	10.5#	50g	12g	4:1

Assuming our example cow meets her dry matter requirements, all pastures were short on crude protein. Similarly, all pastures were shy on Total Daily Nutrients. All pastures exceeded the necessary calcium requirements, which is the norm on the Merlin Ranch. Phosphorous, which is critical to reproduction in cows, was most favorable in the Lawrence Pasture, but still a fair bit below the desired 22 grams.

The calcium to phosphorous ratio is important because calcium has a tendency to make phosphorous unavailable in a cow's system. Ratios that exceed 7:1 can therefore result in health problems like open cows. All of the pastures displayed calcium to phosphorous ratios of four to one, well within the safe zone.

Nutrient Management Recommendations

Analysis of the sample nutrients serves as a guide for management when considering nutritional factors as they relate to livestock performance. That being said, the analysis is intended to be a "shotgun" approach to livestock performance, rather than a precise science. Simply put, livestock have access to a variety of forage sources in each of these pastures, and not just forage from the sample sites. Further, seasonal variations in nutrient content of forage are normal. This provides variety in the diet and likely meets the cow's needs, including those critical crude protein levels.

The Merlin Ranch also moves its livestock through a series of pastures during the course of the growing season, providing cattle with fresh feed sources on a regular basis. This action in itself presents the best means of meeting the needs of the lactating cows.

If livestock performance is lacking, once calves are weaned in the dormant season, management may place dry cows on the hay meadows that were irrigated all season. Nutrient content of these plants should be higher than the rangeland plants. Once hay feeding begins, much of the cow's daily nutrient requirements should be met, and the cow will rebuild body condition.

Lastly, to meet the needs of the herd, management may take more aggressive actions, such as weaning calves earlier. If performance suffers and cow longevity is also an issue, then the calf may be weaned so the body condition of the cow may be replenished more readily. Only pursue this option if cow performance is an issue.

APPENDIX A: DETAILED MONITORING METHODS

The same suite of monitoring methods was repeated at each monitoring site visited during the summer 2016 monitoring effort. A 200-foot tape measure, laid along the soil surface, served as the basis of the monitoring protocol, and represented the transect line. A five-gallon bucket lid was nailed to the soil surface to permanently mark the beginning point of each transect (Figures 1).

FIGURE 1: *An example of the type of five-gallon bucket lid used to mark the beginning of each transect line.*

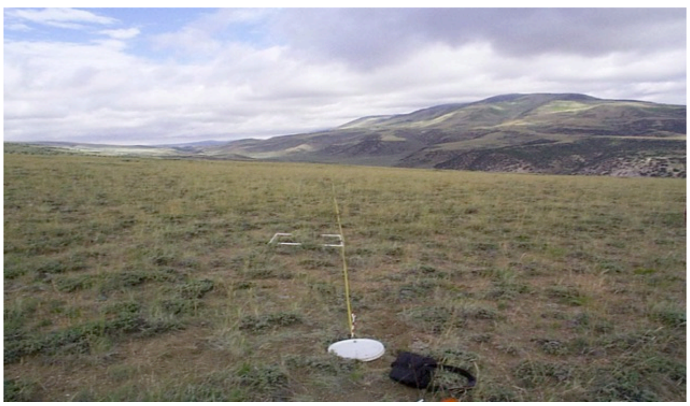


FIGURE 2: *An example of a permanent, 200-ft transect. Note the bucket lid marking the beginning point.*

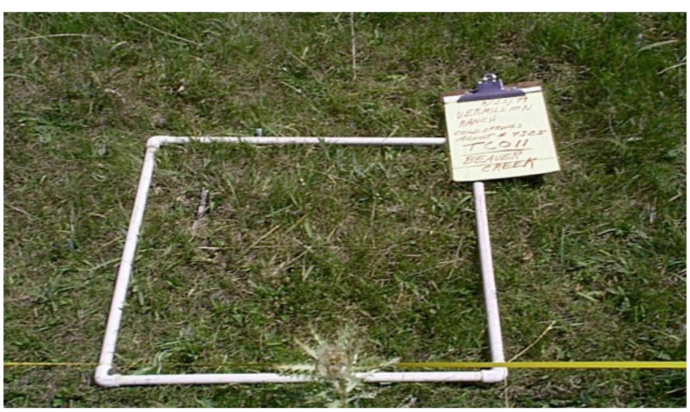


FIGURE 3: *An example of a quadrat plot with the left-hand, lower corner aligned with the 10-meter mark on the tape.*

Photographs of each transect (Figure 2), as well as of a 4.8 square foot quadrat placed at the 10-foot mark along the transect (Figure 3) were taken at each site.

Each assessment began with a qualitative examination of rangeland health using the Bullseye method developed by Gadzia & Graham (2009). This approach was based on several valuable sources, but one worthy of mention here is the 1994 report *Rangeland Health* by the National Research Council. This report defined rangeland health as the degree to which the integrity of the soil and the ecological processes of rangeland ecosystems are sustained. Range in good health produces more forage and better wildlife habitat, while watershed condition is improved, resulting in more stable stream flows and higher water quality (NRC, 1994). Healthy range generally supports more plant and animal diversity and provides greater ecological stability in terms of productivity and population flux.

The qualitative rangeland health indicators used in this initial assessment describe functionality in four fundamental ecosystem processes: the water cycle, mineral cycle, successional process, and energy flow.

An effective water cycle requires covered soil and high biodiversity. When effective, most water soaks into soils quickly where it falls, without running off. Later, this moisture is released slowly through plants that transpire it, or through rivers, springs, and aquifers that collect through seepage what the plants don't use. When biodiversity is reduced and soils

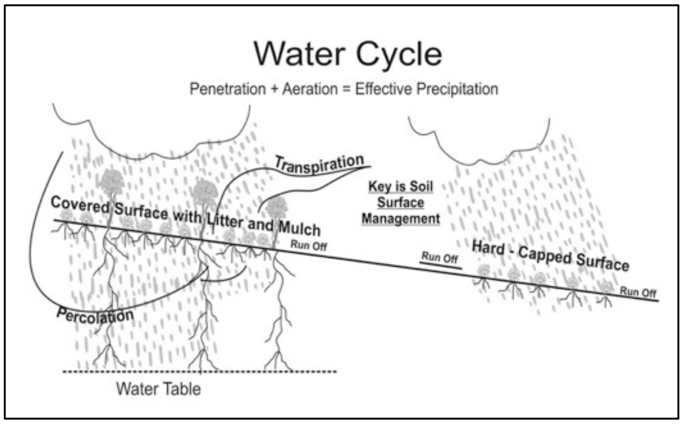


FIGURE 4: *A visual of the water cycle.*

exposed, much water runs off the soil surface. What little soaks in is released rapidly from evaporation which draws moisture back up through the soil surface (Figure 4; Savory, 1993).

The water cycle was described as either "effective," or "ineffective." If the water cycle was described as effective, then precipitation appeared to be moving into the soil and evaporation from the soil surface was minimal. Conversely, sites with an ineffective water cycle displayed signs of water leaving the site, such as erosion, plant pedestaling, and soil capping.

Like the water cycle, an effective and rapid mineral cycle requires covered soil and high biodiversity. When effective, many nutrients cycle continuously between living plants and living soil. When soil is exposed and biodiversity low, nutrients become trapped at various points in the cycle, or are lost to wind and water erosion (Figure 5; Savory, 1993).

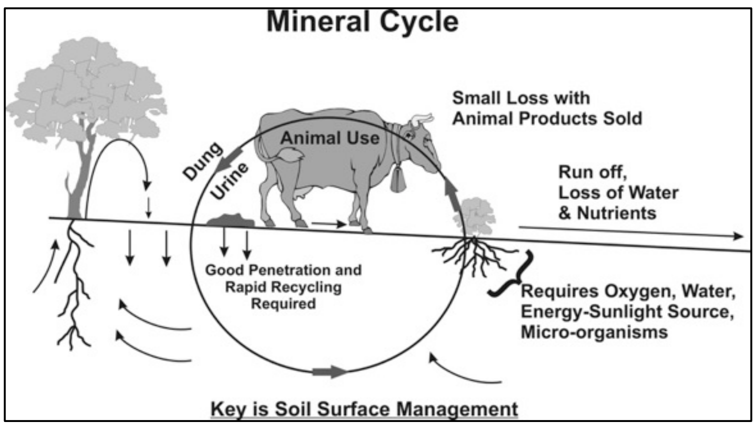


FIGURE 5: *A visual of the mineral cycle.*

In the monitoring report, the *speed* of the mineral cycle was described. If the cycle was moving slowly, then nutrients were not moving back into the system. An indicator of this would be past years' plant growth (known as litter) either elevated above the soil surface or lying idly on the soil surface and showing signs of oxidation rather than decomposition. Ideally, litter should contact the soil surface where soil-borne organisms of decay may begin to break it down and speed the re-utilization of nutrients in the system.

With few exceptions, ecological communities tend to cycle through processes of building complexity in response to disturbances, which tend to reduce complexity. From unstable bare ground, where biodiversity is low, stable complex range or forest communities, high in biodiversity tend to develop over time (Figure 6; Savory, 1993). This is succession.

The plant communities composing a site help characterize past management actions as well as shape current expectations for land and livestock performance. Thus, in this monitoring report, plant community composition was described and classified as high seral (meaning desirable), mid seral (neither desired nor undesired), and low seral (weedy or less desired). Importantly, indicators like the presence of seedlings and young plants of different species represent early changes in plant communities likely to become evident in coming years. Such observations further inform management expectations.

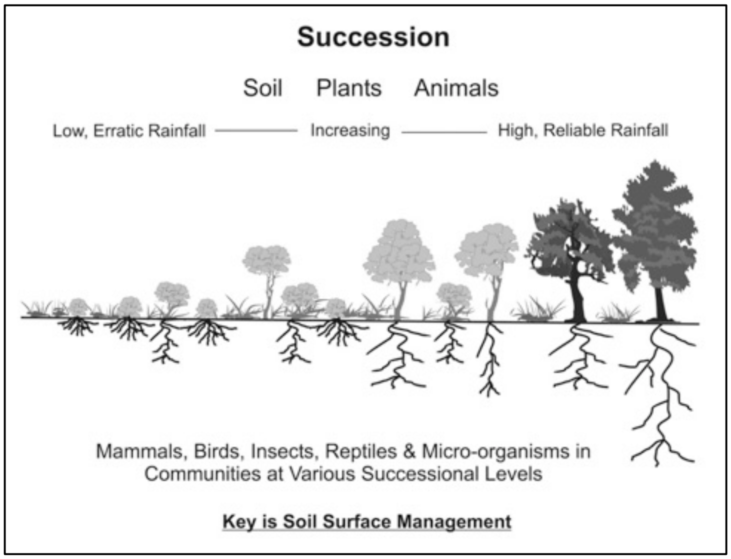


FIGURE 6: *A visual of the successional process.*

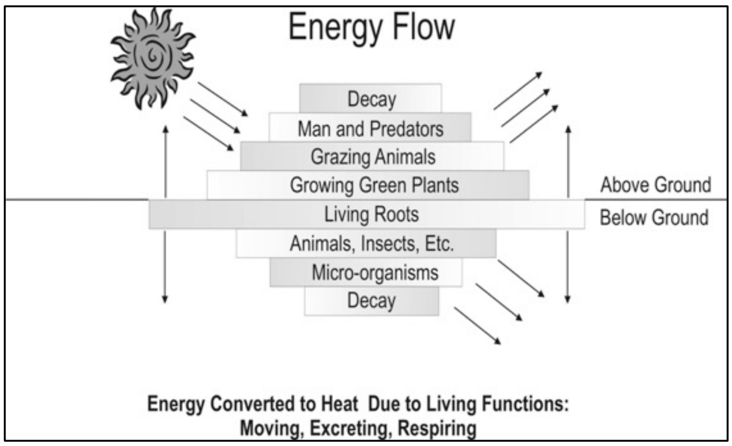


FIGURE 7: *A visual of the flow of energy through ecological systems.*

Almost all life requires energy that flows from the sun. The basic conversion of this solar energy to useable form takes place through plant material on land and in water. Energy passes from plants to whatever eats them, and in turn whatever eats the consumers of plants. Energy doesn't cycle, but flows through the ecosystem until it is consumed (Figure 7; Savory, 1993).

In this report, energy flow was described as "elevated," "moderate," or "reduced." Sites with elevated levels of energy flow showed signs that much solar energy was being captured by living plants and that much photosynthesis was occurring. The indicators of elevated energy flow include robust canopy cover, high plant vigor, and high plant stature. Conversely, sites with reduced energy flow showed signs that much sunlight energy was striking the soil surface and not being captured. These sites displayed higher levels of bare ground (relative to expectations for the ecological site and to current climatic conditions), lower plant canopies, vigor and stature.

A rangeland health qualitative scoring guide accompanies this document (shown on pages below) that describes the parameters by which each of the 14 indicators was evaluated. Each indicator was assigned a "score" relative to its degree of functionality. Each score has an associated color and position on the "Bullseye Target," providing an efficient, but effective means of characterizing the condition of a site (Figure 8).
If, for example, the indicator "litter distribution" displayed uniform cover across the soil surface, this indicator was considered functional, and a mark was placed in the gold area on the Bullseye Target. The final product provides management with a visual portrayal of ecosystem function at a given point in time. More information on the Bullseye Target method of scoring can be viewed online at: http://ranchadvisory.com/rangelands-monitoring.

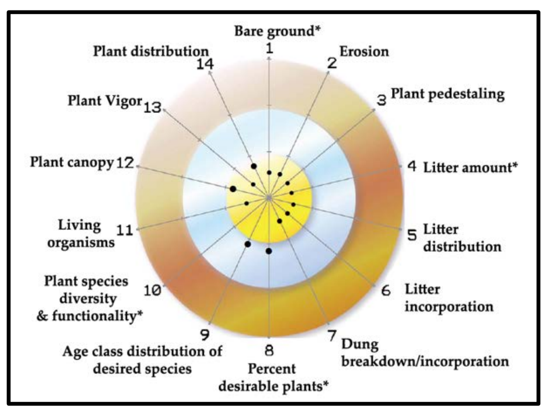


FIGURE 8: *The Bullseye Target provides a representation of the 16 indicators of rangeland health assessed during the qualitative component of the monitoring effort.*

In addition to the qualitative methods described above, several quantitative methods were part of the monitoring process. First, a custom soil survey was generated for the sample area using NRCS's Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm). The custom report generated provides information on desired plant species, expected shifts in species composition under differing management regimes, and expected productivity of a site. Using this information, indicators for desired plant community composition, functional and structural groups, and expected levels of erosion, bare ground, and litter cover can be reviewed and compared to current conditions.

Second, various data were collected at each site along a permanent transect of 200 feet. The data in the charts entitled ***Predominant Plant Species by Weight*** provide a measure of plant species composition by most productive species. Ten quadrats were evaluated every 20 feet starting at the 10-foot mark to determine which species produce the most biomass by weight. The top five most abundant species by weight were estimated within each quadrat with the most abundant species receiving a score of 5 and the least abundant receiving a score of 1. The combined scores yield a percent composition by species for each monitoring site, and the top five most abundant plant species by weight were presented in a chart like the one portrayed below in Figure 9.

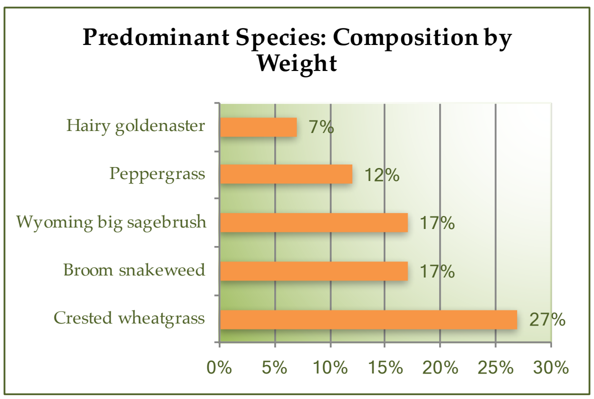


FIGURE 9: *An example of the data presentation for the most abundant plant species by weight. This provides information on the composition of the most productive species at a site.*

The 200-foot transect was also used as the basis for collecting data on ground cover, relative basal plant spacing by species (an assessment of those species with the broadest basal areas), and canopy cover by species using the ***line-point intercept method***. With this method, a steel rod or sturdy metal wire was lowered to the soil surface at every other foot along the tape measure (Figure 10) for a total of 100 points. At each point where the wire touched the ground, ground cover was recorded as either bare soil, litter (dead plant material), a living plant, or rock/gravel. The data from all 100 points were compiled and the percentage of each ground cover type calculated to yield a pie chart like the one portrayed in Figure 11.

FIGURE 10: *A visual of the line-point intercept method in action.*

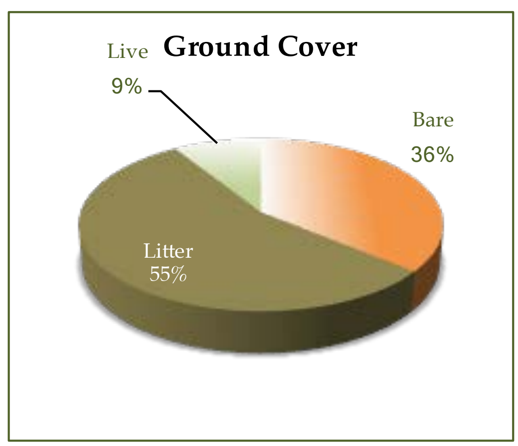


FIGURE 11: *An example of the ground cover chart generated from the line-point intercept data.*

In addition to ground cover data, the line-point intercept method was used to collect information on the most abundant perennial plant species covering the soil surface. At each point where the wire was lowered to the ground, the distance to the nearest perennial plant was measured and the species recorded. This data was compiled for all 100 points and the distance to each species averaged. The top seven most basally abundant species encountered were portrayed in a chart like the one in Figure 12. This data provides another look at species composition, but from the perspective of basal area rather than productivity.

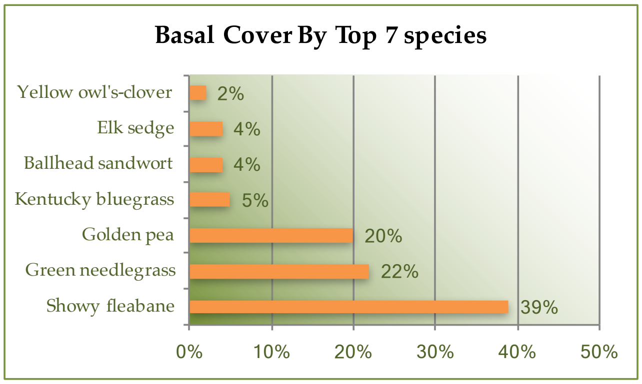


FIGURE 12: *An example of the basal cover graph. In this instance, showy fleabane was the most abundant plant on the soil surface, accounting for 39% of the total basal cover.*

Finally, the line-point intercept method was used to collect plant canopy data. Canopy cover is generally referred to as the percentage of ground surface covered by vegetation (USDI, 1996). More specifically, the line-point intercept method was used to collect *foliar cover*, which is the area of ground covered by the vertical projection of a plant's leaves. In contrast, *canopy cover* is the area of ground covered by the vertical projection of the outermost perimeter of the natural spread of foliage on plants (Figure 13). Canopy cover was measured using the line-intercept method (see below for more detail). Foliar cover data provides information on the relative contribution of each species to the plant community and therefore a look at community composition. This information is also useful in assessing the hydrologic function of a site.

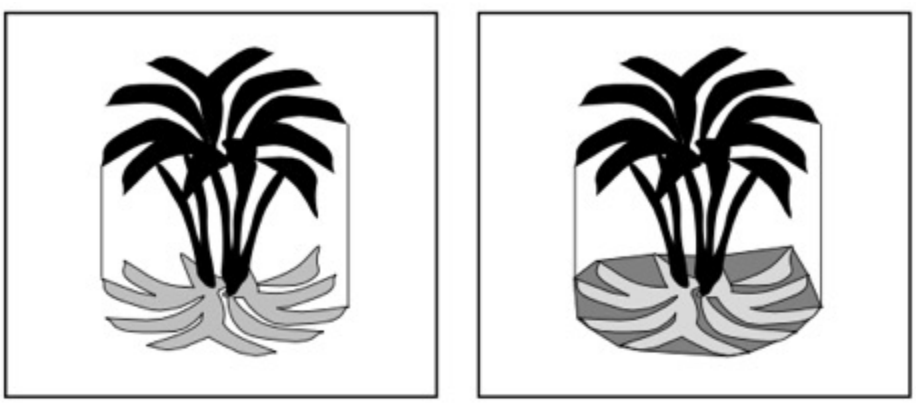


FIGURE 13: *A visual comparison of foliar cover (left) and canopy cover (right). The line-point intercept method was used to measure foliar cover. Any foliage intercepted by the wire used in this method was recorded by species and level (18in and below = Level 1 Foliar Canopy; 18in – 5ft = Level 2 Foliar Canopy; >5ft = Level 3 Foliar Canopy).*

Foliar cover data was collected using the same wire used in the collection of ground cover and basal cover data. Foliar cover was measured in levels from the top down. The first plant species intercepted by the wire was recorded as Level 1 cover, the second species as Level 2 and the third species as Level 3. Figure 14 provides a sample of the line-point intercept data output for foliar cover.

The ***line-intercept method*** was used to measure the canopy cover (versus foliar cover) of living plants intercepted by the transect tape measure. Importantly, the line-intercept method is best suited to sites where the boundaries of plant growth are well-defined. For this reason, this method is useful for measuring the canopy cover of shrubs, but less useful for measuring cover on single-stemmed species like grasses where the distinct boundaries between plant canopies can be difficult to discern. Canopy data on shrubs was thus collected by looking straight down on the transect tape measure and recording the number of centimeters of canopy intercepted by each shrub species (Figure 15). Canopy cover by species was then tallied and displayed as a percentage.

Complementing the line-intercept data, shrub density was measured using the using the ***belt transect method***. In this method, a five-foot long rod was held perpendicular to the transect tape and the number of shrubs intercepted by the rod noted by species. In addition, the height and age class (seedling, young, mature, or decadent) of each shrub was recorded. Following this protocol along the entire 200 feet of the tape provided a shrub density estimate for the site (i.e. number of shrubs per 1000 square feet). A sample of the data output for both the line-intercept and belt transect methods is provided in Figure 16.

Point Intercept Data	
Level 1 Canopy	
Big sagebrush	20%
Crested wheatgrass	19%
Needleandthread	1%
Broom snakeweed	2%
Total Level 1 Canopy	42%
Level 2 Canopy	
Crested wheatgrass	11%
Big sagebrush	1%
Needleandthread	1%
Total Level 2 Canopy	13%
Level 3 Canopy	
None	None

FIGURE 14: *An example of the line-point intercept data output for foliar cover.*

Shrub Data (Mountain Big Sagebrush)	
2016	
27	# of plants encountered
	Age Class Distribution
0%	*seedling*
0%	*young*
100%	*mature*
0%	*decadent*
18.9	Avg plant height (in)
17%	% canopy intercept
65	Density per 1000 sq ft

FIGURE 16: *An example of the line-intercept and belt transect data output for shrub canopy and shrub density.*

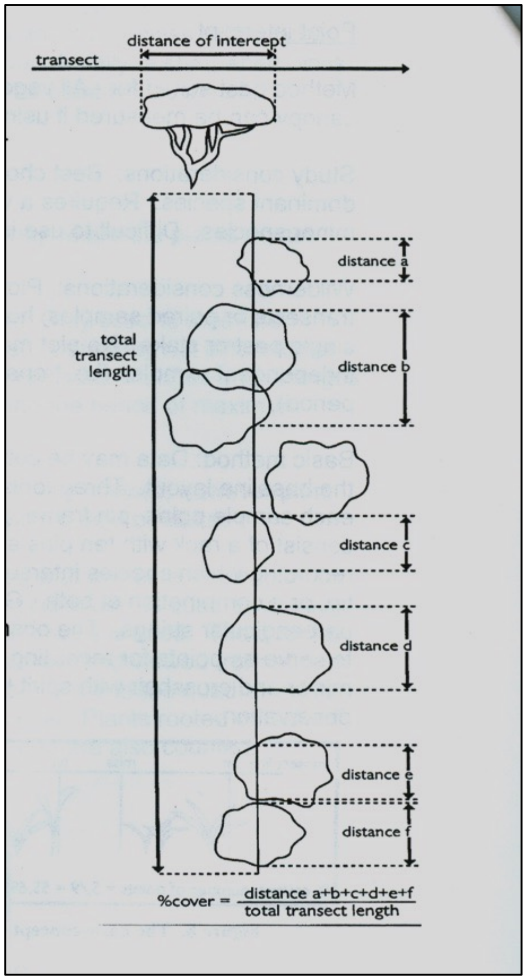


FIGURE 15: *A visual representation of the line-intercept method. The straight line (no arrows) represents the outstretched tape measure of the transect. Each polygon represents the canopy cover of a shrub. The canopy intercept for each species is represented by the dotted lines. The total number of inches intercepted by each species was tallied and divided by the total inches in the transect (2,400) to yield a percent intercept by species.*

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ABOUT THE AUTHORS

Ranch Advisory Partners, Inc. provides agricultural advisory services in the ecological and financial aspects of ranching and agricultural properties. Services include total ranch management; structured finance strategies; operations financial optimization; agricultural operations design, implementation, and oversight; grazing planning; rangeland health evaluations and monitoring; wildlife habitat vegetative manipulation and monitoring; and hydrology.

RANCH ADVISORY
PARTNERS
P.O. Box 6279 Bozeman, MT 59771
P: 406-282-7005
W: ranchadvisory.com