Thompson Rivers University

FINAL UREAP REPORT
September 2019

Plant Response to Grazing: Observing Changes in Community Structure and Individual Characteristics

Written By:
Sarah Bayliff
Bachelor of Science, Major in General Biology

Supervised by: Dr Lauchlan Fraser and Dr. Wendy Gardner

1. Introduction

Plants, like all living organisms, are capable of responding to their environment by adapting and evolving to better survive and reproduce. The phenomenon of this plant adaptation is known as phenotypic plasticity, when a genotype is capable of expressing different phenotypes in response to different environments (West-Eberhard 2008). Put more simply, phenotypic plasticity refers to the ability of a plant to change its characteristics in response to environmental variables, such as available nutrients, weather conditions, or disturbance. Among grasslands throughout British Columbia, grazing is a common disturbance that can affect the expression of plant characteristics and the structure of plant communities.

A plant's typical response to grazing includes changing its characteristics to be tolerant of, or resistant to, grazing (Wang et al. 2017). Characteristics known to show plasticity include size and number of leaves and tillers (Wang et al. 2017), as well as plant height (Olson and Wallander 1997). The direction and magnitude of which these characteristics will change depends on several variables, including grazing intensity and frequency (Wang et al. 2017), annual precipitation (Lohmann et al. 2017), and available light and nutrients (Hayashi et al. 2007). Typically, plants that have been subject to long term grazing will exhibit a lower number of shoots or tillers, smaller and fewer leaves, and will grow closer to the ground. This change in characteristics is an attempt to become grazing resistant or tolerant by lowering the likelihood that they will be grazed and reducing the amount of lost plant material when grazing does occur (Launchbaugh and Walker 2006).

The structure of plant communities is also subject to change when grazing occurs. As grazing intensity changes, the functional groups and composition of the plant community also change (Zhang et al. 2018). There are mixed opinions on the ideal grazing intensity to manage the health of grasslands. Some studies argue that the occasional 'resting' of grasslands, meaning a period where no grazing occurs, can benefit grassland health and productivity by increasing the amount of palatable species, and reducing the amount of undesirable species (Zhang et al. 2018). Common between most papers, a high grazing intensity is thought to reduce grassland health and forage availability by increasing the amount of weeds present, and lowering the amount of grass species (Zhang et al. 2018, Pakeman RJ. 2004). However, it is also thought that grazing at a proper intensity can increase grassland health and biodiversity by reducing the amount of competitive and dominant species, allowing other species to better compete and successfully grow (Zhang et al. 2018).

Managing the health of a grassland is not only important for the ecosystem, but should also be a concern of cattle ranchers who have grazing rights to the land. Biodiversity is important for an ecosystem to maintain function and productivity (Maestre et al. 2012), as well as increasing the resistance of a grassland to grazing (Lyons and Hansel 2001). As biodiversity and grazing resistance increases, so does the health and productivity of a grassland. With higher productivity comes more available forage for cattle, increasing the profitability of a rancher's rangeland.

This experiment explored how plant characteristics and community structures change in response to grazing. Plant characteristics focused on throughout this project were plant height, number of tillers produced per plant, and average leaf area. Available biomass and vegetation surveys were also examined. To compare the effects of grazing, three different treatments were performed. An exclusion cage treatment was constructed to examine plants which were not grazed for a single grazing event, but had been grazed in previous years. A grazed treatment consisted of area that has been continuously grazed, including throughout the study months. The final treatment involved a range reference area, where plants have not been subject to any cattle grazing since 1920 (Government of British Columbia 2003). It was hypothesized that grasses that have been exposed to long-term grazing, such as those in the cage and grazed treatments, would show signs of grazing resistance. As the literature suggests, it was thought that plants with higher grazing resistance would exhibit a lower plant height, fewer number of tillers, and reduced leaf area. It was also hypothesized that grazed sites would have higher measures of diversity as grazing reduces competition, allowing less-dominant species to succeed.

2. Materials and Methods

2.1 Site Selection

Two study sites were selected for this project, one near Merritt and one in the Lac du Bois grasslands. The Merritt site was located in the Drum Lake Pasture, approximately 3 kilometres north of the Laurie Guichon Memorial Grasslands Interpretative Site. This site was also used by Master's students conducting grazing trials to try to control spotted knapweed and there were three 50m x 50m enclosures already laid out. On May 8th, 2019, six exclusion cages were set up around the existing enclosures (see Figure 1). The dimensions of the exclusion cages were approximately 1.5m x 1.5m. All sampling at the Merritt site occurred on June 12th, 2019.

Figure 1: Grazing exclusion cage overlooking the town of Merritt

The Lac du Bois site consisted of four different site locations, each containing five exclusion cages. These cages had been previously set up by a past student and have been in place since the summer of 2017. Due to time constraints, only two of the five cages at each site were sampled from, to give a total of eight cage samples. All sampling at the Lac du Bois site was performed on June 19th, 2019 (see Figure 2).

Figure 2: View of Kamloops from one the Lac du Bois cage sites

Grazed sites were selected by placing a 1m x 1m quadrat frame five metres to the east of the exclusion cage, measured by a transect tape. This was done for each exclusion cage, giving six grazed samples from the Merritt site and eight grazed samples from the Lac du Bois site. In Merritt, sampling was also done within a range reference site. To determine sites here, two diagonal transects were run across the enclosure, with samples being taken every fifteen metres, for a total of six samples.

2.2 Vegetation Surveys

For each cage, grazed, and reference site, a vegetation survey was completed to estimate species abundance and density. Surveys were done within a 1m x1m quadrat frame. Plants were identified to species and percent cover of the area was estimated for each species.

2.3 Biomass and Plant Characteristics

To attempt to see changes in species between the treatments, biomass and several plant characteristics were measured. As the cage sites were also being used in other studies, these measures had to be relatively small so as to not disturb the site too much. To select where to sample from, a 50cm x 50cm quadrat frame was placed in the bottom left corner of the previously placed 1m^2 quadrat, then a 25cm x 25 cm quadrat frame was placed in the bottom left corner of the 50cm^2 quadrat (see Figure 3).

Figure 3: Quadrat setup for vegetation surveys, plant characteristics, and biomass samples

Biomass samples were taken from within the 25cm x 25cm quadrat by harvesting all available vegetation, cutting it to ground level, and placing it in a labeled paper bag. Biomass samples were taken from each site for a total of 18 samples from the Merritt site and 16 samples from the Lac du Bois site. The biomass samples were then put in the drying oven for 48 hours at 65 degrees Celsius. Once dried, the samples were then weighed to give an idea of the available forage and plant density between treatments.

Within the remaining area of the 50cm x 50cm quadrat, plant characteristics were measured. Several of the dominant species (i.e. grasses and invasives) were selected and plant height, tiller number, and leaf area were measured for each individual plant. Plant height was determined by measuring from the plant base to the tallest point of the plant. Tiller number was only measured for grasses and was determined by counting the total number of tillers, or stems, on each individual grass. In order to measure leaf area, the entire plant was harvested and placed in a plastic bag with moist paper towel in order to keep the leaves hydrated. Once back at the lab, three leaves from each plant were selected to quantify leaf area. These leaves were taped to a transparent folder cover and were then scanned to transfer their image onto the computer (see Figure 4). Originally, for the Merritt plants, all leaves were analysed. However, it proved too time consuming to transfer every single leaf so the protocol was changed for the Lac du Bois site and only three leaves per plant were transferred. In order to select three leaves from the Merritt plants, each leaf was numbered and a random number generator was used to select three leaves to be analyzed for area. The scanned leaf images were analyzed by ImageJ, an image processing program, to determine the area of each leaf. Once the areas of the three leaves were determined, the average was taken of those values to give an average leaf area for each individual plant.

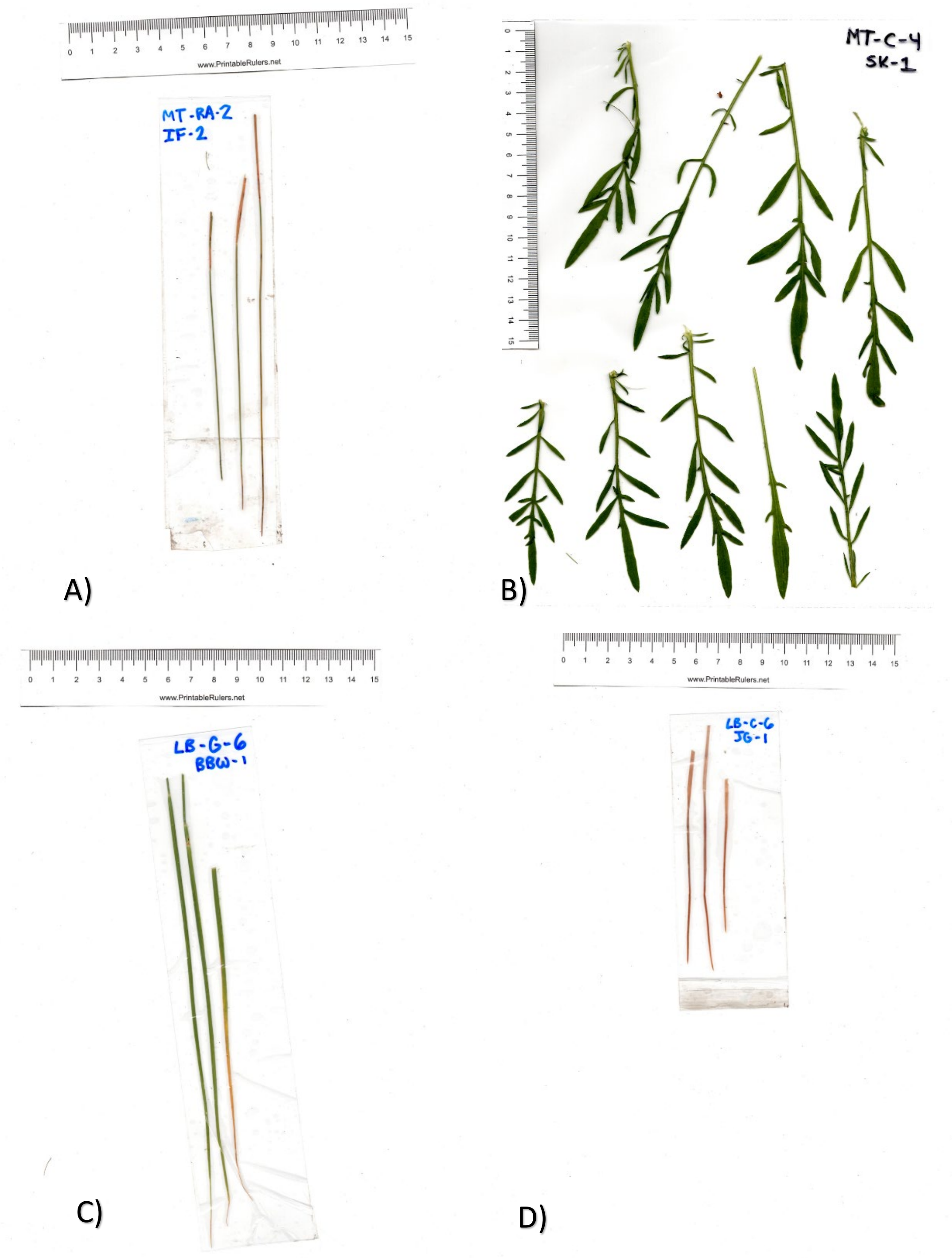

Figure 4: Scanned images of leaves, A) Idaho Fescue from Merritt reference area, B) Spotted Knapweed from Merritt cage treatment, C) Bluebunch Wheatgrass from Lac du Bois cage treatment, D) June Grass from Lac du Bois cage treatment

2.4 Statistical Analysis

Due to low sample size, plant characteristics were grouped to functional groups. The Merritt site compared groups of grasses and invasives between the treatments. The Lac du Bois site only compared grasses. Comparisons were made between Merritt treatments, between Lac du Bois treatments, and also between Merritt and Lac du Bois sites. All data was tested for the assumptions of fitting a normal distribution and having equal variances. The majority of the data met these assumptions and thus underwent parametric tests. To compare between the three Merritt site treatments, ANOVAs were used. If a p-value of less than 0.05 was returned, subsequent two-sample t-tests were performed to find where the difference between treatments was occurring. The Lac du Bois site only had two treatments which were compared using two-sample t-tests.

Several groups of data did not meet the assumptions of parametric tests. Merritt biomass, Lac du Bois tiller number, and Lac du Bois biomass data sets were able to be transformed using the log10+1 function. Once the data was transformed, it fit the assumptions of parametric tests and were then able to undergo ANOVA and t-test statistical tests. Merritt tiller number was unable to be transformed and had to be analyzed using non-parametric tests. Non-parametric tests included Kruskal-Wallis and Mann-Whitney U tests.

The values from the vegetation surveys were analyzed using the Shannon-Wiener Diversity index, the Simpson Diversity index, and counts of species richness. Once calculated, these data sets were also tested for normality and equal variances. Once confirmed that the data met the assumptions of parametric tests, ANOVAs and t-tests were performed for these three measures of diversity to test for different measures of diversity between treatments.

3. Results

3.1 Merritt site results

Grasses in the reference area showed several differences from grasses in the cage and grazed treatments. Reference grasses were significantly taller (p=<0.001) and showed a larger leaf area (p=0.0456) than grasses that had been in the grazed treatment. Reference area grasses also appeared to have significantly larger numbers of tillers than grasses in the cage (p=<0.05) and grazed treatments (p=<0.05) (see Figure 5). Grasses inside the cages were found to be significantly taller than grasses that had been grazed (p=<0.001).

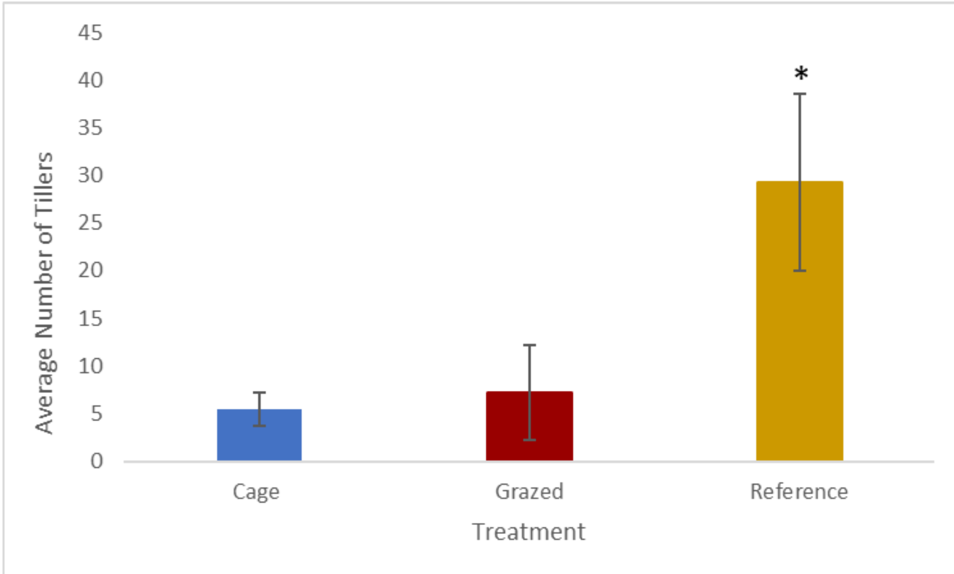

Figure 5: Comparison of average number of tillers on grasses between treatments at the Merritt site

When looking at the invasive functional group, which contained only spotted knapweed, plants in the grazed treatment were significantly shorter than knapweed plants in the cage (p=0.0013) or reference treatments (p=0.0009), see Figure 6.

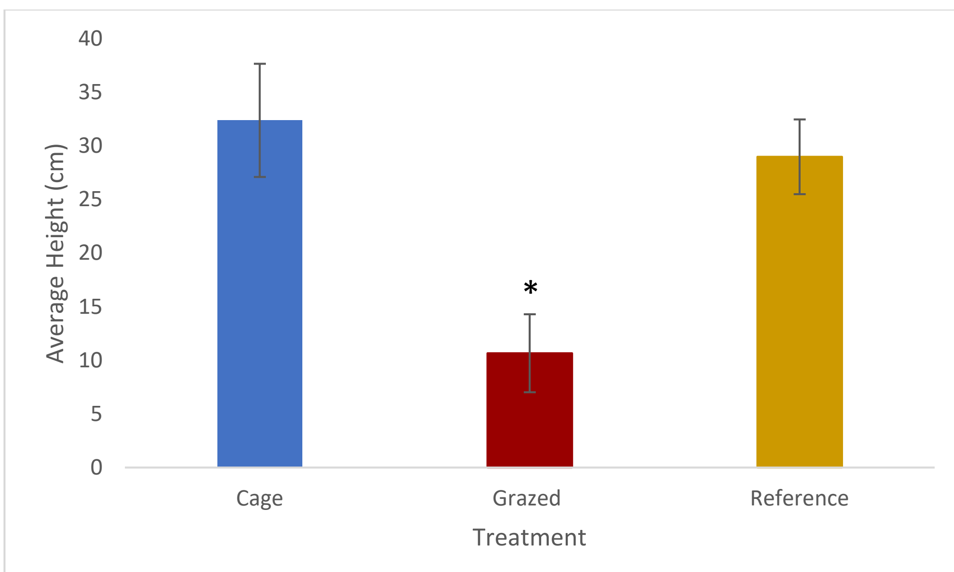

Figure 6: Comparison of average height of spotted knapweed plants between treatments at the Merritt site

Upon analysis of the diversity indices, the Shannon-Weiner diversity index gave the grazed sites a significantly higher value of biodiversity than the reference sites (p=0.036). Similarly, the reference site also showed a significantly lower species richness than the cage (p=0.0045) and grazed (p=0.0015) treatments (see Figure 7).

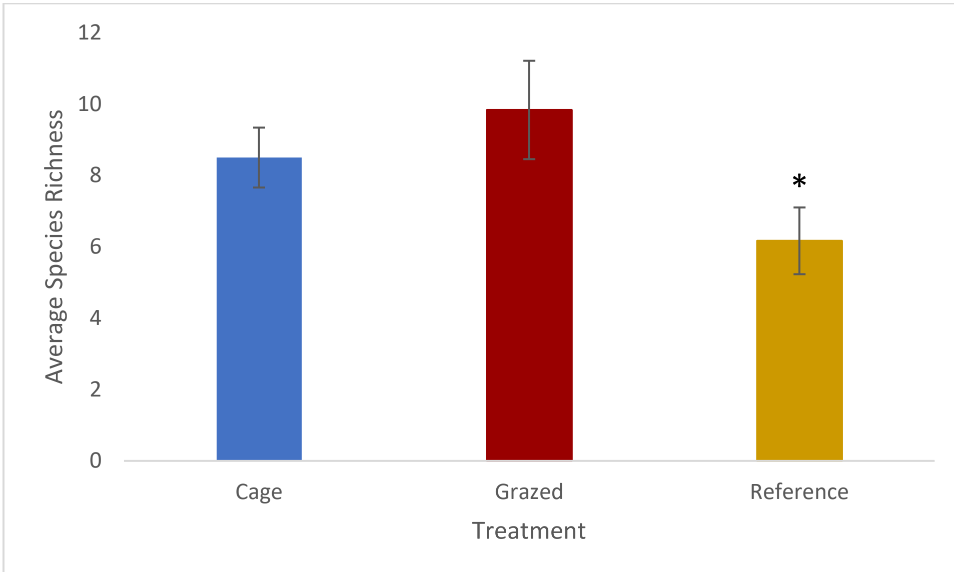

Figure 7: Comparison of species richness between treatments at the Merritt site

3.2 *Lac du Bois site results*

There were no significant differences between treatments for any variables at the Lac du Bois site.

3.3 *Comparison between Merritt and Lac du Bois sites*

Lac du Bois grasses in the cage treatment were significantly higher than grasses in the Merritt cage treatment (p=0.009). Grazed grasses in Lac du Bois were also significantly taller than grazed grasses in Merritt (p=0.0002), see Figure 8. Lac du Bois grasses in cages showed a significantly lower number of tillers than grasses in the Merritt cages (p=<0.05). When comparing leaf area, Lac du Bois grasses had a significantly higher value than Merritt grasses for the cage (p=<0.001) and grazed treatments (p=<0.001). Lac du Bois grasses from the cage and grazed treatments were also compared to grasses within the Merritt reference site. Leaf area was found to be significantly lower in reference area grasses than both Lac du Bois cage (p=<0.001) and grazed grasses (p=<0.001). There were no other significant differences for any other variables between the Lac du Bois grasses and the Merritt reference area grasses.

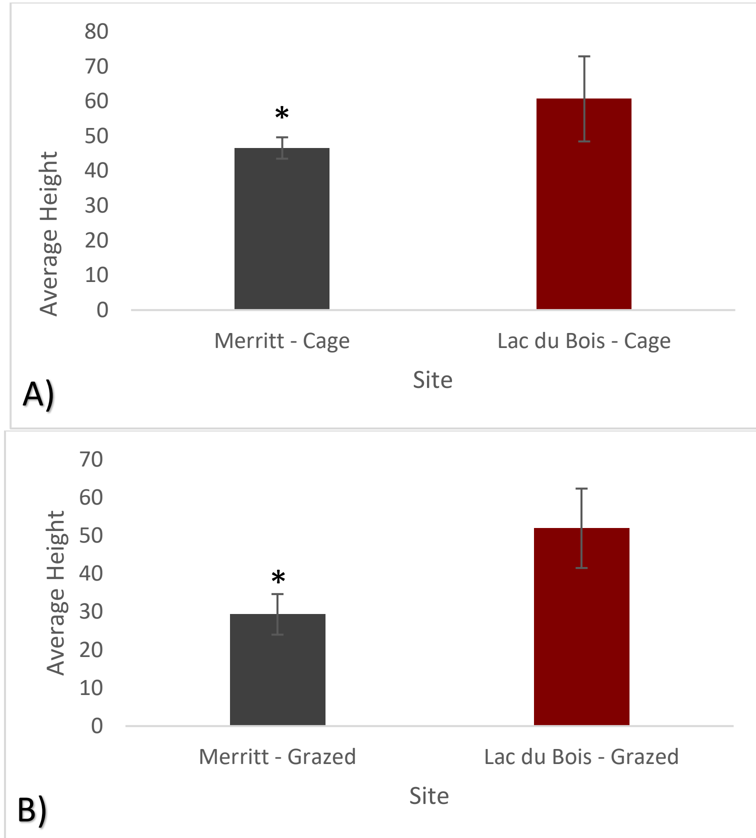

Figure 8: Comparison of average height of grass species between sites, A) Cage treatments, B) Grazed treatments

Diversity index values were also compared between Merritt and Lac du Bois sites. The Shannon-Wiener H-values given showed that grazed Merritt sites having significantly higher diversity than grazed Lac du Bois sites (p=0.008). The Simpson index also showed grazed Merritt sites as more diverse than grazed Lac du Bois sites (p=0.0103). Lastly, species richness for grazed Merritt sites was significantly greater than that of grazed Lac du Bois sites (p=0.014).

4. Discussion

4.1 Plant Height

At the Merritt site, grass height was found to be significantly lower in grazed plants when compared to cage and reference plants. While it is thought that plant species respond to grazing by lowering their height and growing lower to the ground (Launchbaugh and Walker 2006), this is likely not the case here as there was no difference between grasses in the cages and grasses in the reference area. What is the more likely explanation for this is herbivory. The plants in the grazed treatment were subject to grazing. When cattle graze, they generally decrease the height of the plant as defoliation occurs. For this reason, the difference in grass height between treatments is not an important finding.

The invasive functional group however, did produce interesting results when comparing heights between treatments. Spotted knapweed plants had a significantly lower height in the grazed treatment than in other treatments. While this is also likely due to defoliation, this result has more significance than the grass functional group. Shorter knapweed plants in grazed area suggests the cows have eaten this invasive plant. This supports the use of cattle grazing as a successful way of controlling the growth and spread of this competitive invasive species using targeted grazing practices.

4.2 Number of Tillers

Merritt grasses in the reference area appeared to have a greater number of tillers than grasses in the cage or grazed treatment. Grasses in the cage and grazed treatments have been previously grazed and should show grazing resistance, so this result is consistent with the hypothesis that plants with a higher grazing resistance will lower the number of tillers produced. The number of tillers a grass produces is a very plastic trait that varies with grazing intensity (Wang et al. 2017). Previous studies suggest that many grass characteristics tend to reduce in magnitude in response to disturbance (Li et al. 2015). For example, reducing the number of tillers produced in response to grazing. These studies' findings coincide with the results found in this experiment. As the reference area grasses have been enclosed for nearly one hundred years, they have not been subject to high grazing pressure and haven't had to change any characteristics as a response to grazing disturbance. The grasses within the cage and grazed areas however, have been subject to grazing and may have produced phenotypic changes in order to adapt to continuous grazing pressure, thus lowering the number of tillers produced.

4.3 Leaf Area

Leaf area is another plant characteristic that is subject to change in response to disturbance (Wang et al. 2017). At the Merritt site, grasses in the reference area had a significantly larger average leaf area than grasses in the cage and grazed treatments. Again, this is possibly due to the miniaturization of plant traits that occurs in response to grazing. The grasses within the cage and grazed treatments have been exposed to grazing and perhaps have adapted to be more grazing resistant by lowering the area of their leaves. This is unlike the reference area grasses which have not been grazed and have not had the need to adapt to such disturbances.

4.4 Diversity Indices

Grazing can alter ecosystem structure and change the composition of plant communities (Zhang et al. 2018). Upon analysis of the three Merritt treatments, it appeared as though the Merritt reference area had a lower measure of diversity than the cage and grazed treatments. This result supports the hypothesis that grazing changes community structure, and can be beneficial by increasing biodiversity (Zhang et al. 2018). As grazing occurs, competition is lowered between different plant species. As defoliation of dominant species occurs, opportunity is given to less dominant species to successfully grow, increasing the biodiversity of the area (Zhang et al. 2018).

4.5 Comparing Study Sites

The Merritt site supported the hypothesis that grazed sites would have higher biodiversity and lower measures of plant characteristics. However, no significant results were found from the Lac du Bois site. To investigate this finding, all variables were compared between the Lac du Bois and Merritt sites. Grasses at the Lac du Bois cage and grazed sites were significantly taller than grasses at the Merritt site. This result suggested a lower grazing intensity in Lac du Bois as they have not been defoliated as much and do not show signs of reducing their plant height in response to grazing. Overall, the Lac du Bois grasses were quite similar to the grasses in the Merritt reference area, the only significant difference between the two being a larger leaf area in the Lac du Bois grasses. These results suggested that the Lac du Bois grasses, like the Merritt reference area, have not been subject to intense grazing and thus have not undergone phenotypic plasticity. The Merritt site, which has been subject to grazing, shows higher diversity measures and plants with grazing resistant characteristics. From these results, it appeared as though the Merritt site was more resistant to grazing than the Lac du Bois site. The reason for no significant results between Lac du Bois treatments was likely due to low frequency, low intensity grazing, which does not produce drastic phenotypic changes in grasses, as the response of plants is dependent upon grazing intensity (Zhang et al. 2018).

5. Conclusion

The results of this experiment suggested that in response to grazing, grasses will miniaturize their characteristics to become more resistant to grazing. In this experiment, the traits that showed reduction were leaf area and the number of tillers produced. While grazing can alter the structure of individuals, it can also cause changes at the community level. As shown at the Merritt cage and grazed sites, it appeared as though proper grazing practices can increase biodiversity, enhancing the health of the grassland. Overall, grassland ecosystems change depending on grazing intensity. With proper grazing management practices, grasslands can become rich in biodiversity while providing sufficient forage for range use.

6. Potential revisions for future studies

If this study were to be repeated, it should take place over a time period longer than four months. This four-month study was too short to observe phenotypic plasticity in response to grazing between the cage and grazed plants as there was only a single sampling period. Ideally, grasses would be measured before grazing, after grazing, and the previous year when they’ve had the time to possibly adapt to the grazing disturbance.

Another area of concern was the biomass samples. No significant differences were found for any biomass samples for this experiment. This was likely because the samples were so small. If this study were to be done again, larger biomass samples should be taken at an attempt to properly quantify the sites.

This study would also benefit from an increased sample size so plant characteristics could be compared down to species level between treatments to give more accurate results.

References

Government of British Columbia. 2003. Range Reference Areas of the Southern Interior Forest Region- Drum Lake RRA. [Internet]. Cited September 11th, 2019. Available from: https://www.for.gov.bc.ca/rsi/range/RRA/cascades/drumlake.htm

Hayashi M, Fujita N, Yamauchi A. 2007. Theory of grazing optimization in which herbivory improves photosynthetic ability. 248(2):367-376. [Internet]. Cited September 11th, 2019. Available from: https://www.sciencedirect.com/science/article/pii/S0022519307002494

Launchbaugh K and Walker JW. 2006. Targeted grazing—a new paradigm for livestock management. Targeted grazing: a natural approach to vegetation management and landscape enhancement. American Sheep Industry Association. 2006: 1-56. [Internet]. [Cited September 11th 2019]. Available from: http://sccd.org/wp-content/uploads/2015/08/Section-1-principles-and-overview.pdf

Lohmann D, Guo T, Tietjen B. 2017. Zooming in on coarse plant functional types-simulated response of savanna vegetation composition in response to aridity and grazing. 11(2):161-173. [Internet]. Cited September 11th, 2019. Available from: https://link-springer-com.ezproxy.tru.ca/article/10.1007%2Fs12080-017-0356-x
Li X, et al. 2015. Contrasting Effects of Long-Term Grazing and Clipping on Plant Morphological Plasticity: Evidence from a Rhizomatous Grass.10(10):1-19. [Internet]. Cited September 11th, 2019. Available from: https://eds.a.ebscohost.com/eds/pdfviewer/pdfviewer?vid=3&sid=9c449f9a-9adc-4a4b-b85e-348a56b3a8f8%40sdc-v-sessmgr01

Lyons RK and Hansel CW. 2001. Grazing and Browsing: How Plants are Affected. AgriLife Extension Texan A&M System. [Internet]. [Cited September 11th 2019]. Available from: http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/87088/pdf_1523.pd

Maestre FT, Quero JL, Gotelli NJ, Escudero A, Ochoa V, Delgado-Baquerizo M, Garcia-Gomez M, Bowker MA, Soliveres S, Escolar C, et al. 2012. Plant species richness and ecosystem multifunctionality in global drylands. NCBI. [Internet]. [Cited February 2nd 2019]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3558739/ DOI: 10.1126/science.1215442

Olson B and Wallander RT. 1997. Biomass and carbohydrates of spotted knapweed and Idaho fescue after repeated grazing. 50(4):409-412. [Internet]. Cited September 11th, 2019. Available from: https://www-jstor-org.ezproxy.tru.ca/stable/4003308?seq=1#metadata_info_tab_contents

Pakeman RJ. 2004. Consistency of plant species and traits to grazing along a productivity gradient: a multi-site analysis. 92(5):893-905. [Internet]. Cited September 11th, 2019. Available from: https://www-jstor-org.ezproxy.tru.ca/stable/3599387?seq=1#metadata_info_tab_contents

Wang D, Du J, Zhang B, Ba L, Hodgkinson KC. 2017. Grazing Intensity and Phenotypic Plasticity in the Clonal Grass *Leymus chinensis.* 70(6):740-747. [Internet]. Cited September 11th, 2019. Available from: https://bioone-org.ezproxy.tru.ca/journals/rangeland-ecology-and-management/volume-70/issue-6/j.rama.2017.06.011/Grazing-Intensity-and-Phenotypic-Plasticity-in-the-Clonal-Grass-iLeymus/10.1016/j.rama.2017.06.011.full

West-Eberhard MJ. 2008. Encyclopedia of Ecology. Phenotypic Plasticity. [Internet]. Cited September 11th, 2019. Available from: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/phenotypic-plasticity

Zhang C, Dong Q, Chu H, Shi J, Li S, Wang Y, Yang X. 2018. Grassland Community Composition Response to Grazing Intensity Under Different Grazing Regimes. 71(2):196-204. [Internet]. Cited September 11th, 2019. Available from: https://bioone-org.ezproxy.tru.ca/journals/rangeland-ecology-and-management/volume-71/issue-2/j.rama.2017.09.007/Grassland-Community-Composition-Response-to-Grazing-Intensity-Under-Different-Grazing/10.1016/j.rama.2017.09.007.full