Spotted Knapweed (*Centaurea maculosa*) and its Effect on Forage Quality and Elevation Changes

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Abstract

Spotted knapweed is an invasive plant species that invades rangelands, and can lowers forage production for livestock and wildlife. In this study I evaluated forage production on the National Bison Range and on the Confederated Salish and Kootenai tribal lands. Spotted knapweed has been managed using various methods including: mechanical, chemical, and biological controls. On my sites off the bison range I also used 2 methods of removal: mechanical and chemical. I had 2 hypotheses that I studied: the first was to evaluate reduced forage production with the presence of spotted knapweed; the second was to determine if spotted knapweed is less abundant at different elevations. I had 3 study areas in which I clipped grasses, 2 sites were on the backwater areas of tribal lands, and the other site was on the National Bison Range.

Introduction

The impact of diffuse spotted, and Russian Knapweed (*Centaurea difusa, C. maculosa, and Acroptilon repens*) in the state of Montana caused 42 million dollars in direct and secondary economic impacts, enough to support 500 full time State employees (Hersch & Leitch, 1996). Typically these introduced plants can out-compete native plant species for resources. Invasive plants typically exhibit higher population performance in their invaded range than the native range (Hinz & Schwarzlaender, 2004), an economics report (Hersch and Leitch, 1996) completed for the State of Montana estimated the annual cost to the livestock industry caused by spotted knapweed in the state exceeded $11 million dollars. For example, alien species interfere with grazing practices by lowering yield and quality of forage which results in increasing livestock production costs. Poor quality rangeland suffering from an infestation of invasive plants can results in slow animal weight gain, reduced quality of meat, milk, wool, hides, and even poisoning of livestock (DiTomaso, 2000).

Spotted knapweed (*Centaurea maculosa*) is an invasive plant that was introduced in the United States through alfalfa seeds in the 1800'S (USDA, 2007). Spotted knapweed is a short lived biennial plant that is native to the Mediterranean Region (Shinn, & Thill, 2003). It forms between one and 20 slender, upright stems 1-3.5 feet (30-100 cm) tall, and can produce as many as 146,000 seeds/year in areas of heavy infestation (USDA, 2007). The spread of spotted knapweed has reduced desirable native plant diversity and forage for livestock and wildlife where established (Less, et al., 2002). Mature knap weed plants are coarse, and the stems and spines can irritate grazing animals, that makes it less desirable for animals. (Shelly et al., 1998).

Spotted knapweed has been managed using a variety of methods including: mechanical, use of fire, herbicides, biologically, and the use of grazing animals. Mechanically removing spotted knapweed can be time consuming and expensive depending on the treatment areas: size, location, and plant density. Mechanical removal can be as simple as using a shovel, or can be a big project involving heavy machinery. Mowing is a common mechanical technique that is used to remove the tops of unwanted plants.

Fire is another useful removal method and has been successfully used in the removal of other invasive range plants. Yellow star thistle is a listed noxious weed in Montana (NRCS, 2001) and prescribed burns have been used to remove Yellow star thistle seed beds (Keeley, 2006). Fire has utilized for Yellow star thistle seed beds because; seeds may remain viable in the soil for up to 10 years (Callihan et al., 1993), and spotted knapweed seeds can remain viable in the soil for at least 8 years (Davis et al., 1993).

Biological control (e.g., fungi, moths, larvae, and beetles) has been used to control invasive plant species. Most bio-control techniques use insect larvae that damage the host root, shoot, leaf, or flower, resulting in reduced seed production. Spotted knapweed has several agents that target the plant; *Larinus minutus* a beetle that targets the flower head feeder, *Cyphocleonus achates a* beetle that is a Root feeder, *Urophora affinis a* fly that feeds on the Flower head and, *Urophora quadrifasciata* fly Flower head feeder all are native to Eurasia (NRCS, 2001). Two seed head-feeding flies (*Urophora affinis* and *U. quadrifasciata*) are well established on diffuse and spotted knapweeds (Sheley, et al. 1998). Another study (Story, J. M., et al., 1989) showed that larvae from two seed head-feeding flies reduced seed production by fifty percent.

On the National bison range there are a variety of biological controls for invasive plant species including spotted knapweed. There are a total of 24 biological controls to treat 9 different invasive plant species. There are 5 biological controls that specifically target spotted knapweed on the bison range (Table1).

Grazing of invasive plant species has been applied with domestic animals. In a three year study (Olson & Wallander, 2001) sheep grazing on spotted knapweed helped to lower its abundance. This study concluded that sheep grazed native bunchgrass and Idaho fescue more than spotted knapweed, but long term sheep grazing can restore a balance to infested areas.

Herbicides can also be applied to manage unwanted and invasive plant species. Herbicides can reduce photosynthesis, disrupt vegetative growth, or interrupt the production of essential proteins. Chemical applications to control Spotted knapweed with picloram, clopyralid, and 2,4-D have high efficacy when properly applied (Rice, et al., 1997). Another study was effective in lowering spotted knapweed abundance when grazing and herbicides were both applied. Treating weeds also increases the availability of resources needed by desired neighboring plants (NRCS, 2001). Herbicides can have negative

In this study I will apply 2,4-D a common herbicide. 2,4-D was used in another study (Lacey, 1999) that showed 90% control in spotted knapweed, but stated that it does not provide long term control.

Invasive plant management is important to maintain a productive rangeland. Range health is determined by scoring a site's: soil stability, hydrologic function, and its biotic integrity (Pellant, et al., 2005). Having a healthy productive range is important for animals, humans, and wildlife. Spotted knapweed can reduce forage availability, and could lower the carrying capacity of winter range habitat for elk (Rice, et al., 1997). Humans are impacted by invasive plants through a reduced income due to a reduced livestock production (Hersch and Leitch, 1996). Other studies have shown that spotted knapweed grows well many soils, and elevations. This study will apply known mechanical and chemical removal methods, and evaluate forage production with the presence and absence of spotted knapweed at different elevations. Forage production is important to know a ranges carrying capacity. I hypothesis that forage production will be greater when knapweed in not present, and that knapweed will be less present at higher elevations.

Methods

In my first experimental design I worked on tribal lands of the Confederated Salish and Kootenai tribes, in the backwater areas of the Flathead River (Figure

3). I had two sites (Figure 3) that I analyzed forage production with the presence of spotted knapweed. Each site had three treatment groups; control, mechanical, and chemical (figure 1). I had 15 1-meter quadrats (5 control, 5 mechanical, and 5 chemical) at each site, for a total of 30 quadrats for both sites. In selecting my quadrats I will chose areas that were abundant in knapweed, and have forgeable grasses. All quadrats had the same percent cover: 30% grass, 30 % forbs/knapweed, and 40% bare ground/ litter. In the control quadrat I located areas that had no spotted knapweed and clipped all grasses and forbs. I chose control plots that were no more than 300 feet from treatment areas in order to maintain the same environmental conditions. For each quadrat I recorded: Latitudes and longitudes using a Global Position System Points (GPS), elevation, slope, and aspect.

The chemical application used on the two sites was Ortho™ Weed be Gone Max, the main ingredients are; 2, D-4, Quinclorac, and Dicamba. 2,4-D was used in another study (Lacey et al., 1998) that showed 90% control in spotted knapweed, but stated that it does not provide long term control. I will follow the manufactures recommendation on application rates. The recommended rate per on gallon is 2.5 ounces per one gallon of water. Chemical applications were applied through a one gallon tank hand sprayer. Mechanical removal was completed using a shovel and hand pulling. In the mechanical and chemical quadrats I clipped all grasses that were within the 1-meter quadrat, but left knapweed standing for chemical and mechanical removal. Mechanical applications occurred once at the beginning of the study. Chemical removal was completed at the end of the study period. Clipping of grasses and forbs was completed twice for all quadrats, once in the beginning of the study and once at the end of the study. Statistical analysis information was completed using the dry weights of grasses, forbs, and knapweed.

The second part of my study was to evaluate if spotted knap weed biomass was different at various elevations on the National Bison Range (Figure 2). Locations were limited to the bison range, because of past management applications. Biological control has been ongoing at the bison range for the past 25 years. Beetles, weevils and moths have been introduced on the bison range (Table 1) to control a variety of invasive plants on the Bison range including spotted knapweed. In keeping all of my quadrats on the bison range I hope to limit the amount of variability within my quadrats. I will locate as many sites at different elevations; high, medium, and low. I will evaluate if forage production changes with high, medium, and low elevations. For each quadrat I will record: GPS points, elevation, slope, and aspect. Sites will be selected based on presence and absence of spotted knapweed; quadrats will be randomly paired together. One quadrat will have knapweed present (i.e., > than 30% cover) and another will not have knapweed. Quadrat placement will be randomized. Randomization will be completed by closing both eyes and throwing a quadrat in the general direction of knapweed being present or absence. Each paired quadrat will be clipped for grasses, forbs, and knapweed. The variables that will be used in a multiple regression will be the total dry weights of grass, forbs and knapweed; elevation, slope, and aspect. A regression will be used to determine the relationship between the amount of knapweed and available forage. My hypothesis is that total forage production will be lower with knapweed, and knapweed will be less present as the elevation increases.

Results

In my first experimental design i clipped grass, forbs, and knapweed in all my quadrats. My total grass biomass for both sites (Figure 4) on my first clipping was 3415.35 grams, forbs were 1896.73 grams, and mechanical removal of knapweed weighed 1408.97 grams. On my second set of clippings I had little regrowth in my quadrats grasses weighed 222.3 grams, forbs weighed 47.97 grams, and chemical removal of knapweed after spraying weighed 601.63 grams. I also had some regrowth of knapweed in my mechanical quadrats on my second clipping; knapweed removal weighed 7.85 grams.

A linear regression and ANOVA tests were used to evaluate if knapweed reduced total biomass in grasses and forbs. i first used the total of grasses and knapweed biomass at low elevations on the bison range and off sites using my first clippings to test if knapweed significantly lowered biomass. When I used an ANOVA I received a significant P-value (0.003), this shows that at low elevations grasses are affected when spotted knapweed is present. When I tested knapweed against grasses just off the bison range I did not receive a significant P-value (0.207), but when I used forbs I received a significant P-value (0.006). My second set of clipping did not have much regrowth (<3 cm), so I was not able to get any significant results in my quadrats. I also completed a regression shown in figure 5 which illustrated that knapweed lowers biomass of: forbs, grasses and total biomass.

On my second experimental design I wanted to test if knapweed grows better at different elevations, and its effect on grass and forbs. When I analyzed grass biomass with knapweed biomass at different elevations with ANCOVA (Figure 6), I did not get a significant P-value (0.989). I found that grass and knapweed grows well at all elevations. By analyzing forb biomass with knapweed I got a P-value (0.477), which is not significant. When I Analyzed total grass biomass on and off the bison range at low elevations, with the presence of knapweed I received a significant result, P-value (<0.00001). Having a very low P-value indicates that knapweed presence reduces the amount of grasses biomass. I also did a proportion (Figure 8) of total grass biomass with and without spotted knapweed, and found that knapweed presence reduced grass bio mass by 259.98%. My total weights of biomasses on the bison range are shown in figure 7.

Conclusion

In my first experimental design I tried to evaluate if the presence of knapweed can limit forgeable plant species. In my experimental design I had 1-meter square plots that I clipped. In my design I was planning that regrowth would occur over the summer. I chose sites that were needle and thread, because of its ability to regrow after precipitation occurs. However after 6 weeks after my first set of clippings had occurred, I saw very little regrowth (< 3cm). Having little regrowth made my second set of clippings unusable. Other studies (Shelly et al. 2000, Shelly et al., 2001, & Rice et al., 1997) have indicated that at least 2-3 growing seasons is needed to analyze data on treatments, and reseeding efforts. In another study (Anderson, 2003) completed in 2003, also looked at knapweed infestations and reseeding native grasses in the Kicking Horse . This study used two types of chemical applications; 2-4-D, and picloriam. The total length of this study lasted 3 years; my study only lasted 9 weeks.

In my design I applied a herbicide containing 2, D-4, Quinclorac, and Dicamba. These are herbicides that specifically target broad leaf forbs which may have also affected my final clippings. In my quadrats that were chemically treated I only had 5.09 grams of forb regrowth while mechanical quadrat was 13.07, and total forb biomass was 29.81. The amount forb of regrowth that occurred in chemical quadrats was only 10.61% of the total forb regrowth. Cover crops or forbs are important to help remove excess that could be utilized by knapweed (Herron et al., 2001). The timing of my application may have had an effect on my chemical quadrats as well.

To analysis my data I used data from my first set of clippings. I found that grass biomass is not influenced by the presence of knapweed (p-value 0.207); I did find that forb biomass is influenced by the presence of knapweed (p-value 0.006). this may be attributed to areas on the backwater by; not having a specific management plan, grazing by domesticated animals, past grazing practices (overgrazing), or possible wildlife grazing. Overgrazing on the sites could have occurred, because of the large abundance of invasive plants.

My hypothesis that knapweed will be less present at higher elevations was not significantly proven. I found knapweed growing abundantly at all elevations. My lowest elevation I sampled was at 2578 feet, while the highest elevation sampled was 4886 feet. By analyzing my data by running an ANCOVA with elevation numbers, total grass biomass, and total knapweed biomass, I did not get a significant result (P-value 0.942). This indicates that elevation did not make a difference in knapweed biomass. From this result I cannot determine if knapweed grows better at higher or lower elevation. This could be for many reasons including; management plans on the bison range, small sample size, grazing pressure; wildlife grazing, or a small variation in elevation change.

The current management plan on the National Bison Range is to rotate the bison every three weeks (Lisk, 2011). The management plan is to avoid the possibility of overgrazing any of one pasture. The herd size is about 350 bison including calves (Lisk, 2011), this number is to keep a genetically stable herd. Bison generally forage on grasses but some wildlife will consume grasses and forbs. On the bison range there are a variety of wildlife including: pronghorn antelope, elk, white tail deer, mule deer, and big horn sheep. In most cases wildlife do not actively graze on knapweed. However some studies have shown that elk do graze the flowers of spotted knapweed (Rice et al., 1997), and bighorn sheep will eat knapweed before it seeds (Miller, 1990). Because some wildlife may consume knapweed could be another reason for my analysis showing opposite results on areas on the bison range and the backwater areas.

DISCUSSION

In my study of knapweed I was able to show that the presence of spotted knapweed does significantly lower forgeable grasses and influences forb growth this supports my first hypothesis. My second hypothesis on elevation and knapweed at different elevations did not show significant results. On the bison range I found that total grass biomass is can be linked to the presence of spotted knapweed. In the backwater areas I found the opposite, forb biomass is affected by spotted knapweed presence. On the bison range I was also able to show that total grass biomass was lowered by 259.98% when spotted knapweed was present.

In future trials a larger sample size should be used I was limited in my time for clippings. A longer time frame is also needed, in my study I only clipped one time, possibly at the end of the growing season, so I was not able to accurately record any regrowth in my quadrats. Having only one growing season will not take into account any seeds that may have been dispersed or previous seed banks in the soil. Seed banks may regenerate plants the following season and can remain viable for many years.

In my clippings I should have used a larger plot area; I used a 1-meter square quadrat, and clipped everything inside the quadrat. Because I clipped all vegetation inside my quadrat I was unable to get regrowth. One possible method could have been to use a split plot, where I would split my quadrat in half. I would then clip half of the quadrat before treatments, and later come back and clip the other half to get comparable data.

For my elevation data I did not generate a significant difference in knapweed densities. Future experiments may want to use line transects to collect data. By completing a line transect I would be able to gather more data, do randomized quadrat placement, and my sampling would be less biased. The US Department of Agriculture (1996) has listed several methods for analyzing range health including Daubenmire Method, line intercept, step-point, and point intercept. in the daubenmire method a 20 X 50 cm plot is used in grass clippings. The small size allows for more samples to be completed, allows for more data. It has been shown that 40 daumenmire plots in a transect spaced one plot apart, gives a satisfactory coverage (Daubenmire, 1959). Other advantages of the daubenmire are: its small size does not allow it to be influenced by personal bias, positive errors in canopy coverage and negative errors are balanced when averaged.

In my study I found that clipping a 1-meter square quadrat took me an average of 45minutes- 1 hour depending on the density of the quadrats. Having smaller quadrats would allow for more sites to be clipped. I also noticed in many quadrats I saw a change in the size of knapweed. At low elevations I noticed that spotted knapweed grew very tall, while at high elevations spotted knapweed did not grow as tall. Another improvement would be to measure the height of vegetation, and complete individual stem counts

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APPENDIX

Table 1

Table 1 shows the biological controls for knapweed on the National Bison Range.

WEED	AGENT	DESTR.STAGE	DESCRIPTION	SITE OF ATTACK	SEASON	ADULT DESCRIPTION	SEASON
SPOTTED KNAPWEED	*AGAPETA*	LARVAE	CREAMY WHITE	ROOT MINE	SPRING	YELLOW MOTH	MID JUNE-
CENTAUREA	*ZOEGANA*		W/RED BROWN			W/BROWN	MIDAUG
MACULOSSA			CAPSULE			MARKINGS 11MM	
SPOTTED KNAPWEED	*CYPHOCLEONUS*	LARVAE	CREAMY WHITE	ROOT MINE	MID-LATE	GRAY W/BLACK	EARLY
CENTAUREA	*ACHATES*		W/RED BROWN		SUMMER	SPOTS WEEVIL	AUG-LATE
MACULOSSA			CAPSULE			15MM	SEPT
SPOTTED KNAPWEED	*URAPHORA*	LARVAE	SMALL, WHITE	SEED HEAD	SUMMER	4 MM BLACK FLY	JUNE &
CENTAUREA	*AFFINIS*		FORMS, TEARDROP			W/FAINT	JULY
MACULOSSA			SHAPED GALLS			HORIZONTAL	
			IN FLOWER			WING MARKINGS	
SPOTTED KNAPWEED	*URAPHORA*	LARVAE	SMALL, WHITE	SEED HEAD	EARLY	BLACK FLY W/DARK	SPRING-
CENTAUREA	*QUADRIFASCIATA*				SUMMER &	WING BANDS FORM	LATE FALL
MACULOSSA					EARLY FALL	UV PATTERN 4MM	
SPOTTED KNAPWEED	*METZNERIA*	LARVAE	WHITE W/DARK	SEEDS	JUNE=	MOTTLED BROWN	EARLY
CENTAUREA	*PAUCIPUNCITELLA*		BROWN HEAD		AUGUST	MOTH W/FOLDED	JUNE
MACULOSSA						BACK WINGS 8MM	

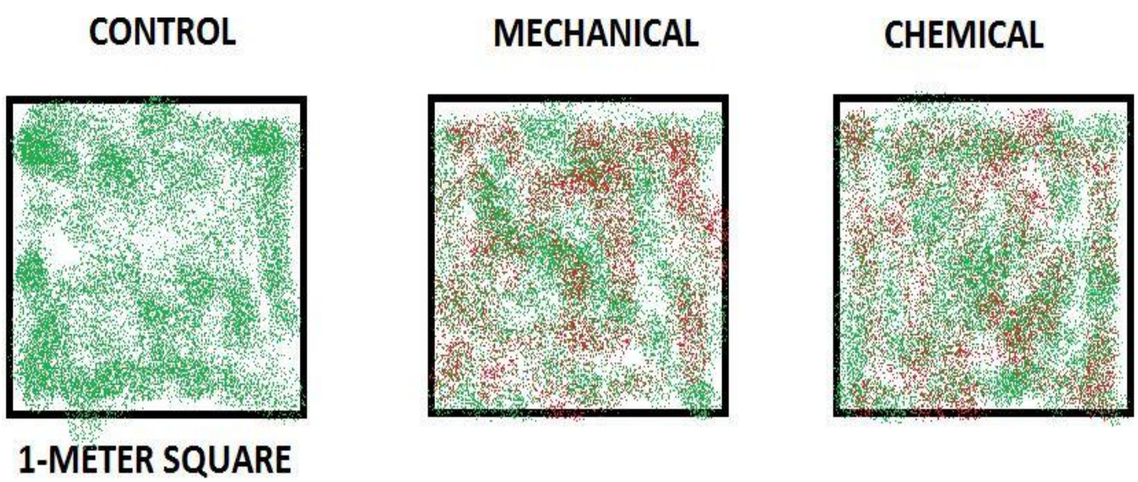


FIGURE 1
Figure 1 illustrates the three quadrates used in the first study (Control, Mechanical, and Chemical). Each quadrat will have the same coverage percent of grasses (30%), forbs/knapweed (30%), and litter (40%). I had 15 quadrats, 5 of each for each site, 30 total for both locations.

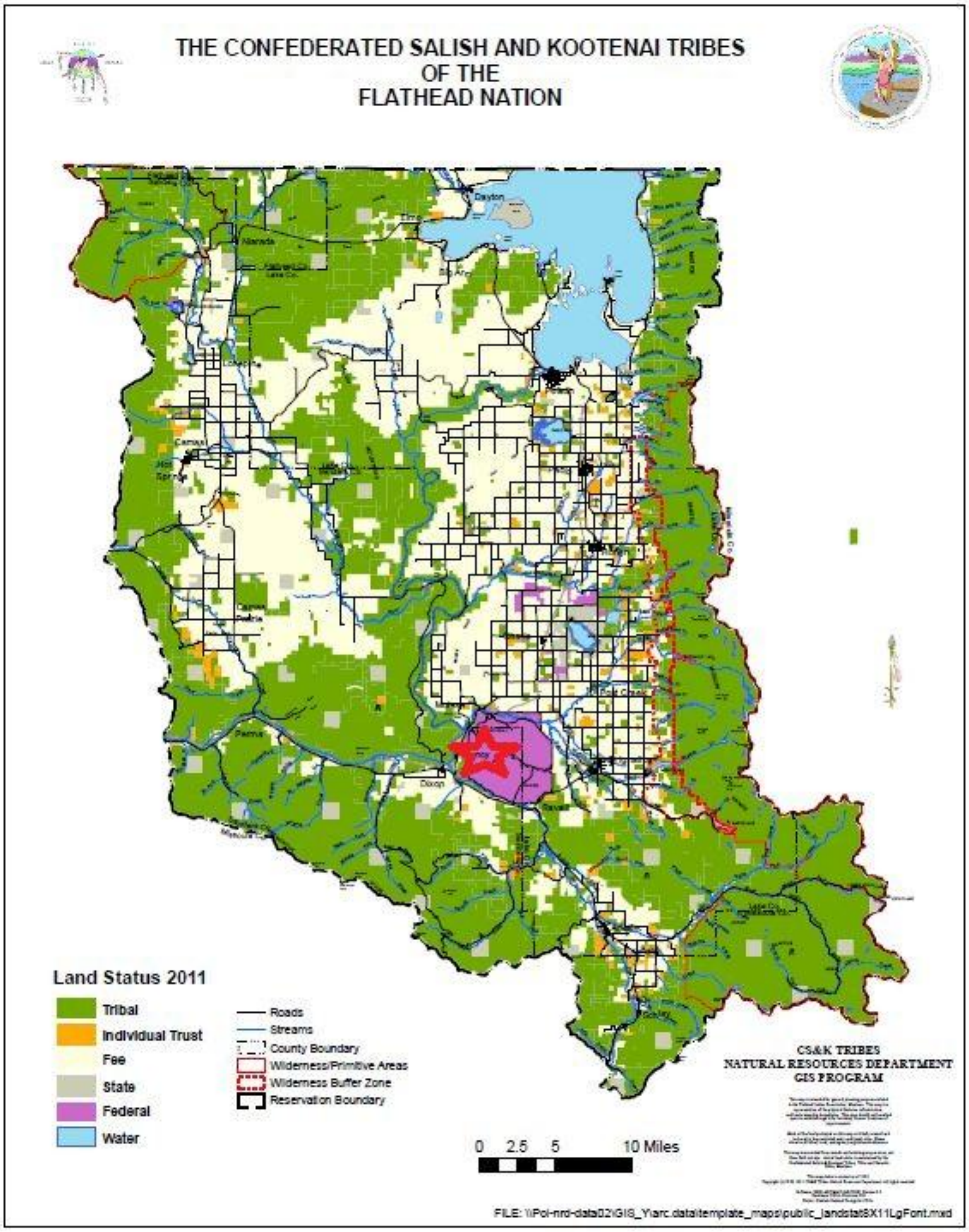


Figure 2

Figure 2 shows the general location (STAR) of my study site sites which are located on the Confederated Salish and Kootenai tribal land.

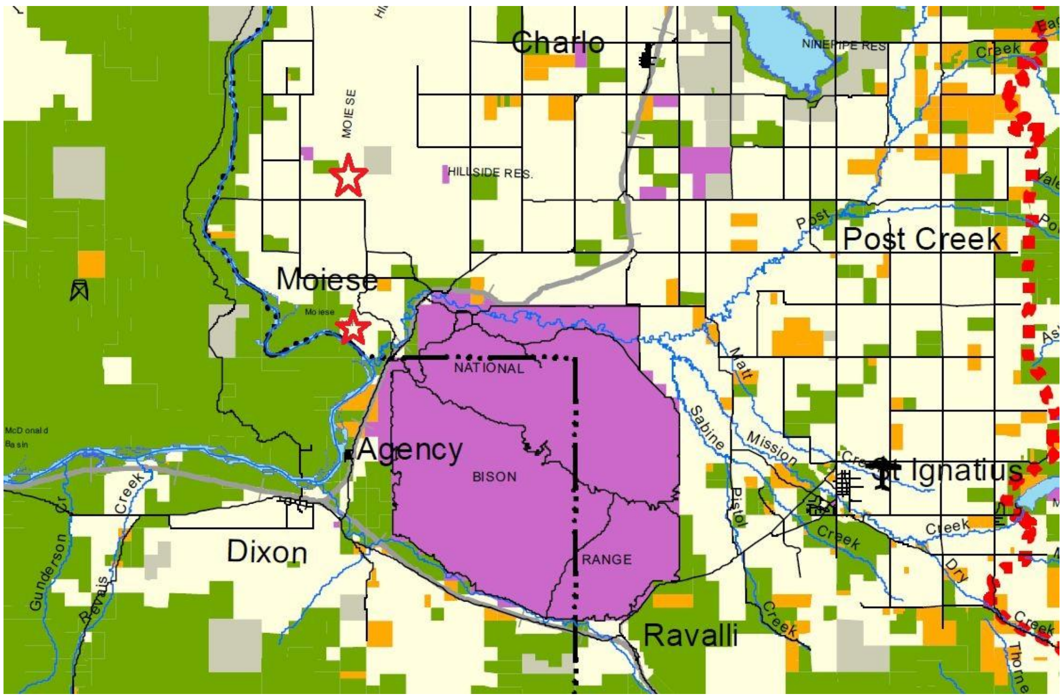
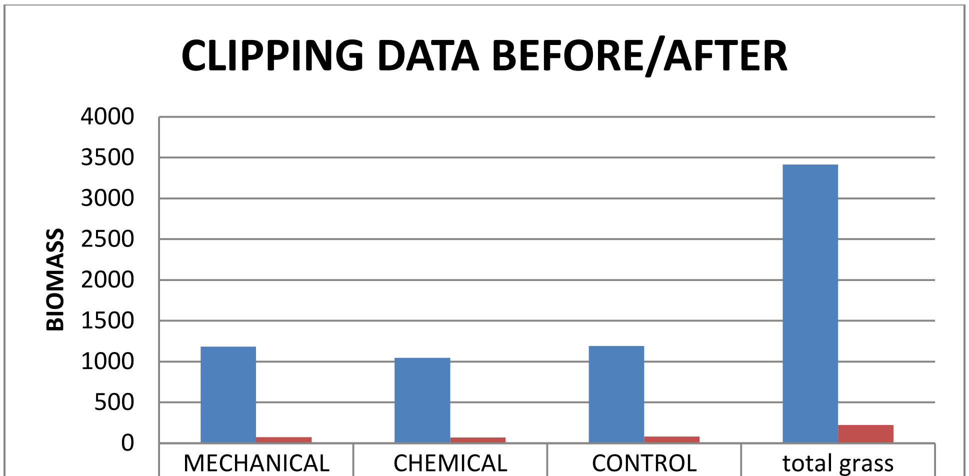


Figure 3

Figure 3 shows my 2 sites off the Bison range that were chosen for my Chemical, and Mechanical applications.



	MECHANICAL	CHEMICAL	CONTROL	total grass
before	1181.41	1043.44	1190.5	3415.35
after	74.36	68.92	79.02	222.3

Figure 4

Figure 4 illustrates data from my before and after clippings. The blue bars shows data from my first clippings. The red bars are from my second clippings. My second set of clippings did not have a lot of regrowth so data was omitted from my statistical analysis.

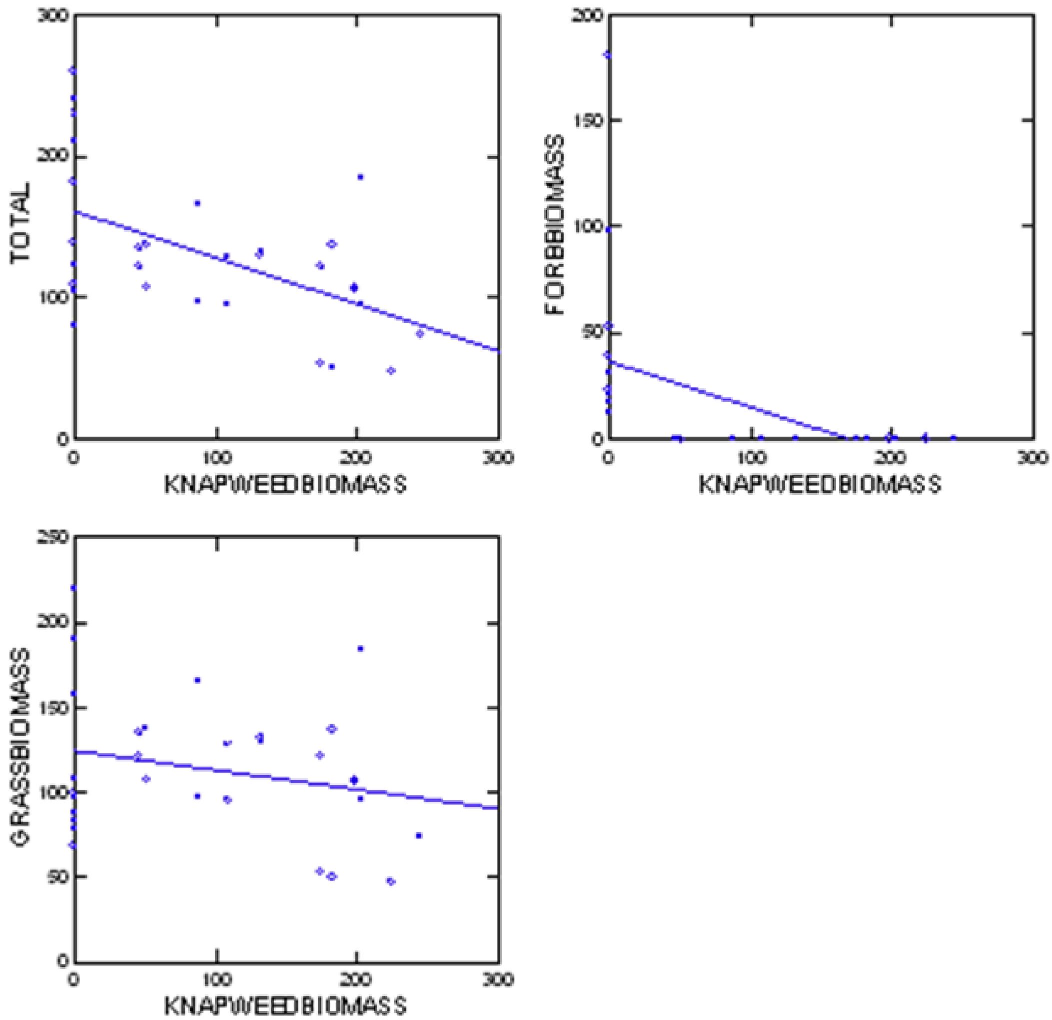


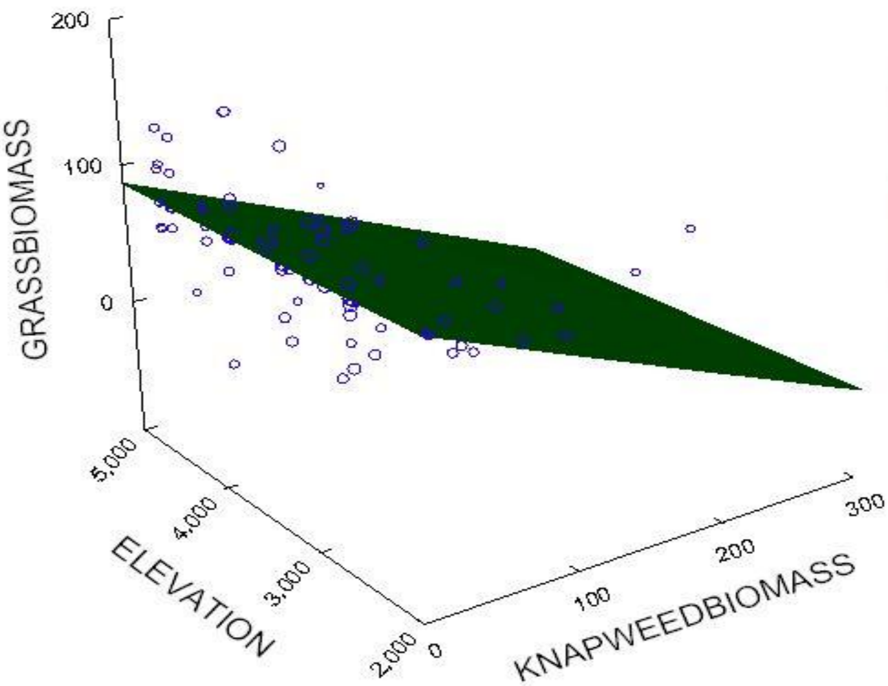
FIGURE 5

Figure 5 illustrates the total amount of biomasses for forbs, grasses, and Total biomass of forbs and grass, against spotted knapweed.

Information Criteria

AIC	630.287
AIC (Corrected)	630.989
Schwarz's BIC	638.796

Fitted Model Plot



Plot of Residuals vs Predicted Values

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Figure 6

Figure 6 is from and ANCOVA that I tried to complete but I did not have significant results (p-value 0.942). Data used for the ANCOVA were elevation, knapweed biomass and grass biomass.

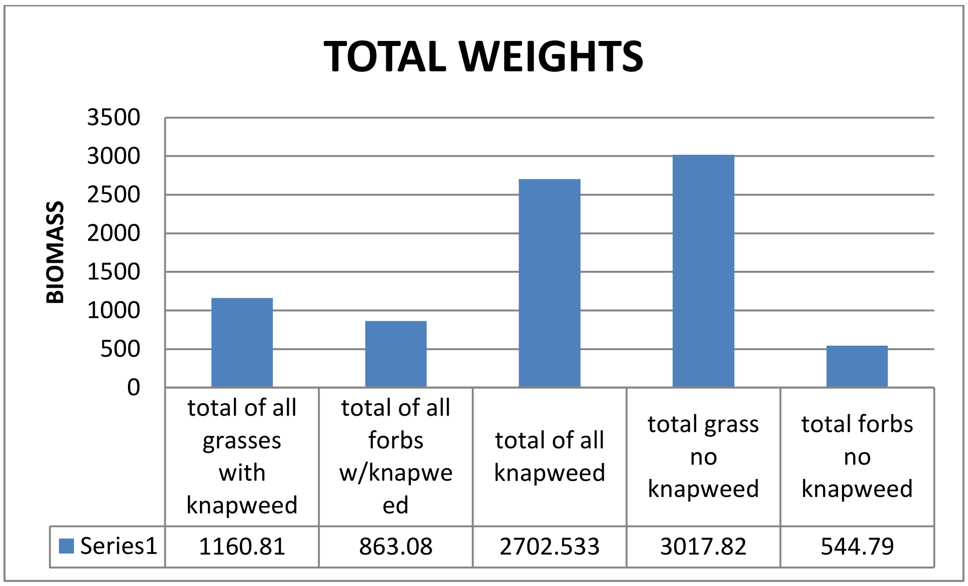

Figure 7

Figure 7 shows Total weights of clippings on the Bison range for the elevation study.

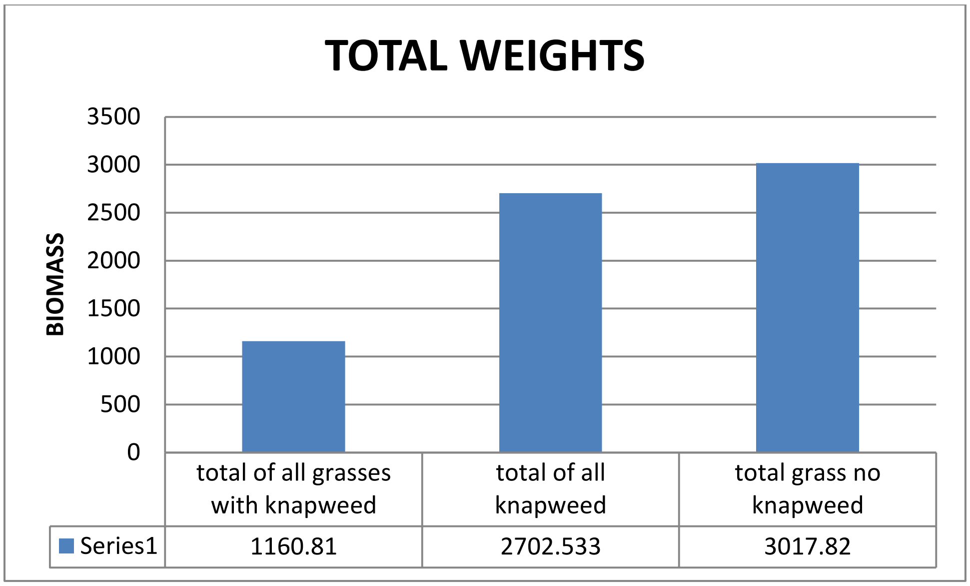

Figure 8

Figure 8 illustrates a proportion of grass with knapweed and grass without knapweed. A reduction of 259.98% was observed in areas with no knapweed