The Impact of Wood Shrub Encroachment on a Montana Grassland

By Chelsea Merriman

The University of Notre Dame Environmental Research Center—West

Advisor: Dr. Angela Laws

2014

Abstract

Woody shrub encroachment has been a much-studied topic over the past few decades. Causes of this encroachment have been attributed to man sources, including fire suppression, climate change, changes in nutrient availability, and overgrazing. At the National Bison Range National Wildlife Refuge in Moiese, Montana, species and cover information was obtained by analyzing the abundance of shrub islands, as well as differences in cover, composition, species density, and soil characteristics of shrub islands and native grasslands in the National Bison Range. Shrub islands showed significantly higher presence throughout the Eastern portion of the National Bison Range, as well as at median elevation levels. Within plots, shrub islands showed a decrease in species richness yet an increase in total cover. By understanding the trends of encroaching shrub islands, the National Bison Range may be better able to understand future implications of woody vegetation on the biodiversity and function of is refuge.

Introduction

Over the past few decades, density, cover, and biomass of shrubby plants have increased throughout grasslands across the globe (Van Auken 2000, Archer et al 2001). Since then, both the causes and the consequences of this shrub encroachment onto arid and semi-arid grasslands has been the subject of extensive study across the globe (Eldridge et al 2011, Van Auken 2000, Knapp et al 2008), with incredibly variable results. In addition to displacing native grasslands, shrub encroachment has been called both a primary step towards desertification (Eldridge et al 2011, Bhark et al 2003, Garner and Seinberger 1989) and, in other contexts, a valuable future carbon sink (Houghton et al 1999, Knapp et al 2008, Montane et al 2010). This variation in the understanding of the importance and potential effects of shrub islands provides a number of potential questions regarding ecosystem stability and dynamics (Van Langevelde et al 2003).

The causes of this shrub encroachment has been said to be dependent on the context of each individual site currently experiencing shrub cover (Eldridge et al 2011, Van Auken 2009). Fire suppression (Briggs et al 2005), grazing (Briggs et al 2002), climate change (MacDonald 1989), changes in water availability (Gilad 2007), and changing nutrient availability (Kochy and Wilson 2001) have all been cited as potential explanations for this shift in vegetation composition.

While shrub encroachment is often associated with invasion or ecosystem degradation, it is usually always by a native shrub species moving beyond its former natural habitat (Van Auken 2009)

Similarly, consequences of woody shrub encroachment on vegetation and soil dynamics have also been found to be context specific (Eldridge et al 2011). While many studies have seen this shift in vegetation dynamics to be indicative of environmental degradation (Geist and Lambin 2004, Garner and Seinberger 1989, Huenneke et al 2002), it has also been predicted to be yet another part of ecosystem projection (Eldridge et al 2011, Eldridge et al 2013), as well as a future valuable carbon sink (Knapp et al 2008).

Shrub encroachment in Northwestern Montana has yet to be studied in great detail, despite the extensive amounts of grasslands used there for both agriculture and conservation. As global climate change alters local precipitation and temperature patterns in the region, understanding the causes and impacts of this woody shrub encroachment is becoming increasingly important to understanding future shifts in management and conservation planning.

While much of the Bison Range has been studied previously, little emphasis has been given to understanding the movement of these shrubs from formerly natural areas across the entirety of the range. This study sought to determine how shrub islands are situated throughout the National Bison Range National Wildlife Refuge, as well as how those islands affect local vegetation dynamics in the refuge.

It was hypothesized that both elevation and grazing intensity would play a large role in determining presence, abundance, and composition of woody shrub islands on the National Bison Range. Lower elevations are likely to find a higher availability of water, increasing the probability for success of shrub islands. While intermediate levels of grazing are shown to increase the heterogeneity of their grasslands (Montane et al 2011), extreme amounts of grazing has been shown to reduce this heterogeneity due to increased disturbance (Eldridge et al 2013). Therefore, it was also predicted that areas with medium amounts of grazing would be more likely to exhibit a more balanced habitat composition.

Vegetation characteristics between shrub islands and grasslands were hypothesized to vary according to species composition in each area. As shrubs are generally taller and thicker than grasses, it was predicted that shrub islands would have far more cover and less diversity than their surrounding grasslands habitat.

Materials and Methods

Site Description

This research was conducted at the National Bison Range National Wildlife Refuge in Moiese, Montana. The National Bison Range is historically an arid bunchgrass prairie grazed upon by a number of animals including Bison (*Bison bison*), Mule and White Tail Deer (*Odocoileus hemionus* and *virginianus*), Pronghorn antelope (*Antilocapra americana*), Elk (*Cervus elaphus*), ad bighorn sheep (*Ovis canadensis*).

Among others, common native grassland plant species include Tailcup Lupine (*Lupinus caudatus*), Arrowleaf Balsamroot (*Balsamorhiza sagittata*), White sagebrush

(*Artemisia* ludoviciana), Snowberry (*Symphoricarpos occidentalis*), Woods' rose (*Rosa woodsii)* and Bunchgrass (*Festuca idahoensis*). Common invasive species recognized in this region include Cheatgrass (*Bromus tectorum*), Pepperweed (*Lepidium latifolium*), St. John's Wort (*Hypericum perforatum*), Canada Thistle (*Cirsium arvense*), Dalmation Toadflax (*Linaria vulgaris*), and Sulphur Cinquefoil (*Potentilla recta*).

Site Selection & Measurement

Shrub encroachment at the National Bison Range was estimated paralleling the methodology used by Eldridge et al (2013b) using 12 randomly sampled 50 meter by 50 meter plots with level slopes throughout the perimeter of the refuge (Figure 1). Due to traffic, the Northern portion of the Bison Range was avoided. Sites in forested areas, along roads, and in drainage areas were not included. Within each site, elevation was recorded and the species of vegetation was recorded every half meter along three 50 meter transects (located at 5m, 25m, and 45m). Shrub islands were marked and counted and their length and width recorded.

Plant diversity was measured by measuring 30 0.5m x 0.5m quadrats throughout each of the 12 plots. Each quadrat was classified as "Shrubby," "Edge," or "Grassy," and species richness, plant cover, and density was measured using a Daubenmire Frame (1959) and recorded.

Statistical Analyses

Shrub proportion and abundance at the National Bison Range was compared to elevation using a linear regression in order to estimate trends in encroachment. Shrub proportion was also compared by location on the National Bison Range using Analysis of Variance. Similarly, vegetation characteristics between Shrubby, Edge, and Grassy quadrats were also compared using Analyses of Variance.

Results

The two main species of shrub found within research sites were the native shrubs Snowberry (*Symphoricarpos occidentalis*) and Woods' rose (*Rosa woodsii).* Elevation of sites ranged only from 2,661 feet above sea level to 3,199 feet above sea level. Soils at most sites were composed of either silty or gravely loam. Average number of islands for all sites was five islands per plot, with an average total area of 4,517 m^2.

Shrub proportion at the Bison Range was shown to be significantly higher on the East side of the National Bison Range (F- 7.178,, df=2, p=0.014). When analyzed with a Non-Linear Regression, elevation showed a parabolic curve emphasizing median elevations in higher shrub areas that approached significance (F=3.520, df=11, p=0.068). Within plots, species richness was significantly higher in grassy areas than shrubby areas (F=22.85, df=2, p<0.01), while total cover was significantly higher in shrubby areas (F=18.5, df=2, p<0.01).

Discussion

Woody shrub encroachment has been an intensely studied theme in ecology in the Western United States for the past few decades (Eldridge et al 2011). Despite this, little is still known about the movement of these shrubs throughout the National Bison Range. While no temporal research was conducted, this study found a significant pattern to shrub placement at the National Bison Range, both by elevation (Figure 2) and by portion of the Bison Range (Figure 3). Areas of medium elevation were more positively associated with increasing amounts of shrub, whereas lower elevation and moderately high elevations were less likely to host shrub islands. There were no islands seen at all on the western portion of the Bison Range and in one of the plots on the Southern portion of the Range.

These patterns in elevation and orientation of shrub islands at the National Bison Range could be for a number of reasons. If shrub islands are moving out of their natural habitats (Van Auken 2009), there could still be a gradual climb from mid-sized ravines within the Bison Range to higher elevations that is still in progress. Similarly, questions of light availability and soil nutrient and moisture availability could also be affecting island location (MacDonald 1989, Gilad 2007, Kochy and Wilson 2001). As there are more and longer drainage flows on the Eastern portion of the Bison range (Figure 4), this could be a source of increased soil moisture capable of facilitating shrub growth (Gilad 2007, Sankaran and Anderson 2009).

Additionally, bison graze much more commonly in the summer on the Eastern side of the Bison range, often in areas where evidence of shrub encroachment can be found. This could be a source of intermediate disturbance that is native to the Bison Range but still capable of positively facilitating a heterogeneous landscape that is more conducive to shrub growth (Montane et al 2011, Eldridge et al 2013). This, coupled with browsing by pronghorn and mule deer, may further promote the spread of these plant species. As bison grazing reduces the amount of grasses present, woody shrubs are better able to find a place to settle. Once there, shrub islands are able to affect soil resources and light availability, promoting the fertile island effect (Schlesinger et al 1990, Schlesinger et al 1996) that leaves islands more resilient to disturbance and better able to spread.

As was also predicted, plant richness was much higher outside of shrub islands (Figure 5), while cover was greater within the shrub islands (Figure 6). Most diversity in the quadrats was attributed to multiple species of grass surrounding one or two different forb species. Due to the naturally larger size and spread of woody shrub, this lack of diversity but increase in cover agrees with most studies regarding general ecosystem health (Montane et al 2011, Eldridge et al 2011, Schlesinger and Pilmanis 1998).

Future studies at the National Bison Range regarding shrub encroachment should focus on understanding the abiotic factors facilitating the variable encroachment of the shrub throughout its property. Additionally, understanding the larger effects of shrub encroachment on habitat structure could help to understand changing ecosystem composition. As shrubs move out of their natural habitat, they open up new niches within grasslands that could potentially alter herbivore and avian composition on a local scale (Wiezik et al 2013, Ayres et al 2001). Understanding how other trophic levels respond to changing vegetation structure and composition may help influence future management strategies within the Bison Range.

Conclusion

The National Bison Range National Wildlife Refuge focuses on conserving wildlife and plants in a bunchgrass prairie ecosystem. As woody shrub encroachment changes the overall vegetation structure of these median elevations throughout the refuge, management questions will need to focus on understanding how those shifts affect the larger diversity at the National Bison Range. As these encroaching shrubs are largely native, species composition is less likely to change, though overall structure may be affected. Understanding how and where woody shrubs are moving into the grasslands at the Bison Range is the first step to maintaining ecosystem function in order to conserve this mission of conservation.

Acknowledgements

Special thanks to the National Bison Range National Wildlife Refuge for the use of their property throughout this study, as well as to University of Notre Dame Environmental Research Center and the generosity of the Bernard J. Hank Family Endowment for the funding of this program. Thanks to Dr. Angela Laws and Dr. Gary Belovsky for their generous time and teaching.

References Cited

Archer, S, TW Bouton, and KA Hibbard. 2001. Trees in grasslands: biogeochemical consequences of woody plant expansion. *Global Biogeochemical Cyclesin the Climate System* (eds ED Schulze, SP Harrison, M Heimann, EA Holland, J Lloyd, LC Prentice and D Schimel) pp 115-130. Academic Press. Sand Diego, CA.

Ayres, D., G Melville, J Bean, D Beckers, M Ellis, T Mazzer et al. 2001. *Woody Weeds, Biodiversity and Landscape Function in Western New South Wales*. WEST 2000, Dubbo, Australia. 221pp.

Bhark, EW, EE Small. 2003. Association between plant canopies and the spatial patterns of infiltration in shrubland and grassland of the Chihuahuan desert, New Mexico. *Ecosystems*. 6:185-196.

Briggs, JM, AK Knapp, BL Brock. 2002. Expansion of woody plants in tallgrass prairie: a fifteen year study of fire and fire-grazing interactions. *American Midland Naturalist*. 147:287-294.

Briggs, JM, AK Knapp, JM Blair, JL Heisler, GA Hoch, MS Lett, K McCarron. 2005. An ecosystem in transition: woody plant expansion into mesic grassland. *BioScience*. 55:243-254.

Eldridge, D.J., MA Bowker, FT Maestre, E Roger, JF Reynolds and WG Whitford. 2011. Impacts of shrub encroachment on ecosystem structure and functioning: towards a global synthesis. *Ecology Letters*. 14:709-722.

Eldridge, DJ, S Soliveres, MA Bowker, and J Val. 2013. Grazing dampens the positive effects of shrub encroachment on ecosystem functions in a semi-arid woodland. *Journal of Applied Ecology*. 50:1028-1038.

Daubenmire, RF. 1959. A Canopy Coverage Method of Vegetational Analysis. *Northwest Science*. 33:43-64.

Garner, W and Y Seinberger. 1989. A proposed mechanism for the creation of 'fertile islands' in the desert ecosystems. *Journal of Arid Environments*. 16:257-262.

Geist, HJ, and EF Lambin. 2004. Dynamic causal patterns of desertification. *Bioscience*. 54:817-829.

Gilad, e., M Shachak, E Meron. 2007. Dynamics and spatial organization of plant communities in water limited systems. *Theoretical Population Biology*. 72:214-230.

Houghton, RA, JL Hackler, JT Lawrence. 1999. The US carbon budget: contributions from land-use change. *Science*. 285:574-578.

Huenneke, LF, JP Anderson, M Remmenga, WH Schlesinger. 2002. Desertification alters patterns of aboveground net primary production in Chihuahuan Desert vegetation: implications for sampling methods in semi-arid ecosystems. *Journal of Arid Environments*. 47:257-270.

Knapp, A., J.M. Briggs, S.L. Collins, S.R. Archer, M.S. Bret-Harte, B.E. Ewers, D.P. Peters, D.R. Young, G.R. Shaver, E. Pendall, and M.B. Cleary. 2008. Shrub encroachment in North American grasslands: shifts in growth form dominance rapidly alters control of ecosystem carbon inputs. *Global Change Biology*. 14:615-623

Kochy, M, SD Wilson. 2001. Nitrogen deposition and forest expansion in the northern Great Plains. *Journal of Ecology*. 89:807-817.

Montane, F., J Romanya, P Rovira, P Casals. 2010. Aboveground litter quality changes may drive soil organic carbon increase after shrub encroachment into mountain grasslands. *Plant Soil*. 337:151-165.

Sanaran, M. and TM Anderson. 2009. Management and restoration in African Savannas: Interactions and Feedbacks. In: *New Models for Ecosystem Dynamics and Restoration* (eds Hobbs, R., and K Sading). Island Press, Washington, pp 136-153.

Schlesinger, WH and AM Pilmanis. 1998. Plant-soil interactions in deserts. *Biogeochemistry*. 42:169-187.

Schlesinger, WH, JF Reynolds, GL Cunningham, LF Huennee, WM Jarrell, RA Virginia *et al*. 1990. Biological feedbacks in global desertification. *Science*. 247:1043-1048.

Schlesinger, WH, JA Raikes, AE Hartley and AE Cross. 1996. On the spatial pattern of soil moisture in desert ecosystems. *Ecology*. 77:364-374.

Van Auken, OW. 2000. Shrub invasions of North American semi-arid grasslands. *Annual Review of Ecology and Systematics*. 31:197-215.

Van Auken, OW 2009. Causes and consequences of woody plant encroachment into western North American grasslands. *Journal of Environmental Management*. 90:2931-2942.

Van Langevelde, F, CADM Van de Vijver, L Kumar, J van De Koppel, N de Ridder, J van Andel, AK Skidmore, JW Hearne, L Stroosnijder, WJ Bond, HHT Prins, M Rietkerk. 2003. Effects of fire and herbivory on the stability of savanna ecosystems. *Ecology Letters*. 84:337-350.

Wiezik, M., M Svitok, A Wiezikova, M Dovciak. 2013. Shrub encroachment alters composition and diversity of ant communities in abandoned grasslands of western Carpathians. *Biodiversity & Conservation*. 22:2305-2320.

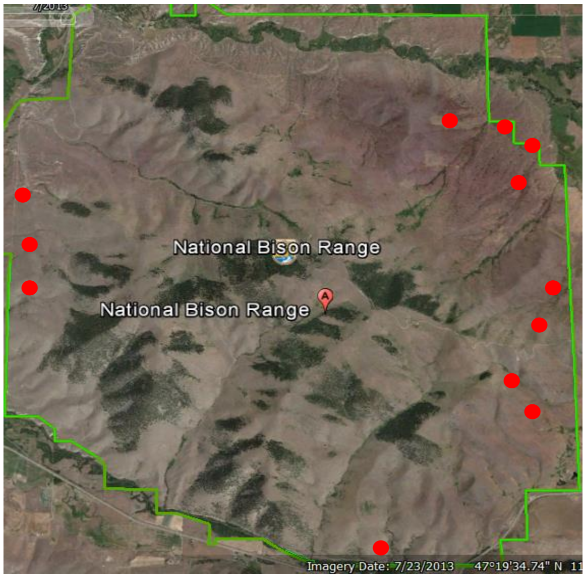

Figure 1: Map of the National Bison Range National Wildlife Refuge and plot sites.

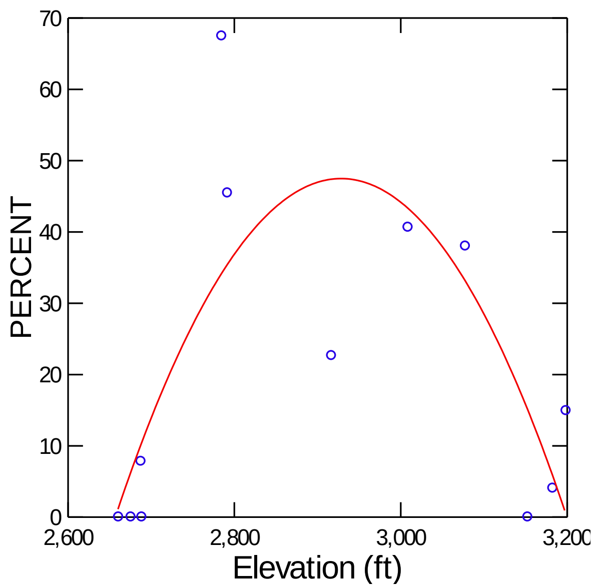

Figure 2: Shrub cover varied Non-linearly with changing elevation. F=3.520, df=11, p=0.068

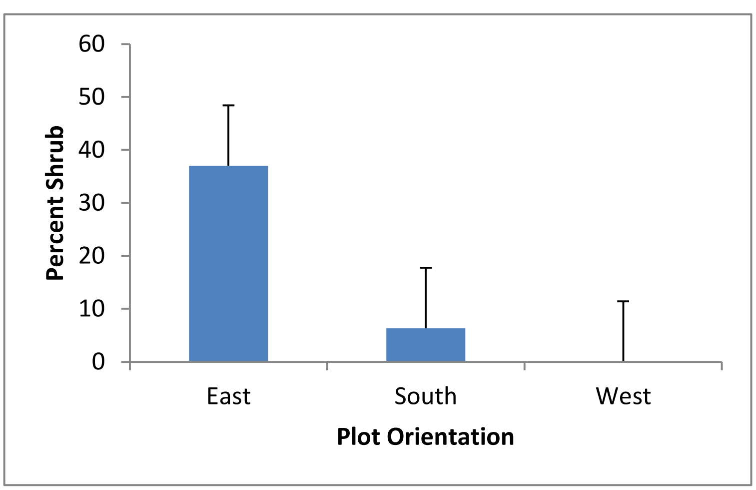

Figure 3: Shrub cover varied on different faces of the Bison Range, with more shrubs being visible on the East side of the Bison range. F=7.178, df=2, p= 0.014.

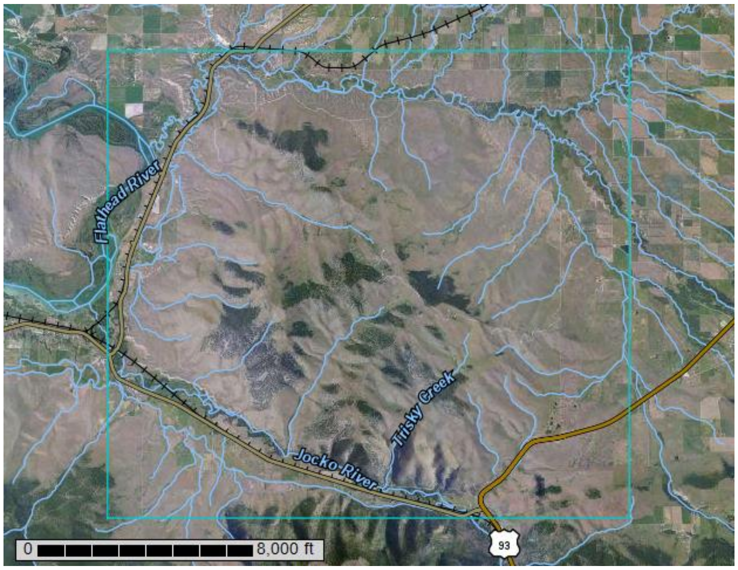

Figure 4: Water routes of the National Bison Range National Wildlife Refuge.

Figure 5: Species Richness was much higher in non-shrubby areas than areas with shrubs. $F=22.85$, $df=2$, $p<0.01$.

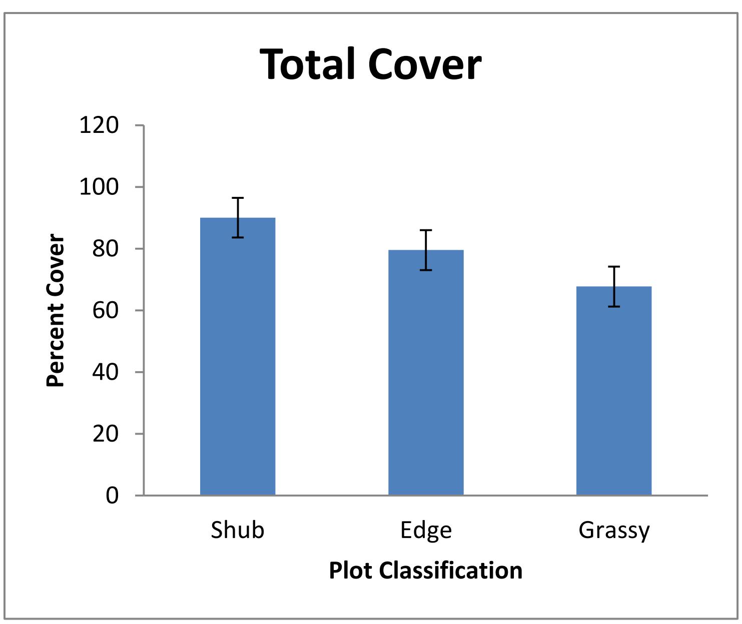

Figure 6: Total cover is higher in shrubby areas than grassy areas. $F=18.5$, $df=2$, $p<0.01$.