University of Nevada, Reno

Post-fire monitoring of multiple riparian indicators

A thesis submitted in partial fulfillment of the requirements

for the degree of Master of Science in Hydrogeology

By

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Abstract

Bureau of Land Management (BLM) customarily prohibits grazing near riparian areas for two years post-fire in order to let bank stabilizing vegetation to recover. However, there is a lack of science to justify this tradition. Wildfire in northern Nevada in 2012 provided an opportunity to explore this as well as to compare spring-only grazing with hot-season grazing. Multiple Indicator Monitoring (MIM) was used to evaluate riparian health and short and long-term indications of grazing impact. In this study, BLM authorized grazing to resume in eight Designated Monitoring Areas (DMA)s after only one year of exclusion, contrary to custom. Four other pastures were grazed ranging from zero (no exclusion) to four years of grazing exclusion. As these grazing strategies are unreplicated, our results should not be used to infer specific treatment effects. While there were no significant differences found between hot-season grazed areas and spring-only grazed areas, this may be due to the time of sampling (i.e. sampling occurred during summer break from school, so observations did not capture the full hot-season grazing impact).

Acknowledgements

First and foremost, all glory and honor goes to God! There will be many that think this statement has no place here, but they would not have seen the countless obstacles and impossible situations that had to be overcome to make this come to pass. But it could not happen without the help of boots-on-the-ground.

Thank you, Dr. Sherm Swanson, for training me far beyond academic bounds. When we first met, I knew you had much to teach me, and you did not disappoint. Your next publications are highly anticipated. Thank you for mentoring me!

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I no longer see groundwater. Nor, surface water. Water exists as four-dimensional flux.

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Lastly, to the woman that instigated this all, my former mentor, Sarah Trebilcock. Thank you for pushing me towards my dreams, long after i'd deemed myself unworthy.

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Table 1- List of Acronyms

BLM	Bureau of Land Management
DMA	Designated Monitoring Area
ESR	Emergency Stabilization and Rehabilitation Handbook
MIM	Multiple Indicator Monitoring
PFC	Proper Functioning Condition
UNR	University of Nevada, Reno

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Post-fire monitoring of multiple riparian indicators

Brian Rasmussen

Keywords: Multiple Indicator Monitoring (MIM), fire recovery, post-fire grazing management, grazing exclusion

Introduction

Nevadan districts in the Bureau of Land Management (BLM) have customarily closed pastures to grazing for two growing seasons after prescribed or wildfire to allow vegetation (typically upland vegetation) to recover (Wright et al. 1979). When that tradition was established, little research had been conducted to determine the interaction of grazing with vegetation recovery after fire (Roselle et al. 2010). After publication of Multiple Indicator Monitoring (MIM) by Burton et al. (2011), the BLM Elko District was admonished by the BLM Nevada State Office that they should quantitatively monitor riparian recovery for achievement of objectives, rather than rely on riparian proper functioning condition (PFC) (Prichard 1998, Dickard et al. 2015) assessment-observed improvements for decisions about return of grazing. Thus, rate of riparian recovery became more a pertinent question. MIM was the tool chosen to address this as it is a quantitative data collection method with established data reduction tools (Burton et al. 2011)

The Hanson and Holloway lightning-ignited fires of 2012 in northern Nevada provided an opportunity to explore this, as well as comparing recovery between spring-only and hot-season grazed areas. MIM (Burton et al. 2011) was used in tracking long-term indicators to evaluate riparian health and short-term indicators to evaluate grazing impact. This research uses the same study sites established in “Riparian post-fire response: factors influencing vegetation recovery and channel stability” by Dencker et al. (2017) using data collected in 2016.

Stream channels are naturally dynamic with varying rates of annual disturbance, but streams are constantly adjusting as they recover stability and maintain channel capacity and competence (Bernard et al. 1998). Reaches composed of non-cohesive, fine-grained alluvium are susceptible to mass wasting and bank shearing, so may be more dependent on vegetation to maintain bank integrity (Abernethy and Rutherfurd 1998, Gurnell 2014, Swanson 2015). Once destabilization occurs, it may be difficult for vegetation to reestablish as banks stabilize (Corenblit et al. 2007).

Riparian areas may act similarly to a sponge, slowing water runoff, recharging groundwater (Dickard et al. 2015), and retaining moisture availability longer into the growing season (Elmore, 1997; Wagner, 2015). Riparian and stream habitats are most sensitive and dynamic at the interface between substrate or streambank and water. Because hydrophilic vegetation is often heavily rooted with woody or fine roots and rhizomatous stems, it can resist stream erosion due to these superior site-stabilizing characteristics (Manning et al., 1989; Corenblit et al. 2007; Dickard et al. 2015).

Vegetation stabilizes banks primarily by increasing shear strength of the soil (Thorne and Lewin, 1979; Gray and MacDonald, 1989), reducing water velocity (Gray and MacDonald 1989), and armoring the bank (Thorne, 1979; Simon, 2000).

Riparian areas commonly flood, resulting in adaptations by vegetation to mitigate the effects of a frequent disturbance regime (Naiman et al. 1993, Dwire and Kauffman 2003, Corenblit 2007 and 2009, Swanson et al. 2017). Rhizomatous roots and the ability to resprout from remaining plant material allows for quick plant regeneration following above ground vegetation removal. These mechanisms can facilitate survival following wildland fire, giving them a competitive edge in contributing to the rapid recovery of riparian areas. This has direct implications for the functionality of the entire system, as riparian vegetation has a well-established relationship with channel morphology, hydrologic function and geomorphic processes of the stream (Beschta and Platts 1986; Tabacchi et al. 1998; Hession et al. 2003) as assessed in PFC (Dickard et al. 2015). Micheli and Kirchner (2002) found herbaceous riparian vegetation reinforces streambanks by increasing soil strength and stabilizing undercut banks. Root complexes of wetland obligate species are extensive and work to stave erosion and preserve channel form (Wyman et al. 2006). Vegetation stabilizes banks by increasing shear strength of the soil (Thorne and Lewin 1979, Gray and MacDonald 1989, Simon and Collision 2001), reducing water velocity (Gray and MacDonald 1989), and armoring the bank (Thorne 1982, Simon and Collision 2001).

Riparian areas that function properly are much more resilient and resist crossing an ecologic or geomorphic threshold, withstand grazing pressure, and recover from short-term impacts (Swanson, 2015; Dickard et al., 2015). Recovery of vegetation is particularly important in riparian areas, where stability can moderate the devastating effects of episodic floods (Prichard, 1998). Vegetation may persist after fire by regenerating after top-kill, by resprouting, or with seeds that survive fire (Sugihara et al., 2006). Because vegetation relies on foliage for energy production, survival of damaged plants depends on rapid regeneration of burned foliage (Sugihara et al., 2006).

Measuring this recovery and potential impact from grazing requires specific monitoring. In 2011, after extensive review from the U.S. Forest Service and many others, BLM published Multiple Indicator Monitoring (MIM) of Stream Channels and Riparian Vegetation (Burton et al. 2011). These methods built on riparian vegetation monitoring developed by Winward (2000) for the U.S. Forest Service by focusing many riparian vegetation measurements on the greenline, where riparian vegetation is most critical for maintaining bank and channel stability (Wyman et al. 2006; Burton et al. 2011; Swanson et al. 2017). Greenline refers to “the first perennial vegetation that forms… on or near the water’s edge” (Winward, 2000). It is the critical zone for maintaining bank stability and channel form and is highly stressed as an important measure in the Emergency Stabilization and Rehabilitation (ESR) Handbook (DOI, 2007), Riparian Proper Functioning Condition Assessment (Dickard et al. 2015) and riparian grazing management guidelines (Wyman et al., 2006).

The intent of the ESR was to enable post-fire recovery of vegetation for the stabilization of soils, but does not mandate a specific timeframe, enabling management to regulate on an individual, case-by-case basis. PFC involves the interlinking factors of water, vegetation, and soils/landforms. MIM was developed to objectively and efficiently quantify current stream conditions and changes integrated over time when subjected to livestock impact or changes in grazing management.

In 2010, Kozlowski et al. studied pre to post-fire changes of ten riparian attributes sampled from 43 burned streams. Bankfull width decreased 21%, riparian width increased 79%, bank stability slightly increased, and median bank angle slightly decreased. Bank cover, organic debris, bank undercuts, and embeddedness did not change. Furthermore, "overall, degradation to stream channel attributes was minimal to non-existent suggesting riparian stability and/or resiliency." However, post-fire years generally had below average precipitation, and the resulting flows were not large enough to result in the damage that could be expected if there had been a flooding event in nonfunctional or functional at-risk riparian areas as in Myers and Swanson (1996). Overall, they found there was little evidence suggesting that fire caused stream degradation in any of the 43 study streams. On the contrary, many of the streams showed improvement, but whether this resulted from the effects of fire or the changes in land management could not be ascertained (Kozlowski, 2010).

Dalldorf et al. (2013) used livestock grazing variables derived from 24 years of federal grazing management history to "identify interactive effects of grazing strategies, fire, and natural stressors across 81 independent riparian areas." These included those studied by Kozlowski (2010) and another set chosen to approximate similar unburned streams in the various mountain ranges or areas of Nevada. They found that an increase in bankfull width was less likely with a spring-grazing prescription, and that responsible grazing can result in positive stream response.

Dencker et al. (2017) found that a significant negative change in bank stability was observed from year two to year three post-fire. Results suggested a two-year rest from grazing was not adequate to maintain an upward trend towards recovery. After fire, sites with fine textured soils were found to be more susceptible to bank instability and were destabilized with increased duration of post-fire grazing. Bank stability was significantly greater at sites with spring-only grazing versus sites with hot season grazing. They concluded that a longer rest or recovery period from grazing (e.g. 3+ years) may be required to maintain site stability. Minimum values for MIM indices had not yet been determined and may depend on vegetation community, substrate texture, and bank condition prior to the fire.

Methods

All of the Designated Monitoring Areas (DMAs) used for this study were located within one of two areas burned in 2012 on public lands within the Great Basin region of Nevada. The Holloway fire was the largest, burning 175,000 hectares (676 square miles) in Nevada and Oregon between August 5th and 15th. The Hanson fire, also starting on August 5th, burned 5,200 hectares (20 square miles) (USFS, 2019). The Holloway fire burned in the Kings River valley, and the Hanson fire in Paradise Valley (Figure 1- Extent of, page 7). All four of the DMAs in the Hanson fire were grazed as spring only use. All twelve DMAs in this study were in pool-riffle systems (Montgomery and Buffington 1998). Sites were originally selected by Dencker (2017), under the guidance of Winnemucca BLM hydrologist John McCann, to likely reflect BLM priority reaches.

Study area

Figure 1- Extent of the Holloway and Hanson fires

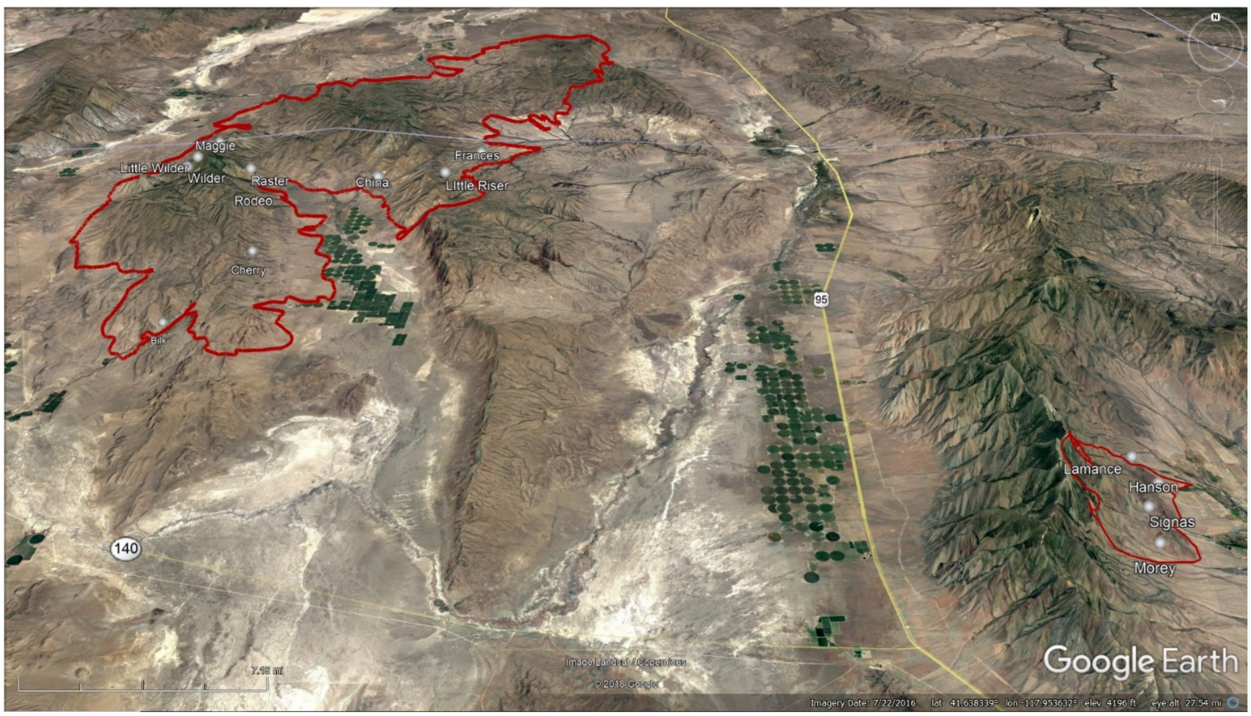


Figure 2- Vicinity map

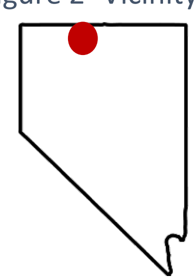
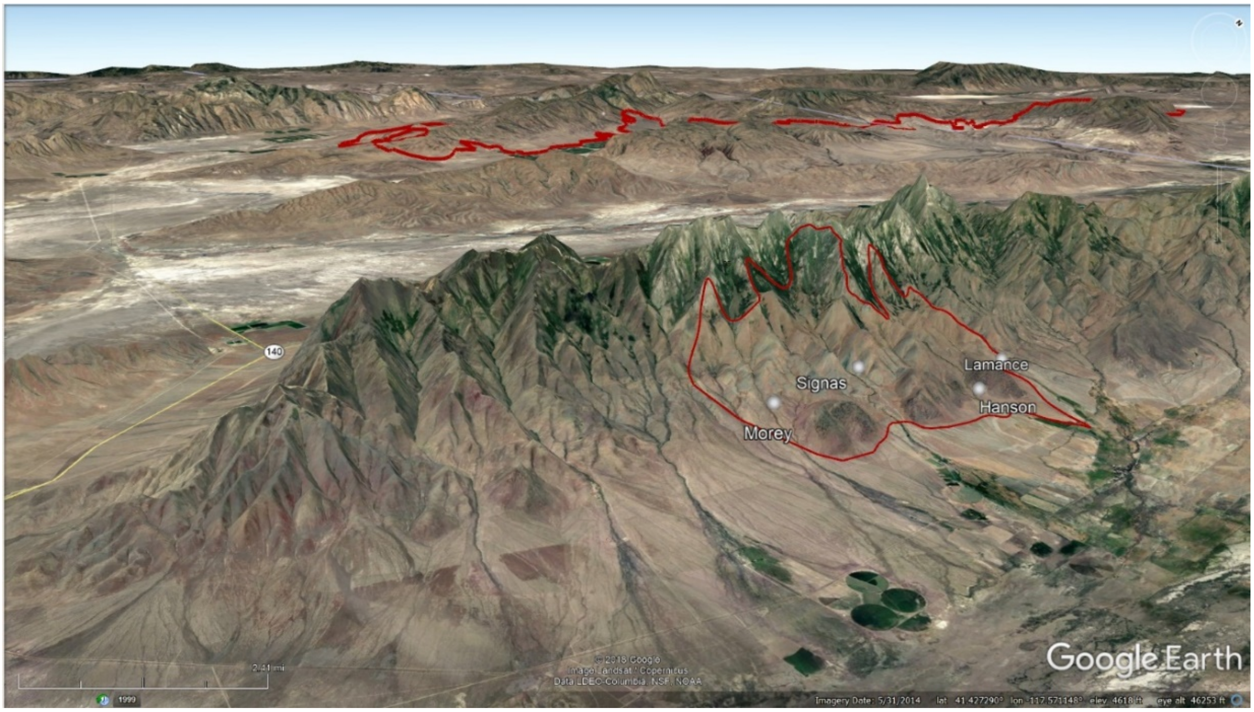


Figure 3- Study sites within the Holloway fire, Kings River valley, looking north

The purple (semi)-horizontal line is the Nevada / Oregon border.

Figure 4- Study sites within the Hanson fire, Paradise Valley, looking northwest



All of the DMAs in the Hanson fire were grazed as spring-only use.

Grazing strategies

Calendar grazing charts were created from BLM grazing permitting records for each DMA to discern grazing strategy, as shown on Figure 5. Each row represents a single DMA. It is important to note that no DMA s were grazed all four years of this study, and only one was grazed three of the four years. “Exclusion” refers to the number of years when grazing wasn’t allowed (i.e. since the fires were in 2012, “none” refers to grazing being allowed in 2013, “1 year” refers to grazing being allowed in 2014, etc.). Spring-season and Hot-season grazed sites were all rested in 2016. Grazing strategies were prescribed by BLM, not experimentally chosen by the authors.

Figure 5- Calendar chart of the permitted grazing that occurred. Only Lamance was grazed in three growing seasons. The number indicated refers to number of years out of four post-fire that grazing occurred.

Spring-season grazing

Paradise Valley	January		February		March		April		May		June		July		August		September		October		November		December	
Lamance								3	3	2														
Morey			1	2	2	2	2	1																
Hanson								1	1	1														
Singas																								

Hot-season grazing

	January		February		March		April		May		June		July		August		September		October		November		December	
Cherry										1	1	1	1	2						1	1			
China										2	2	2	2	2	2	2	1							
Francis										2	2	2	2	2	2	2	1							
Raster												1	1	2	1									

Grazed in 2016

	January		February		March		April		May		June		July		August		September		October		November		December	
Bilk								1	1	1	1	1	1	1	1	1	1	2	2	1				
Li'l Wilder							1	1	1		2	2	2	2	1		1							
Wilder							1	1	1		2	2	2	2	1		1							
Rodeo														1	1	1	1							

<Sampling Occurred mid-May to mid-August>

Legend

0	1	2	3	4
	1	2	3	4

Number of seasons grazed in the four years following fire. None were grazed all four years post-fire.

Despite former custom, most of the sites in this study had one year of exclusion from grazing. There were only four exceptions from which to examine variation, with one site each for no deferment and for two or three years of deferment from grazing.

As there was no replication regarding alternative years for deferment of grazing, this experiment was uncontrolled for the stochastic factor. There is usually at least one level at which replication is obligatory, at least if significance tests are to be employed (Hurlbert, 1984). Improper replication usually results in the underestimation of true variation or the confounding of its sources, thereby increasing the risk of a Type I error (i.e., the chance of rejecting a null hypothesis that is true). At best, such analyses yield the vague statistical result that there was or was not a “treatment effect” that cannot be statistically separated from a “location effect” (Heffner et al. 1996).

Hypotheses tested

The null hypothesis was that grazing strategy (spring vs hot; grazed in 2016 vs rested in 2016) made no impact on the results of the particular riparian indicator analyzed. When the Fisher statistic is greater than the F Critical value or the p-value is less than 0.05, we would be able to reject the null hypothesis. That is, it would show that the means of the grazing strategies were significantly different.

It was hypothesized that DMAs with spring-season grazing would have more favorable long-term indicator ratings than those with hot-season grazing, as they would have had longer during the growing season to recover. Both spring-season grazed sites and hot-season grazed sites were hypothesized to have higher long-term indicator ratings than those grazed in 2016 (also a category with four replicates) because they did not experience any disturbance in 2016, the final year of sampling.

Data collection

Data were collected using Multiple Indicator Monitoring (MIM) (Burton et al. 2011 and 2013). The specific indicators that we analyzed included: bank stability, Winward greenline stability rating, percent hydric species present, percent woody species present, and woody height. A Daubenmire frame (20x50 cm) was placed along the greenline (Figure 6, page 14) and plant species are identified with their proportion of cover in the frame. Next, observations of hoof prints were recorded as alterations, along with any signs of bank instability (e.g., sloughing or slumping of the bank, or erosional scars). Median stubble height of key species, typically graminoids or other herbaceous plants palatable to livestock, were measured to the centimeter and indications of browsing estimated in percent of leaders browsed.

Bank stability describes a plot 50 cm along the streambank from the bottom of the bank at the toe of the bank slope to the top of the first bench. It thus is focused on the active channel bank and not a gully bank from former incision. Bank stability is noted for each bank location that is not depositional in nature, by whether it is covered or uncovered by perennial vegetation or anchored rock or wood and whether it exhibits instability, including undercutting of bank, block or slump failures, or the most common (to our DMAs), sloughs of materials that falls off streambanks and into the channel and that are prone to erosion during the next storm event.

The difference between bank stability and Winward greenline stability rating involves vegetation. Bank stability captures the geotechnical nature of the streambank at the time, as opposed to the Winward greenline stability rating, which deals with the anchoring ability of different species of vegetation on streambanks. Winward greenline stability ranges from zero (being the least effective) to ten (the most effective). Winward greenline stability may not correlate well with whether a species is hydric (e.g.

obligate or facultative wetland species) (Dencker, 2017). Percent hydric species is a worthy indicator due to their complex root structure's ability to resistant stream erosion (Manning et al., 1989). Percent woodies and woody height data were also collected, as these may aid land manager's decision-making process, depending on their objectives.

Over the 110m length of DMA, 80 plots are recorded (with 40 typically spaced every 2.75m on each side of the stream). The authors of MIM created a macro-based Microsoft Excel spreadsheet that generates a weighted value for each long- and short-term indicator observed (Burton et al., 2011 and 2013). Plant characteristics were from the U.S. Department of Agriculture's plant database (USDA, 2019).

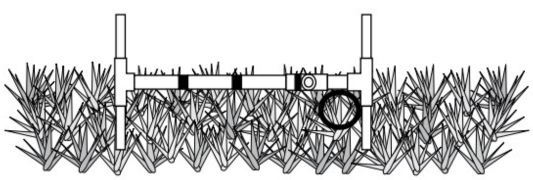
Statistical analysis

We applied ANOVA to analyze seasonal grazing. Of the twelve study DMAs, there are four in each of three categories. One aspect the first two have in common, which differentiates them from the remaining group of four, is that none of these eight were grazed in 2016, the last year data were collected. There were not enough data to apply ANOVA to the question of how many years grazing should be excluded post-fire.

Replication limitation

Statistically analyzing impact due to deferring grazing ran afoul of pseudoreplication errors. Pseudoreplication is "the use of inferential statistics to test for treatment effects with data from experiments where either treatments are not replicated (though samples may be) or replicates are not statistically independent" (Hurlbert, 1984). Therefore, our experiment is of a mensurative nature, not manipulative. Hurlbert (1984) suggests that under these circumstances, the best that one can do is develop graphs that clearly show mean values and the variability of the data on which they are based.

Figure 6- Placing the Daubenmire frame along the greenline



<u>Results</u>

Table *2* Multiple Indicator Monitoring results - ranked in order of perceived grazing impact. For example, Singas was entirely excluded from grazing during the study, while Bilk was grazed the year immediately after fire (and had the longest grazing duration). Factors that were considered included duration of grazing, number of seasons grazed post-fire, and grazing that occurred during the hottest and driest parts of the season

	Bank Stability	**% Depositional**	**Bank Cover**	**Winward Greenline Stability**	**% Hydric**	**% Woody**	**Woody Height (m)**
Singas	59%	26%	84%	5.1	19%	38%	0.95
Hanson	66%	23%	93%	4.8	41%	48%	1.33
Morey	68%	35%	73%	4.5	48%	42%	2.44
Lamance	79%	41%	85%	3.7	43%	43%	1.79
Raster	75%	16%	77%	6.3	50%	35%	1.90
Cherry	80%	9%	88%	4.2	66%	34%	0.83
China	80%	1%	88%	4.2	66%	34%	0.83
Frances	53%	9%	83%	6.7	82%	4%	0.49
Rodeo	80%	4%	94%	4.4	75%	14%	1.16
Wilder	75%	6%	99%	4.1	72%	30%	2.16
Little Wilder	25%	1%	81%	6.4	23%	25%	1.49
Bilk	74%	13%	88%	5.5	63%	46%	2.25
Spring-only use	68%	31%	83%	4.6	38%	43%	1.63
Hot-season use	72%	9%	84%	5.4	66%	27%	1.01
2016 use	63%	6%	90%	5.1	58%	29%	1.77

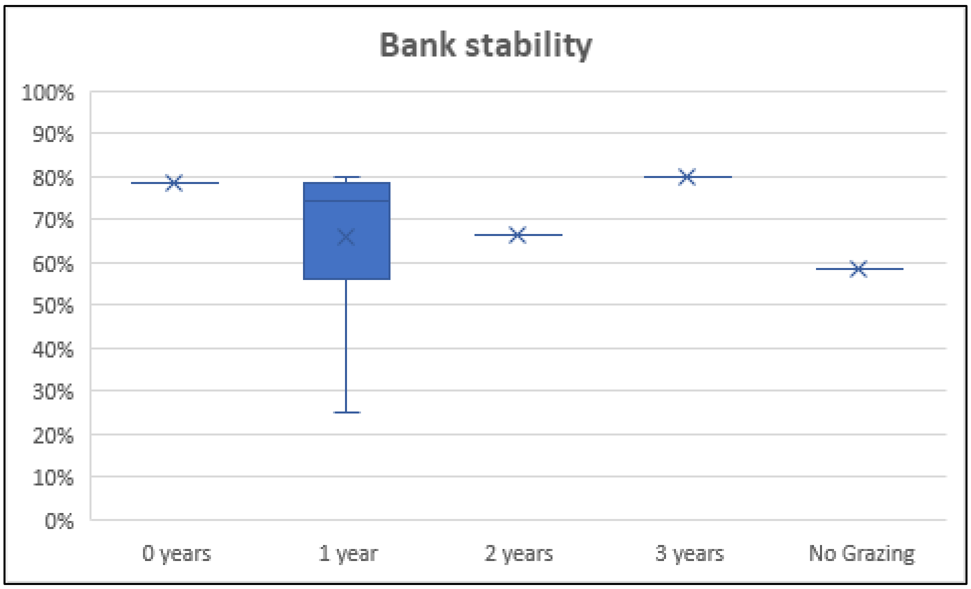
Depositional observations are stable, so it was added to give context to bank stability.

Regarding number of years grazing is excluded post-fire

Bank Stability

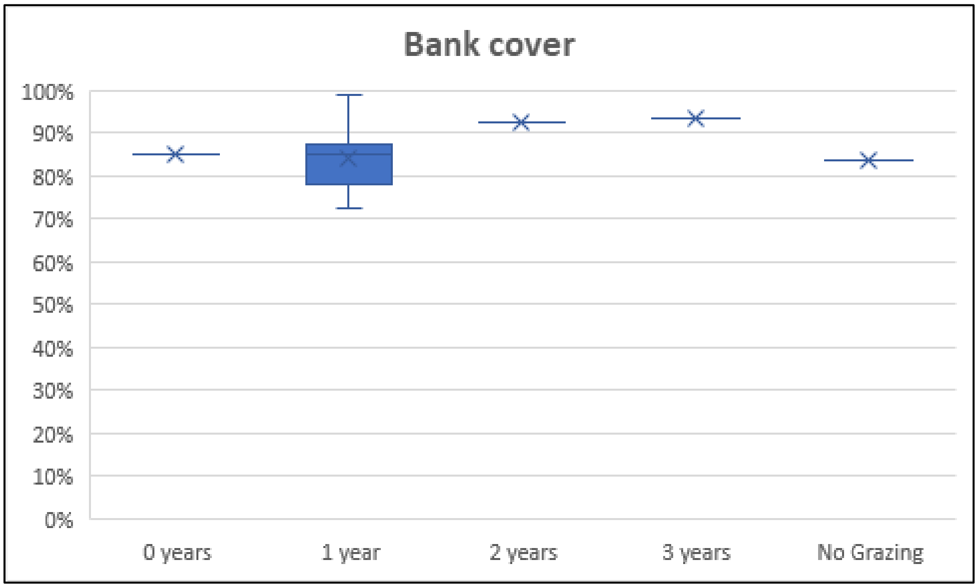
The definition of a stable channel may best be summed up as one in which there is no progressive adjustment in channel form (Schumm, 1984; Montgomery, 1998). Four years post-fire, the results are as shown on Figure 7.

Figure 7- Bank stability versus number of years grazing was excluded



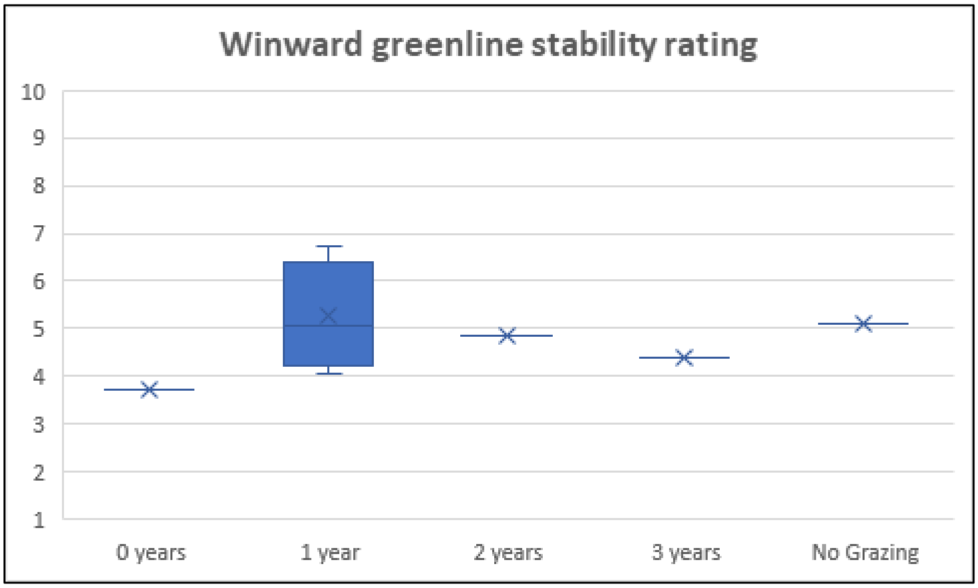
Bank Cover

Figure 8- Bank cover versus number of years grazing was excluded



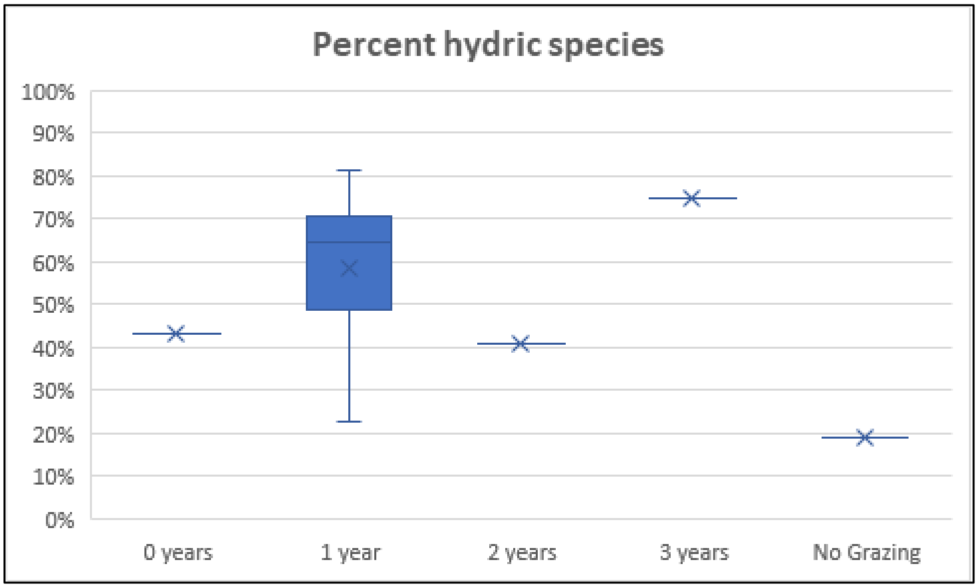
Winward greenline stability rating

Figure 9- Winward greenline stability rating vs. number of years grazing was excluded



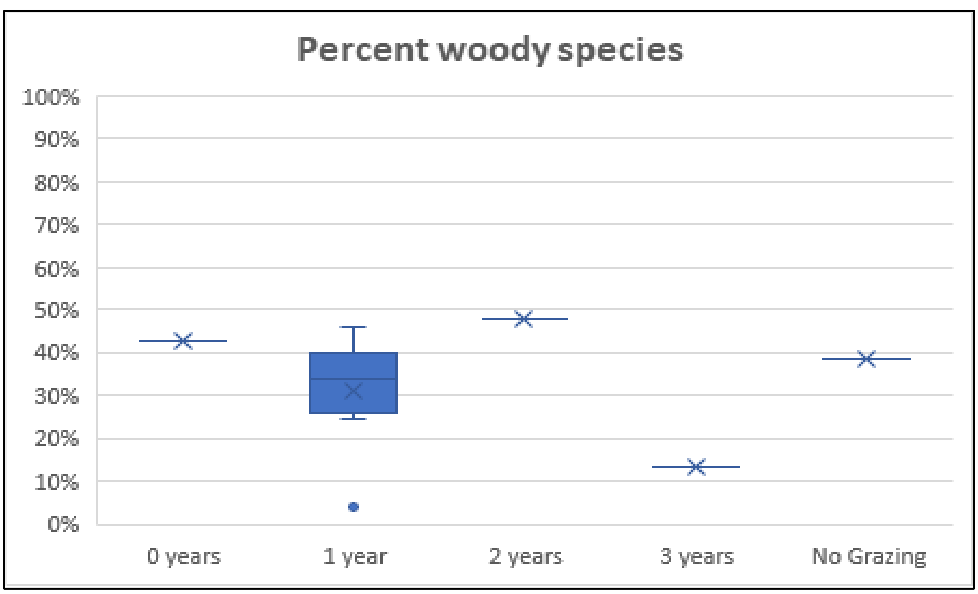
Percent hydric species

Figure 10- Percent hydric species versus number of years grazing was excluded



Percent woody species

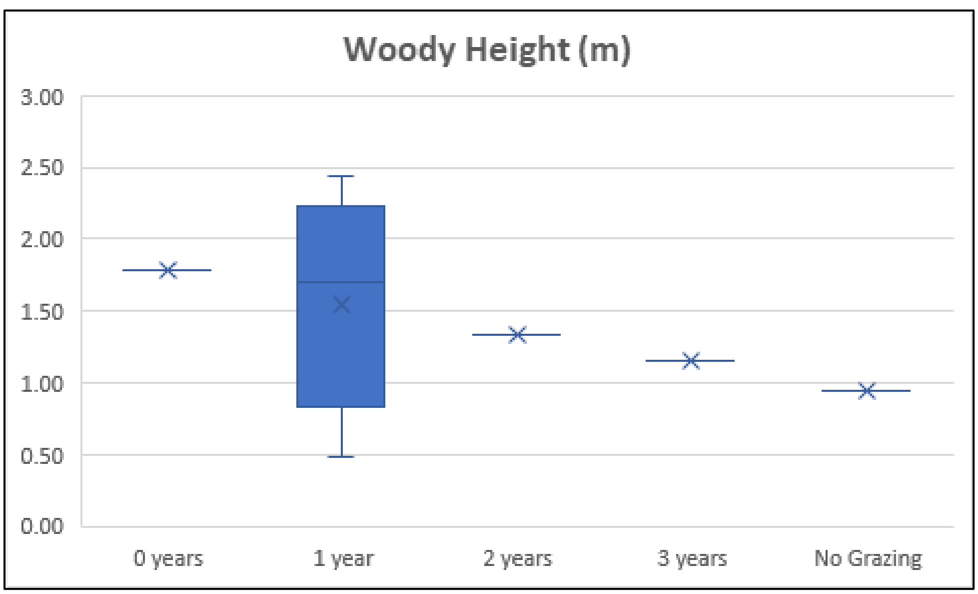
Figure 11- Percent woody species versus number of years grazing was excluded



<u>Woody height</u>

Mean woody height may be a poor indicator when considering objectives due to the tendency to decrease over time (fig. 12) as increasing amounts of young, smaller vegetation emerge. Between 2015 and 2016, Woody height actually decreased in eight of the twelve DMAs. Three DMAs (Bilk, Morey, and Wilder) had mean woody heights of about 2m or more by 2014 (1.95m, 3.40m, 2.06m, respectively). Hanson and Lamance come close to 2m in 2015 (1.83m and 1.94m, respectively). It is generally accepted that woodies reaching 2m have reached "escape height." That is, foliage has grown to escape the reach of browsing ungulates.

Figure 12- Woody height versus number of years grazing was excluded



Regarding spring-season grazing versus hot-season grazing

ANOVA tested the hypotheses that sites with spring-season grazing would have higher indicator values than those hot-season grazed, both of which would have higher values than sites grazed in the last year of this study.

With the Fisher statistic (F=0.24) less than the F Critical value (F_{Crit}=4.26) and the p-value=0.79, we are unable to reject the null hypothesis that the means of the grazing strategies were significantly different. Figure 13demonstrates the lack of significant difference in bank stability. Similar results were observed for bank cover (Figure 14), Winward bank stability (Figure 15), percent hydric species (Figure 16), Percent woody species (Figure 17), and percent woody height (Figure 18).

Figure 13- Bank stability per grazing strategy

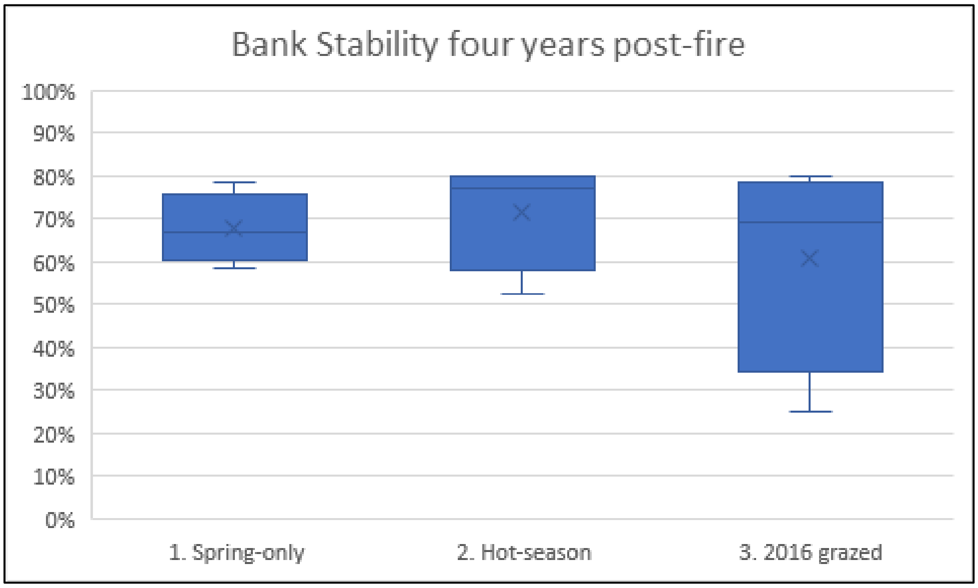


Figure 14- Bank cover per grazing strategy with the Fisher statistic (F=1.21) less than the F Critical value (F_{Crit}= 4.26) and the p-value=0.34.

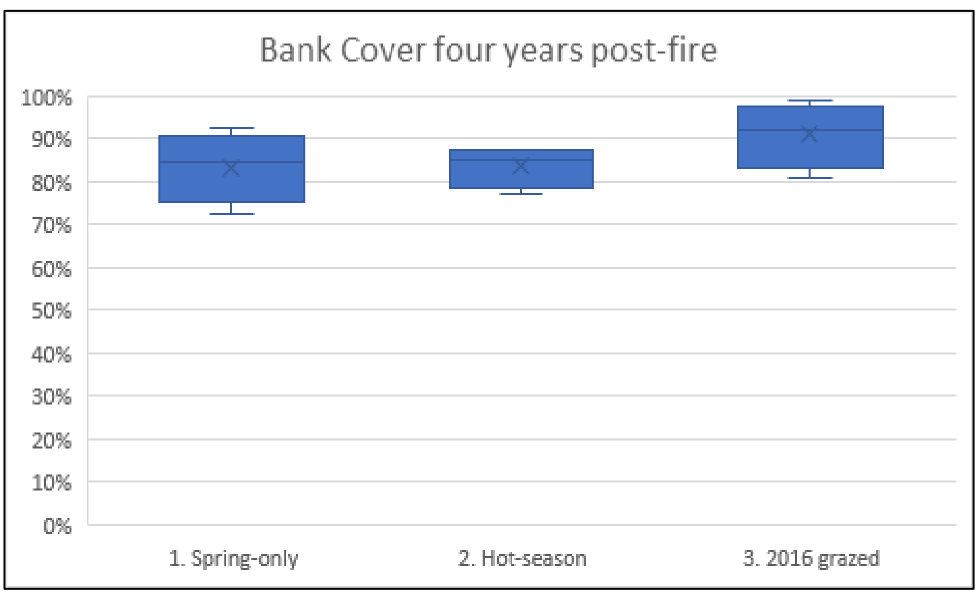


Figure 15- Winward greenline stability rating per grazing strategy with the Fisher statistic (F=0.64) less than the F Critical value (F_{Crit}= 4.26) and the p-value=0.55.

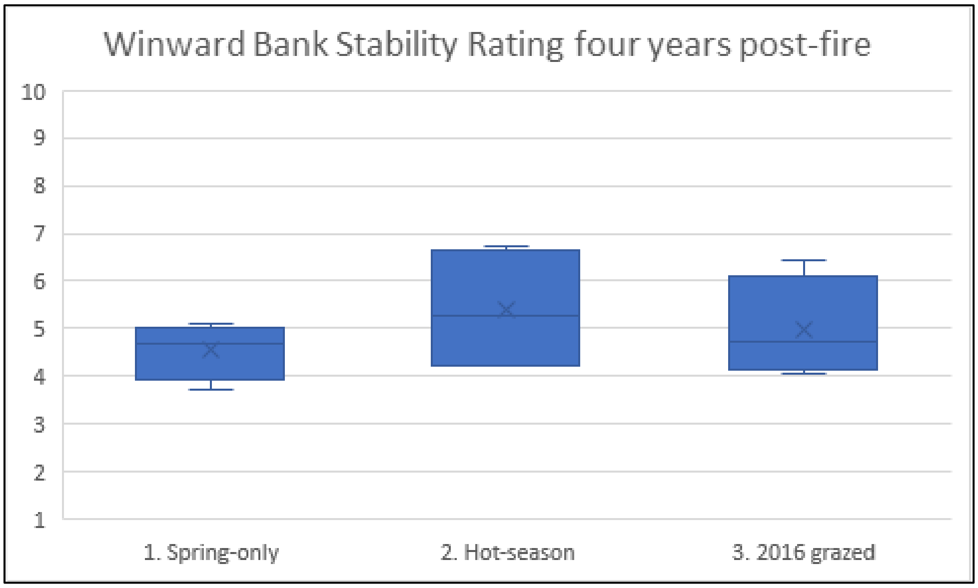


Figure 16- Percent hydric species per grazing strategy, with the Fisher statistic (F=0.14) less than the F Critical value (F_{Crit}= 4.26) and the p-value=0.87.

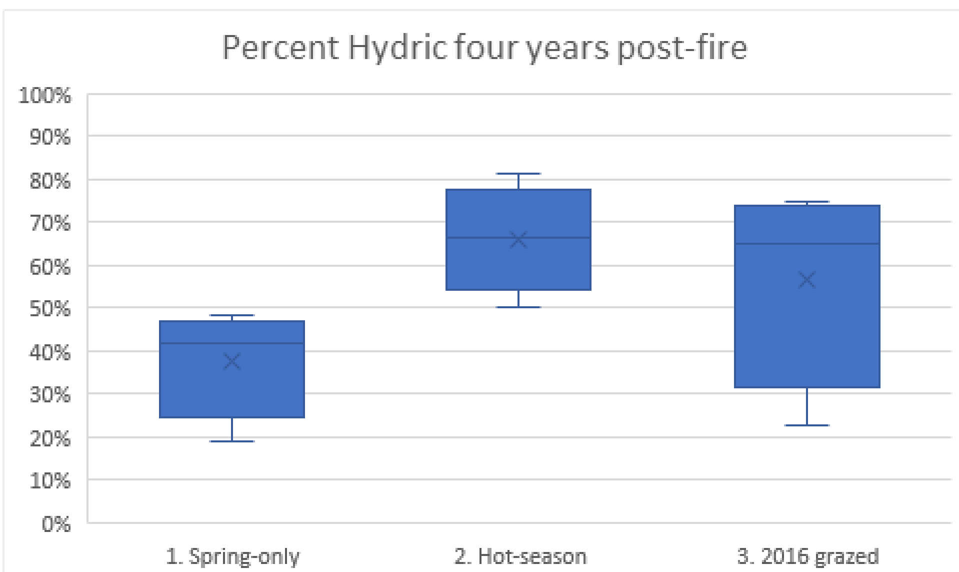


Figure 17- Percent Woody per grazing strategy, with the Fisher statistic (F=0.14) less than the F Critical value (F_{Crit}= 4.26) and the p-value=0.87.

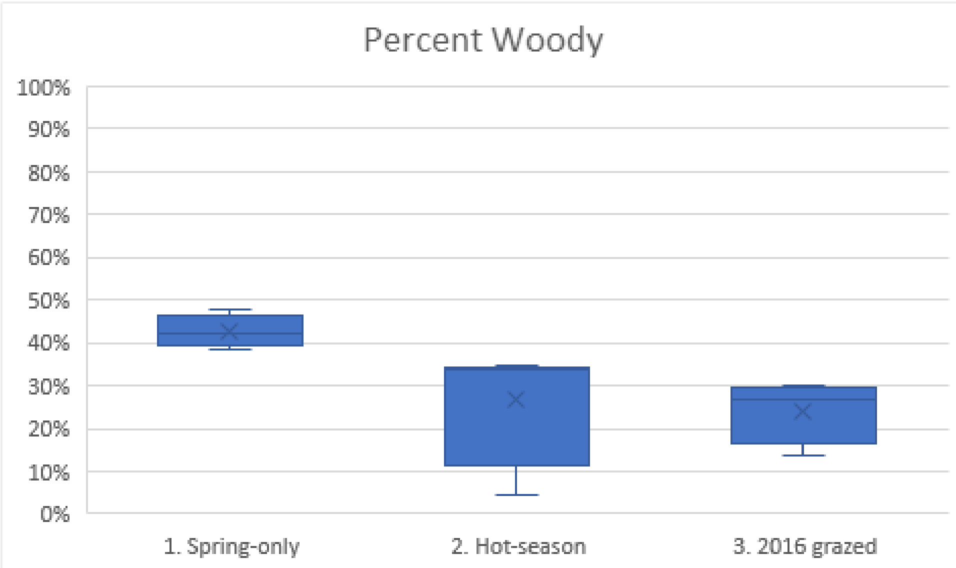
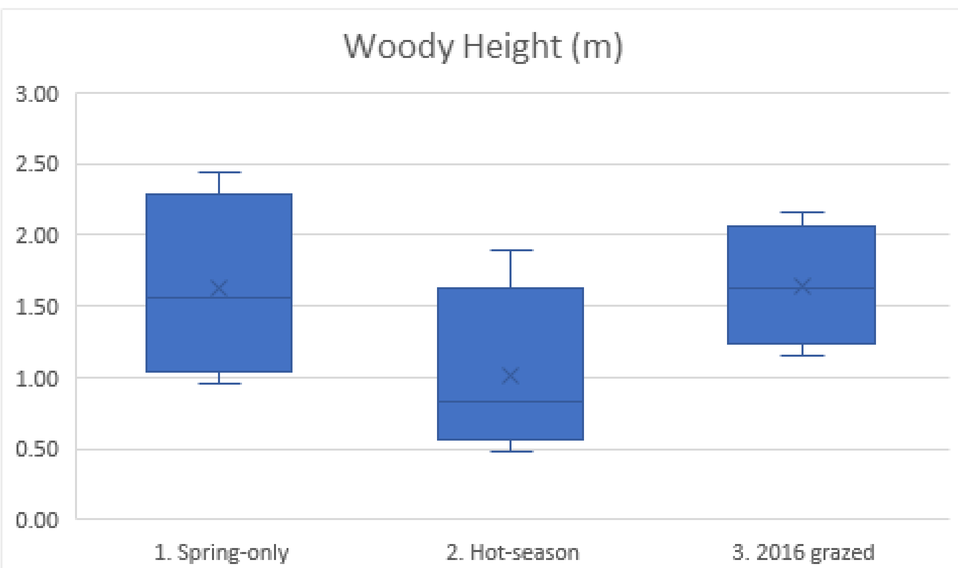


Figure 18- Woody height (m) per grazing strategy, with the Fisher statistic (F=2.19) less than the F Critical value (F_{Crit}= 4.26) and the p-value=0.17.



Discussion

Regarding the impact of number of years of exclusion from grazing

Grazing is important not just as forage for livestock and wildlife, but as a tool for rangeland managers. Grazing uplands would provide fuels removal, but to do so, animals would require the water source that riparian areas can provide. How long a riparian area requires rest to recover post-fire is a worthy question. With the limited number of sites to work from, we were unable to provide a robust analysis. Future studies addressing this question might use many DMA sites, with randomly dispersed grazing treatments among them (Hurlbert 1984).

With unreplicated scenarios, we were unable to differentiate treatment effect from location effect (Hurlbert 1984). So our results should not be used to infer conclusions from treatment effects. It should be noted that the 3-year exclosure was sampled too early to properly ascertain grazing impact (i.e. only three weeks into its two-month plan of hot-season grazing). Actual grazing conditions may not reflect what was permitted and supposed to have happened, compromising our analysis.

Our results agree with Bates et al. (2009), who demonstrated that requiring grazing rest the first two years after fire to encourage herbaceous recovery may not be necessary in all situations. Our results also agree with West and Yorks (2002), who indicated no differences in cover among burned-ungrazed and burned-grazed areas for the first six years after fire. However, West and Yorks also indicated that longer-term monitoring was needed to evaluate post-fire grazing. Similarly, our study may have benefitted from longer (2017 or 2018) monitoring.

Regarding spring-only grazing compared to hot-season grazing

ANOVA tested hypotheses that spring-only grazing would have higher indicator values than hot-season grazing, both of which were hypothesized to outperform DMAs that were grazed in 2016. This was not affirmed by the non-significant differences found in this study, possibly due to lack of replicate DMAs (Hurlbert 1984).

Our research lacks control due to what Hurlbert (1984) coined as “non-demonic intrusion.” That is, “the impingement of chance events on an experiment in progress.” MIM observations from 2014 to 2016 show indications of unauthorized grazing in 2015 (in Raster, the DMA with 3 years exclusion, and in Singas, supposedly with no grazing during the study period). If there was trespass grazing (from fences that burned down and that were not promptly replaced), or if there was a significant wildlife presence, we would have expected to see similar signals in short-term indicators in 2014.

Management Implications

Robust experimental design will be required in the future in order to analyze the question of how long grazing should be excluded from riparian areas post-fire.

Introducing replicate scenarios would be required in order to separate location effects from treatment effects.

Monitoring to support adaptive resource management will enable flexible solutions custom-fit to a specific area. This will, however, require compromises between the scientist's need for experimental rigor with manager's needs for timely decision making (West and Yorks, 2002). There is no single prescribed approach to grazing management that will work on all riparian areas (Wyman et al., 2006). Different streams affected by the same fire event are conceivably ready to resume livestock grazing at different times.

Appendix: To the future graduate student

Things will go wrong. Abrupt changes in your plan can cast fatal doubt. You will face seemingly impossible deadlines. You will lose all hope. It is the unspoken path of all graduate students. It is a rite of passage that you succeed just when you had thought all was lost. At your defense, the culmination of your research, relax knowing that you've spent literally your whole graduate career making that moment come to pass.

Remember what you started this program for. Hold the vision of its rewards close. When you complete this program, you will realize that you are capable of far more than you had thought. It's a feeling worth more than initials on your resume. *Know where your thesis is heading.* Things will likely change, but give full faith to your Advisor. As Dr. Peter Weisberg once explained, at the Bachelor's level, the University teaches one a profession. At the Master's level, the University begins retraining us to become more like scientists. If you have painful gaffes or blunders, like me, remember that it's in the failures and setbacks that one learns the most. But you're in Nevada. You *A*re Battle Born resilient!

General advice

☐ Go to every colloquium! This is your chance to hear cutting edge science from veritable experts in the field. Afterwards, carouse with them over *free food.*

☐ Use your thesis credits wisely, but work on it *continually* in the background. Use three (or less) credits each semester following your fieldwork seasons to process data. If you are working on a funded project, you will be reminded that you are obliged for 20hours during school and 40hours per week gathering data during summer break. You are not the first nor will you be the last to actually work twice that. It's why we deserve free food at all gatherings.

☐ If enough students have a specific need (e.g. learning to program in R), and there is a professor known for their expertise in that matter, approach them to see if they'll start a 700-level course (typically for 1 or 2 credits). Keep in mind, this is an enormous amount of work that you're asking them to perform!

☐ Regularly hold counsel with your advisor so they know your progress and the issues that have you struggling.

☐ Feed your brain in the downtime. This area has lush history! Try "Nevada's changing wildlife habitat" (Gruell & Swanson 2012) or "It Happened In Nevada: Remarkable Events that Shaped History" (Gibson 2010). And when you need to get away, take advantage that Lake Tahoe is just over that mountain ridge.

<u>First Year</u>

☐ Begin working on your Plan of Study. Know what courses you are expected to take to graduate. It's like making a plan before you sail off for Hawaii. You do not want to end up heading towards Japan.

☐ Siphon your Advisor's vision of what your thesis research entails at every opportunity. Engage them with questions to flesh out the details. Aim to have them approve a rough draft of your study plan prior to embarking upon field collection.

☐ Specifically detail your methods and your proposed statistical analysis of data collected in what you give them. You do not want surprises when you think you are getting close to being finished.

☐ While nobody wants to be accused of cherry-picking by using select data, consider adding one or more sites to monitor than you think you will actually need. In two years, there will likely be at least one that gets disqualified from usefulness in some fashion.

☐ Take STAT 652 to learn Analysis of variance (ANOVA)

☐ Did your Advisor warn you you'll need a committee of three? Consider carefully the kind of expertise you will require to guide you through your tricky question. After all, if it were not a difficult question, how could it be interesting? You are, of course, asking them to devote a significant amount of their time to help you. The way to recompense them, without running afoul of the University's Conflict of Interest policies, is:

☐ Plan to get published!

Fieldwork

☐ The uninitiated would be wise to wear a long-sleeved shirt and bring an umbrella for breaks. Even if you've got a shady hat, don't forget that your hands still need sunscreen.

☐ Take lots of pictures! Rename or LABEL THEM *IMMEDIATELY!*

When transferring, "Date Taken" may become the time it was transferred. Consider using timestamps, as they can always be cropped if used for presentations.

☐ Take advantage of UNR's unlimited storage space to document your travels. It's actually an obligation if you are taking public money to fund your research.

Second Year

☐ Remember that you never really have downtime, not if you plan on graduating promptly. Use momentum from finishing coursework to make gains on your thesis research.

☐ Have you nailed your testable hypotheses yet?

How can you collect data properly if you haven't yet asked the right question?!

☐ You are processing data and making gratuitous graphs to look at the variables from all angles. Where are the issues that may require changes in the next season's field work?

☐ If you have time, put together lists of what you anticipate finding during next year's field season. This is Lincoln's proverbial "if you have six hours to chop down trees, spend the first four sharpening your axe." You will be sorely tempted to skip this step, as we all are, but it is precisely in this mire where you will have your most profound insights into what your system is doing.

☐ By now you have an established committee and are in regular communication and consensus. At the very least, get them to sign off on your Plan of Study to prevent having to take unexpected courses.

☐ If you finish coursework, but need time to finish your thesis, sign up for additional thesis credits. If all you sign up for is thesis credits, you will need a minimum of three. It may seem like an unnecessary expense, but the system will drop you (and you will have to begin repaying loans soon after) if you don't.

<u>When things fall apart</u>

☐ Return to the question(s) that your research ultimately got funded for.

☐ Remember to be grateful that Master's students are not held as accountable as if they were Doctoral candidates.

☐ Own up to mistakes. Don't be juvenile with temptations to fudge or influence data. It's a complex world, and you may not know what you've discovered yet.

☐ Remember what you started this program for. Visualize the relief of graduation!

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