



Grazed stubble height along the greenline as a water quality indicator
by Robert Joseph Finck

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Animal and Range Sciences
Montana State University
© Copyright by Robert Joseph Finck (2003)

Abstract:

Two Montana ranches were chosen to evaluate the effects of grazed stubble height on water quality. Within each ranch, the study was replicated with three pastures. Using a 7.5 cm stubble height as an indicator, cattle were moved to the next pasture. Black Angus yearling heifers were used on each ranch with a stock density of 10 heifers per hectare. Cattle went on both ranches the first week of July. Water samples were taken at the upper and lower fence lines of each pasture to obtain a direct measure of cattle impact. Water quality parameters measured were fecal coliform, nitrate, orthophosphate, pH, temperature and suspended sediment.

Grazing a greenline to a 7.5 cm stubble height had no effect on nitrate, pH, temperature, and suspended sediment in 1999 and 2000. Fecal coliform and orthophosphate levels at the Bandy and Bair Ranches were significantly higher in grazed stream reaches in 1999 and at the Bair Ranch in 2000.

Stream temperature was not different between grazed and ungrazed reaches at either ranch, however, temperature and fecal coliform levels were highly correlated at the Bair Ranch. At the Bandy Ranch, stream temperature levels were not correlated with fecal coliform counts. Some other parameter not tested caused the increased fecal coliform levels during the grazing periods.

On the Bair Ranch, depressed stream flow due to drought probably influenced the elevated water temperatures.

Even though cattle use was associated with elevated fecal coliform levels, stubble height and days in pasture did not account for the change. Furthermore, state standards for fecal coliform were seldom exceeded when flows were high and water temperature <18 degrees C. Stubble height standards appear to be poor indicators of the impact of cattle grazing on water quality.

GRAZED STUBBLE HEIGHT ALONG THE GREENLINE
AS A WATER QUALITY INDICATOR

by

Robert Joseph Finck

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Animal and Range Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

May 2003

© COPYRIGHT

· by

Robert Joseph Finck

2003

All Rights Reserved

APPROVAL

of a thesis submitted by

Robert Joseph Finck

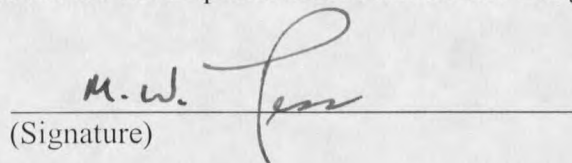
This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Clayton B. Marlow

 3 March '03
(Signature) Date

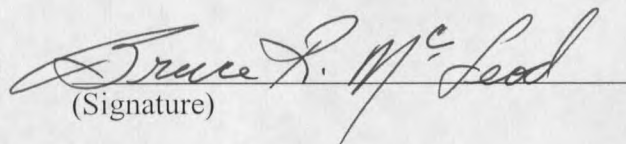
Approved for the Department of Animal and Range Sciences

Michael W. Tess

 3/3/03
(Signature) Date

Approved for the College of Graduate Studies

Bruce McLeod

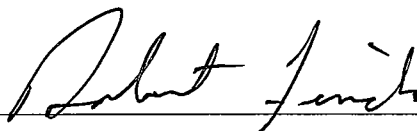
 3-7-03
(Signature) Date

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University-Bozeman, I agree that the library shall make it available to borrowers under rules of the library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Signature



Date

3/3/03

ACKNOWLEDGMENTS

I would like to thank the Montana Grazing Lands Conservation Initiative, the Bair Ranch Foundation and the Montana Forestry and Conservation and Agricultural Experiment Stations for their support and assistance in this project.

I would like to thank Dr. Clayton Marlow for all of his help and support with this project. He always took the time I needed to explain and work through my many problems. Without his expertise, I would in no way understand the complexity of these grazing systems, and how proper functioning riparian systems work. He has become a very good personal friend to my family, and me and I want to say thank you.

I would also like to thank all those on my committee, Dr. Jeff Mosley, Gene Surber and Dr. Dennis Cash for their support and expertise on my thesis. Their knowledge and professional opinions made the project run smoothly and accurately. There were also many other individuals that helped with lab work, entering data, and many hours of field work that I would like to thank.

This all would not have been possible without the guidance and encouragement of my family. My mother and father taught me how to work and take pride in everything that I do. They have always been a great example to me, and taught me to always finish a job once started. Thank you for always supporting me in my career opportunities.

Most of all, I would like to thank my wife Hailey and daughter Sage for their support and love through the many years of schooling. Without your support and dedication, I could have never achieved my success. I owe it all to you. I love you both.

TABLE OF CONTENTS

LIST OF TABLES.....	vi
LIST OF FIGURES.....	vii
ABSTRACT.....	ix
1. INTRODUCTION.....	1
2. LITERATURE REVIEW.....	3
GRAZING SYSTEMS.....	7
DEFERRED ROTATION.....	8
RIPARIAN PASTURE.....	9
TIMING.....	9
FENCING.....	11
EFFECTS OF GRAZING MANAGEMENT PARAMETERS ON WATER QUALITY.....	12
BUFFER STRIPS.....	13
FECAL COLIFORM.....	14
TEMPERATURE.....	15
STUBBLE HEIGHT.....	16
HYPOTHESES.....	17
3. MATERIALS AND METHODS	18
4. RESULTS.....	22
5. DISCUSSION.....	32
6. CONCLUSION.....	37
REFERENCES CITED.....	39
APPENDIX A: NON SIGNIFICANT CHARTS.....	46

LIST OF TABLES

Table	Page
1. Bandy and Bair Ranches with cow days in pasture and the number of sample days per pasture.....	20
2. Summary of statistical analyses using the signed rank test for stream water quality changes in 1999 and 2000 under a 7.5 cm grazed stubble height standard.....	24
3. Mean fecal coliform and ortho-phosphate levels at Bandy and Bair Ranches.....	25
4. Summarization of regression analysis of significant effects reported in Table 3. Simple linear regression was used. Non-significant effects were not analyzed.....	27

LIST OF FIGURES

Figure	Page
1. Grazing locations used in 1999 and 2000. Bandy Ranch is located in the glaciated portion of western Montana, while the Bair Ranch is located in unglaciated south central Montana.....	19
2. Design of experimental pastures at the Bandy and Bair Ranches. Pastures served as the replicates. Stream flow is indicated by arrows, and greenline designated in bold. Values from the upstream pasture boundary represented ungrazed conditions.....	21
3. Stream flow measured on Cottonwood Creek, Bandy Ranch Ovando, Montana. 1999-2000.....	22
4. Stream flow on the Musselshell River, Harlowton, Montana in 1999-2000. Harlowton is 36 km downstream from the Bair Ranch.....	23
5. Fecal coliform counts in Cottonwood Creek during grazing at the Bandy Ranch in 1999.....	26
6. Fecal coliform counts in the South Fork of the Musselshell River at the Bair Ranch in 1999.....	28
7. Ortho-phosphate concentrations in Cottonwood Creek at the Bandy Ranch 2000.....	29
8. Ortho-phosphate concentrations in the South Fork of the Musselshell River at Bair Ranch 2000.....	29
9. Fecal coliform concentrations in the South Fork of the Musselshell River at the Bair Ranch 2000.....	30
10. Non-significant nitrate concentrations in Cottonwood Creek at the Bandy Ranch 1999.....	47
11. Non-significant ortho-phosphate concentrations in Cottonwood Creek at the Bandy Ranch 1999.....	47
12. Non-significant temperature in Cottonwood Creek at the Bandy Ranch 1999.....	48

13. Non-significant pH concentrations in Cottonwood Creek at the Bandy Ranch 1999.....	48
14. Non-significant nitrate concentrations in Cottonwood Creek at the Bandy Ranch 2000.....	49
15. Non-significant pH concentrations in Cottonwood Creek at the Bandy Ranch 2000.....	49
16. Non-significant fecal coliform concentrations in Cottonwood Creek at the Bandy Ranch 2000.....	50
17. Non-significant temperature in Cottonwood Creek at the Bandy Ranch 2000	50
18. Non-significant ortho-phosphate concentrations in the South Fork of the Musselshell River at the Bair Ranch 1999.....	51
19. Non-significant nitrate concentrations in the South Fork of the Musselshell River at the Bair Ranch 1999.....	51
20. Non-significant pH concentrations in the South Fork of the Musselshell River at the Bair Ranch 1999.....	52
21. Non-significant temperature in the South Fork of the Musselshell River at the Bair Ranch 1999.....	52
22. Non-significant nitrate concentrations in the South Fork of the Musselshell River at the Bair Ranch 2000.....	53
23. Non-significant pH concentrations in the South Fork of the Musselshell River at the Bair Ranch 2000.....	53
24. Non-significant temperature in the South Fork of the Musselshell River at the Bair Ranch 2000.....	54

ABSTRACT

Two Montana ranches were chosen to evaluate the effects of grazed stubble height on water quality. Within each ranch, the study was replicated with three pastures. Using a 7.5 cm stubble height as an indicator, cattle were moved to the next pasture. Black Angus yearling heifers were used on each ranch with a stock density of 10 heifers per hectare. Cattle went on both ranches the first week of July. Water samples were taken at the upper and lower fence lines of each pasture to obtain a direct measure of cattle impact. Water quality parameters measured were fecal coliform, nitrate, ortho-phosphate, pH, temperature and suspended sediment.

Grazing a greenline to a 7.5 cm stubble height had no effect on nitrate, pH, temperature, and suspended sediment in 1999 and 2000. Fecal coliform and ortho-phosphate levels at the Bandy and Bair Ranches were significantly higher in grazed stream reaches in 1999 and at the Bair Ranch in 2000.

Stream temperature was not different between grazed and ungrazed reaches at either ranch, however, temperature and fecal coliform levels were highly correlated at the Bair Ranch. At the Bandy Ranch, stream temperature levels were not correlated with fecal coliform counts. Some other parameter not tested caused the increased fecal coliform levels during the grazing periods.

On the Bair Ranch, depressed stream flow due to drought probably influenced the elevated water temperatures.

Even though cattle use was associated with elevated fecal coliform levels, stubble height and days in pasture did not account for the change. Furthermore, state standards for fecal coliform were seldom exceeded when flows were high and water temperature <18 degrees C. Stubble height standards appear to be poor indicators of the impact of cattle grazing on water quality.

CHAPTER 1

INTRODUCTION

Numerous management decisions and policies have been made regarding grazing practices along streams to protect water quality (Hall and Bryant 1995, Beaverhead N.F. 1997). Montana has a prescribed grazing standard to protect and enhance water quality, soil, plant communities, and other rangeland resources on private property (Lee-Campbell et al. 1999). To improve riparian areas and enhance water quality on National Forest lands, the USDA Forest Service adopted stubble height standards of 7.5 to 10 cm to assure sediment entrapment before it enters the stream (Clary and Webster 1989, Hall and Bryant 1995). This policy is supported by a laboratory study conducted by Abt et al. (1994) that indicated that the optimum stubble height to collect sediment and rebuild banks is 7.5 cm. However, a review by Belsky et al. (1999) said that grazing has led to increased sediment load to receiving streams. This is in direct contradiction to recommendations by Clary and Webster (1989) that 10 to 25 cm of "residual stubble" is needed to maintain plant health and filter sediment. Hall and Bryant (1995) reported that 7.5 cm stubble height would indicate when key species would be grazed too much to recover. Montana prescribed grazing standards allow for a sufficient stubble height to remain following grazing, but call for that remainder to be along the greenline. In contrast to these recommendations, Skinner (1998) claimed that stubble height made no difference in the improvement of water quality. These studies all have the same goal of improving stream water quality, but lead to confusion over the actual techniques to

follow to limit the impacts of grazing to riparian areas. Confusion is heightened because all but one of the reports (Abt et al. 1994) are based on field observation and professional opinion. According to Tiedemann et al. (1989), there was no apparent relationship between cattle grazing, or the intensity of grazing management and water quality. In most cases, stocking rates were too low to detect any kind of a response. They found that sampling was generally not frequent enough to allow for any comparisons. On a spring creek in Wyoming, two separate studies were done on the same creek two years apart. Both studies looking at stubble heights, each found different results on how sediment and contaminants could be filtered out (Rumsey 1996, Grey et al. 1997). Rhodes et al. (1995) found that separate reaches within the same stream would react differently to the same grazing treatment. Does stubble height indeed help to improve water quality or are results location dependent, and can they be reproduced in other areas? With these questions in mind, the goal was to expand the scientifically derived information base on stubble height criteria for the protection of water quality on grazing lands.

To evaluate the effects of grazed stubble height on water quality I compared a 7.5 cm stubble height, replicated three times on two separate ranches and streams. This was done to evaluate the interaction between streams in different geographic locations and the grazing treatment.

CHAPTER 2

LITERATURE REVIEW

Within recent years, livestock grazing in riparian zones has become a much-debated topic. Until roughly the 1980's, riparian areas were often set aside as hold over or waste areas for livestock (Beetle 1956, Kauffman and Krueger 1984). Because of the lush vegetation and excess water, cattle congregated in these areas for long periods of time and began to negatively impact them. Consequently new management ideas and grazing strategies were needed to improve the riparian zones that were grazed by livestock. However, early decisions on grazing management were often drawn from years of experience, rather than scientific data. In an effort to inform managers about the scientific information base, Kauffman and Krueger (1984) published a review on livestock impacts to riparian ecosystems. They concluded that proper management of these fragile riparian zones would decrease stream bank erosion (Duff 1979), increase forage production, and increase wildlife habitat (Duff 1979). A recent survey of livestock influences along stream systems concluded that cattle have destroyed most of the riparian areas in the western U.S. (Belsky et al. 1999). These two separate reviews spanning 15 years show that the effects or management of cattle in riparian zones still are not well understood or substantiated by the small scientific data base. Or at least the conclusions they contain are not drawn from replicated studies. The literature of range management and specific information related to livestock and riparian zones is a

controversial subject (Carothers 1977). Consequently, opinion takes precedence over what little research data has been developed and documented.

Livestock managers continue to be questioned about the effects of grazing riparian areas and how this may affect the water quality of the streams. One source of controversy is the level or amount of grazing (utilization) to be allowed in riparian areas. Utilization levels or stubble heights of riparian vegetation are thought to be an important tool to understand the impacts and health of riparian ecosystems. Many managers feel that a higher stubble height along the stream edge will improve or protect water quality (Beaverhead N.F. 1997). Most of the research done has conflicting opinions, results, or personal experiences.

Stubble height is currently being explored as a possible management tool to be used to determine when to move livestock and to set grazing limits to protect streamsides and water quality. Management decisions and policy have been made regarding the height of grazed stubble along streams to protect water quality (Beaverhead N.F. 1997). Stubble height is usually determined by an average height from transects placed along the stream (Clary and Leininger 2000).

Hall and Bryant (1995) recommended moving livestock from riparian pastures when a 7.5 cm key forage species stubble height was attained to relieve grazing pressure on browse species. This was based on observations of excessive grazing and browsing when stubble height was reduced below 7.5 cm.

Some researchers (Abt et al. 1994) have also suggested that grazing vegetation on stream banks to a specific stubble height may be a management tool to help rebuild banks and collect new sediment for riparian vegetation establishment.

These recommendations were bolstered by results from cropland studies like those of Daniels and Gilliam (1996) and Fajardo et al. (2001) that reported substantial reductions in sediment transport and nitrates through implementation of vegetated filter strips. However, very few of the filter strip studies have focused on grazing management.

Grazed stubble increases channel roughness along the banks and dissipates stream energy sufficiently to cause sediment deposition (DeBano and Heede 1987, DeBano and Schmidt 1989). A laboratory study conducted by Abt et al. (1994) indicated that the optimum stubble height to collect sediment and rebuild banks was 7.5 cm. Once the stubble was short enough to become rigid and not lay over, the flow resistance increased sufficiently to initiate sediment deposition. Rumsey (1996) found that vegetation filtered sediment from a Wyoming spring creek, but that stubble height did not affect sediment deposition. A 7.5 cm stubble filtered at least as much sediment or more than the 22.5 cm stubble height. However, Grey et al. (1997) found that the shorter stubble stopped and held sediment on the same stream under high flood levels. Tall vegetation along the banks helps protect banks by slowing down erosion (Chow 1959). This is because when stream discharge exceeds bank full, tall grass lies down in the direction of flow. Little erosion then occurs but there is also insufficient friction to increase sediment deposition to further rebuild banks (Haan and Barfield 1978). Like Chow (1959), Grey et al. (1997)

found that taller vegetation was essential to hold the captured sediment and protect new banks when the large flood events occurred.

In contrast to these studies, Belsky et al. (1999) concluded that grazing has led to increased sediment loading to receiving streams without regard to stubble heights.

Meehan and Platts (1978) stated livestock affect riparian areas directly by trampling and altering runoff and sediment loads. The general consensus is "if livestock are excluded from all or most of the watershed, recovery of channel morphology is more likely" (Kondolf 1993). These disparate accounts in the literature lead to confusion over the impacts of grazing in riparian areas.

For example, to improve riparian areas and enhance water quality, the USDA Forest Service adopted stubble height standards of 10 to 15 cm (Clary and Webster 1989) to assure sediment entrapment before it enters the stream (Clary and Webster 1989, Hall and Bryant 1995). Unlike Clary and Webster (1989), the stubble height recommended by Hall and Bryant (1995) is supported by a laboratory study conducted by Abt et al. (1994) that indicated that the optimum stubble height to collect sediment and rebuild banks is 7.5 cm. This is in direct contradiction to recommendations by Clary and Webster (1989) that 10 to 15 cm of "residual stubble" is needed to maintain plant health and filter sediment. Hall and Bryant (1995) contradicted the former standard by pointing out that the 7.5 cm stubble height is tolerable and once the height was reached, key species would be grazed harder. Clary and Leininger (2000) recommended a 10 cm stubble height for the best compromise in most situations.

Grazing Systems

In addition to the confusion over stubble height, natural resource management literature also contains conflicting arguments over whether or not livestock grazing is destructive to riparian ecosystems (Davis 1982). It has been well documented that continuous heavy grazing by livestock can lead to severe riparian damage (Chaney et al. 1990, Platts 1982). Under continuous grazing, cattle may lounge all day within the riparian zone and on banks of the stream. Many management plans have been designed to overcome this behavior and lessen impacts by livestock. In a review by Kauffman and Krueger (1984), rest-rotation schemes and/or specialized grazing schemes were reported to be more beneficial and have fewer impacts than continuous yearlong grazing. Kauffman (1982) found that the use of specialized grazing systems (such as rest rotation, deferred rotation, riparian pasture, seasonal riparian grazing, short duration/high intensity grazing and corridor fencing) improved livestock production and increased riparian plant vigor and productivity, and produced minimal soil disturbance.

While many management plans have been devised to benefit riparian zones, they should be used correctly and for specific sites. Davis (1982) found that a rest-rotation system was a cost effective and successful method for riparian rehabilitation. Rest-rotation plans allow rest periods for riparian vegetation to recover from past grazing utilization by allowing cattle grazing on all but one pasture each year. The disadvantage of such plans is that livestock graze the riparian area within the pasture continuously until moved to a new pasture. This continuous use can lead to degraded stream banks which in

turn can decrease water quality from erosion. In addition, rest-rotation grazing cannot be implemented without aggressive management (Platts and Nelson 1985a), and streamside habitats should be identified as separate management units to handle the increased, concentrated effects of livestock grazing (Platts 1979) even though livestock may be there for a shorter amount of time.

Deferred rotation:

Deferred rotation is used to give vegetation longer recovery time by shifting the season of use so livestock do not always enter pastures at the same time each year. Myers and Swanson (1995) found that using deferred rotation grazing in three central Nevada streams improved the aquatic habitat and riparian areas. Using deferred rotation helps with livestock distribution and helps control the utilization of pastures. Drawbacks include the need for fencing which can be expensive and moving cattle which is time-consuming, when the stream banks are most susceptible to damage in the spring from grazing (Marlow and Pogacnik 1985). Skinner et al. (1984) compared continuous grazing to deferred rotation, and found that fecal coliform concentrations were significantly greater in the deferred rotation. But at the same time, Myers and Swanson (1995) found that deferred rotation grazing helped the improvement of aquatic and riparian habitats.

Riparian pasture:

The riparian pasture concept has been a successful tool for riparian grazing management (Platts and Nelson 1985b). The riparian pasture consists of fencing off a large enough area to make a pasture of the entire riparian zone. Cattle are not allowed access to the stream until conditions are conducive to promoting riparian health (dry banks, maturing vegetation). Stocking rates need to be managed to avoid over grazing and browsing of riparian shrubby vegetation (Hall and Bryant 1995).

Within a management design, more than one concept may be used. For example, short duration/high intensity grazing can be used in conjunction with the riparian pasture concept. Short duration/high intensity grazing is grazing larger numbers of livestock in a smaller area for shorter amounts of time (Voisin 1959, Savory 1980). The vegetation is grazed evenly because the livestock cannot be as selective. Cattle may be in a pasture for hours to days before being moved to another, and the vegetation is grazed just once in a season and left to recover the rest of the year. Advantages of this approach are the short amount of time in pastures, which limits the time animals have access to the banks and riparian vegetation. Disadvantages are that cattle need to be monitored closely and moved often. No research data has been published to show if water quality was improved under this grazing plan.

Timing:

The timing of grazing seems to influence bank stability (Marlow et al. 1987) and utilization of streamside vegetation (Platts and Nelson 1985a). Seasonal grazing was designed to use this concept, and graze areas when the least amount of impact may occur.

Grazing riparian zones during the cooler part of the grazing season should lessen impacts made by livestock (Bryant 1982) because cattle seem to avoid certain streamside riparian areas during periods when the soils and vegetation are wet and or cold (Platts 1982). However, livestock that spend large amounts of time along the banks may increase the sediment load to a stream. Kauffman et al. (1983) during late season grazing, with a stocking rate of approximately 1.5 ha/AUM, measured significantly larger amounts of lost stream banks in grazed areas, when compared to the banks of the stream in ungrazed areas in northeastern Oregon. In contrast, Johnson et al. (1978) found no difference between grazed areas and ungrazed areas when measuring the amount of sediment released into the stream. However, there was a significant increase of sediment after cattle were removed from the pasture most likely from rain showers and overland movement of detached soil particles. Bank trampling damage is the largest concern before the riparian zones and banks dry out. Marlow et al. (1989) found that grazing should be scheduled for periods when stream discharge is low and banks are relatively dry to reduce negative impacts. This will help to reduce erosion and suspended sediment in the streams. The size of sediment particles also makes a difference. According to Howell et al. (1996) fecal coliform numbers dropped as the sediment particles size became smaller and the temperature decreased. Grazing plans, which incorporate these ideas, may defer grazing or rest these areas until the banks are dry enough to handle the pressure of herbivores, and should reduce sediment input to streams with a corresponding decline in fecal coliform.

Fencing:

Fencing off stream reaches to prohibit use by livestock continues to be a popular solution to cattle impacts in riparian zones. Research shows that riparian habitat improves quickly when fenced to exclude livestock (Duff 1979), but it is generally not economically feasible to fence off every streamside corridor (Platts and Wagstaff 1984). The advantages of fenced exclosures are that no use by domestic livestock is allowed in or near the creek banks. This should protect bank stability and water quality. The disadvantages are that wildlife can still enter these areas and may be destructive. However, work done by Gross and Knight (2000) found that exclosures less than 4 hectares made a difference in the amount of use by grazing wildlife. Therefore, fencing appears to have many advantages to help maintain bank stability, increase stubble height and improve water quality under livestock and wildlife grazing. Through such management practices, the vegetation response is important to understand and manage correctly.

Others have also found that through grazing, vegetation productivity can be improved (Heitschmidt 1990). Research has shown that grazing can help to collect sediment, rebuild banks, and start new propagules growing (Grey et al. 1997, Abt et al. 1994, Rumsey 1996) which can enhance a riparian zone and increase vegetation.

In areas historically grazed by native herbivores, grazing may be beneficial for plant community health. Clary and Webster (1989) found that the accumulation of litter over several years retards the vegetation and herbage production in wet meadow areas. Grazing these riparian areas could have beneficial effects like that in prairie regions,

where grazing is reported to be beneficial in breaking up dense, rank vegetation near wetlands (Weller 1996). Clary and Webster (1989) indicate that cattle can improve areas with old decadent vegetation by grazing. With reduced fire frequency, livestock may be the best solution to revive areas of decadent plant growth. Proper management (i.e., timing, grazing management, etc.) will protect banks and riparian zones to enhance fisheries, wildlife, and livestock uses (Marcuson 1977). But few management plans or strategies provide target stubble heights for the improvement of the water quality.

Most of the reports on the effects of cattle grazing on riparian zones compared continuous grazing verses non-grazed (Rinne 1988, Leege et al. 1979). This comparison was an example of two extremes; whereas many grazing practices are between these extremes. Furthermore, many of the study citations are based on anecdotal or results from non-scientific trials. It is also hard to distinguish science from opinion in the literature (Kauffman and Krueger 1984) because so many studies quoted do not have replicated data. Consequently, little is known on how the different grazing techniques affect water quality or give any directions on how to manage livestock.

Effects of grazing management parameters on water quality

Livestock grazing presents a possible source of pollution to streams draining rangeland watersheds. As greater numbers of people use these rangelands for recreational purposes, particularly National Forests and Bureau of Land Management lands, the character and magnitude of this pollution becomes of increasing importance (Darling 1973). Because of increased recreational use of the nation's watersheds, governmental agencies have stepped in to control water quality in all rivers and streams.

One such example is a maximum contaminant limit of 10 mg/L nitrate-N for human drinking water set by the EPA (USEPA 1989). At present, national ortho-phosphate standards have not been established for the control of fresh water eutrophication. A standard of 1000 Colony Forming Units (CFU) /100 ml of fecal bacteria for secondary water contact has been established (USEPA 1986). In Montana the fecal coliform limit is 200 organisms /100 ml in water over 15.6 degrees C. Water quality parameters of interest in this paper include nitrate, ortho-phosphate, fecal coliform (FC), temperature and sediment because these are the parameters of most concern for the public.

Livestock grazing in riparian areas or along streams may greatly increase the chances of pollutants moving into the stream. A study by Trlica et al. (1999) showed that a single heavy grazing event increased runoff rates by 70 percent in a montane riparian ecosystem. Manure and urine deposited during heavy grazing significantly increased the concentrations of nitrate, phosphate, and fecal coliform in runoff as compared with their concentration in runoff from ungrazed control plots.

Buffer strips:

Management using buffer strips along streams has gained the most success and popularity in agricultural areas. The buffer strips leave longer stubble heights along streambanks at various distances from the stream. The buffer strips intercept the raindrops and also slow down the surface runoff. The grass then limits the amount of detachment and overland movement of soil particles to decrease erosion (Cooper et al. 1987). Reduction in soil movement is important because dislodged soil particles help transport particles such as fecal coliform and other nutrients that move down a stream system.

Therefore, erosion can be a major contribution to the degradation of the stream system (Osborne and Kovacic 1993).

Fecal coliform:

The presence of livestock in riparian areas tends to decrease the water quality of the stream. Direct deposition of feces into a stream causes bacterial contamination. Gary et al. (1983) found that the levels of fecal coliform depended on the stock density, but Dixon et al. (1979) after a one-year study found that stocking rate had little influence. Tiedeman et al. (1989) reported that most samples are not taken frequently enough to allow for comparisons. After cattle are removed from a pasture, fecal coliform counts may remain high for months (Jawson et al. 1982) even though other literature suggests that bacterial pathogens do not persist for extended periods after fecal deposition (Elliott and Ellis 1977). Stephenson and Street (1978) found that fecal coliform counts could persist up to three months after the removal of cattle. In a study by Gary et al. (1983) grazing increased fecal coliform organism counts by up to 10 fold. Others have demonstrated that as grazing intensity increases, fecal coliform counts in the stream also increase with cattle still in the pasture (Buckhouse and Gifford 1976, Johnson et al. 1978). But once cattle were removed, both the fecal coliform and fecal streptococci bacterial counts dropped dramatically within nine days to a statistically non-significant level. The exact cause of prolonged existence of these organisms in stream systems has gone unexplained (Sherer et al. 1988).

Biskie et al. (1988) reported that the majority of bacteria in fecal matter deposited into a stream settle to the bottom where they are available for re-suspension. This research showed that over 95 percent of these organisms settle to the bottom and a large fraction die while buried in the sediment. They reported that one animal defecation increases the fecal coliform concentration by approximately two fecal coliform per 100 ml. Van Donsel and Geldreich (1971) found that river sediment could contain 100 to 1000 times more fecal coliform per unit volume than overlaying water. However, fecal coliform in sediment had a 90% die off after seven days. Wildlife are also found to deposit and resuspend bottom microorganisms in the sediment when drinking or crossing the stream (Sherer et al. 1988) and can be contributors to the total fecal coliform in a watershed (Jawson et al. 1982). However, direct fecal deposition is not the only pathway for fecal coliform to enter the water column.

It has been suggested that high numbers of fecal coliform can survive up to 30 days inside feces deposited throughout the pasture (Thelin and Gifford 1983). This study showed that feces less than five days old had FC counts on the order of millions per 100 ml of water while 30-day old feces contained about 40,000 FC per 100 ml of water. Greater periods of survival are reported by Buckhouse and Gifford (1976), with viable fecal coliform in feces for at least one grazing season after deposition.

Temperature:

Stream temperature is a major concern for both water quality and fisheries. Shade from riparian vegetation overhanging aquatic communities provides cooler in-stream temperatures (Swanson et al. 1982). Thus, the removal of vegetation may cause an

increase in water temperatures with subsequent decreases in levels of dissolved oxygen (Brown 1983). Larson and Larson (1996) disagreed with this theory. They found that watershed attributes such as air mass characteristics, elevation gradient, adiabatic rate, channel (water) width and depth, water velocity, surrounding landscape, and interflow inputs all influence water temperature and can be of equal or greater importance to stream temperature than vegetation shade. Fish species within the rithron (faster currents, coarser substrates, allochthonous sources) regions need cooler more highly oxygenated waters than fishes of the potamon (slower currents, finer substrates, autochthonous sources) where there is greater variety of size, depth and flow of the larger river systems (Bayley and Li 1992). Van Velson (1979) on a creek in Nebraska found that mean temperatures dropped from 24 degrees C to 22 degrees C after livestock were removed for one year.

Stubble height:

Stubble height seems to have an effect on the amount of sediment released into the stream. Livestock will graze an increasing amount of riparian vegetation along the streamside as the stubble height further from banks is reduced (Clary and Leininger 2000). As stubble heights decrease, along with a decrease in organic matter, the intake rate of livestock decreases and animal performance decreases (Redmon et al. 1995, Ellis et al. 1984). The number of animals searching for higher quality forage along the streamside will increase and this can help to decrease water quality (Wright et al. 1990, Bailey et al. 1996).

So through all the literature cited and knowledge learned, still no management decisions were discussed to help managing livestock, or improve water quality. Few criteria have been established for the management of cattle on grazing lands to protect water quality. The criteria that are available address the control of cattle grazing impact on riparian vegetation. But at what point in the grazing management, season of use, or the utilization of vegetation do negative changes in water quality occur. At what point does all the methodology help to improve the water quality. The greenline concept is yet another approach of managing cattle utilization to achieve water quality improvement. The use of stubble heights to improve water quality has not yet been justified, so I decided that many questions on grazed stubble height and water quality needed to be addressed. The goal of this study was to evaluate the effectiveness of a 7.5 cm grazed stubble height on controlling cattle impacts to water quality at two different geographic locations in Montana. Based on the literature I hypothesized:

Hypothesis 1:

Ho: Grazing to a 7.5 cm stubble height does not change water quality from ungrazed conditions.

Ha: Grazing to a 7.5 cm stubble height does change water quality from ungrazed conditions.

Hypothesis 2:

Ho: There is no difference between geologic regions A & B when stubble height is used as a grazing criteria. (A= Bandy Ranch, B= Bair Ranch)

Ha: There are differences between geologic regions A & B when stubble height is used as a grazing criteria. (A= Bandy Ranch, B= Bair Ranch)

CHAPTER 3

MATERIALS AND METHODS

Two separate ranches across the state of Montana were used (Bandy-west central Montana and the Bair-south central Montana) in this study (Fig. 1) because of the variability within and between streams documented by Rhodes et al. (1995). The Bandy Ranch is a jointly owned research ranch for Montana State University and the University of Montana. Cottonwood Creek flows through the middle of the ranch draining a heavily glaciated landscape. Because of the presence of large amounts of glaciated cobble, a large sub-irrigated riparian zone exists on each side of Cottonwood Creek. The dominant vegetation in the area is a geyer willow (*Salix geyerana*) community type (Hansen et al. 1995). The pastures are dominated by tall graminoids like timothy (*Phleum pratense*), brome grass (*Bromus* spp.) and beaked sedge (*Carex urticulata*). The Bair Ranch is a working ranch owned by the Alberta Bair Foundation. The South Fork of the Musselshell River flows through a non-glaciated sandstone substrate within a cottonwood (*Populus deltoides*) habitat type/mountain brome (*Bromus carinatus*) community type (Hansen et al. 1995). Herbaceous vegetation along the South Fork is mostly mountain brome and beaked sedge.

At each ranch, three pastures that averaged 4 to 6 hectares in size with the stream running down the middle were constructed to serve as replicates. The values that are reported are for the entire grazing period in each pasture. It must be emphasized that pastures not day of sampling were the replication. I used enough cattle to achieve a

density of 10 heifers per hectare. Black Angus yearling heifers were used on both ranches and began grazing the first week of July both in 1999 and 2000. Grazing always began on the lowest downstream pasture, and moved upstream to the next pasture to not interfere with the water quality measure in the grazed pasture (Fig. 2). Permanently marked transects 30 m in length were placed along the stream running parallel to the channel on just one side in each pasture. Transects were placed on one side of the stream because the opposite side was covered in dense willows. The transects were used to monitor grazed stubble height along the greenline so that cattle could be moved at the target height. The greenline defined by Winward (2000) is the first perennial vegetation that forms a lineal grouping of community types on or near the water's edge. It most often occurs at or slightly below the bankful stage.

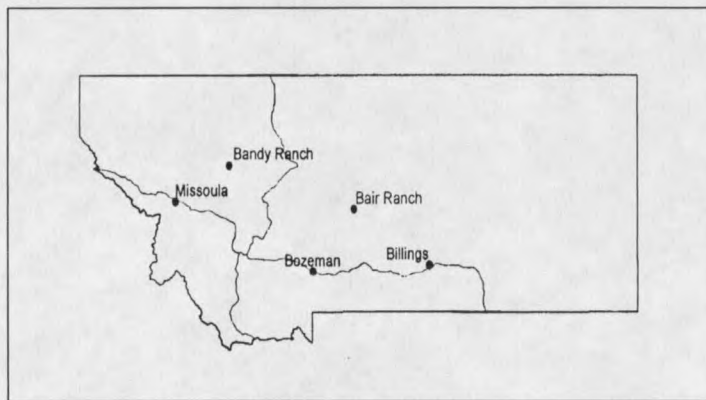


Fig. 1. Grazing locations used in 1999 and 2000. Bandy Ranch is located in the glaciated portion of western Montana, while the Bair Ranch is located in unglaciated south central Montana.

Before cattle entered the pasture, 100 stubble height measurements were taken at 0.3 m intervals along the greenline transect. Once cattle were moved into the pasture, stubble height measurements were taken at the same interval every four days along the transect.

Stubble height measurements were taken every 30 cm to total 100 hits per pasture. When the target height of 7.5 cm was achieved, cattle were moved upstream to the next pasture. Water quality samples were taken at the downstream and upstream fence lines on the same days stubble height was measured. A grab sample from within the water column was collected and placed into specifically labeled, sterilized bottles throughout the study. A standard mercury thermometer was used to detect water temperature near the stream bottom immediately following water sample collection. Stream pH was measured on site with an electronic meter. Water quality parameters measured included fecal coliform, nitrate, ortho-phosphate, temperature, pH and suspended sediment. Water samples were submitted to the Montana Environmental Laboratory in Kalispell, Montana for fecal coliform, nitrate and ortho-phosphate analysis following Clesceri et al. (1998).

Table 1. Bandy and Bair Ranches with cow days in pasture and the number of sample days per pasture.

Bandy Ranch				
	1999		2000	
Pasture	Days in pastures	# of days H2O samples taken	Days in pastures	# of days H2O samples taken
1	12	3	14	4
2	8	3	12	4
3	14	4	8	3
Bair Ranch				
	1999		2000	
Pasture	Days in pastures	# of days H2O samples taken	Days in pastures	# of days H2O samples taken
1	16	5	7	3
2	8	3	4	2
3	19	5	4	2

Suspended sediment was measured by collecting 100 ml of water from within the stream's water column and placing the samples in an Imhoff cone (personal contact Bridger Plant Materials Center) for measurements within a two-week period of collection.

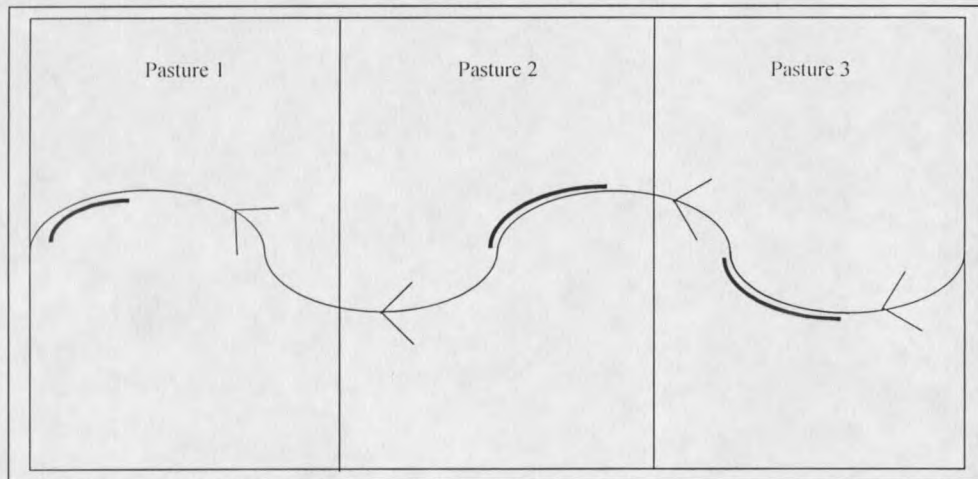


Fig 2. Design of experimental pastures at the Bandy and Bair Ranches. Pastures served as the replicates. Stream flow is indicated by arrows, and greenline designated in bold. Values from the upstream pasture boundary represented ungrazed conditions.

Direct comparisons were made between water quality differences from the upper fence (ungrazed) and the lower fence (grazed) values for fecal coliform, nitrate, orthophosphate, temperature, pH and sediment levels. A signed rank test was used for evaluating the seasonal water quality differences for the grazed and ungrazed locations. A signed rank test was necessary because of extreme fecal coliform levels during some sample periods.

Simple linear regression was then used to compare the water quality parameters to stubble height, days in pasture, stream flow volume, and the temperature of the water column. All statistical results were declared significant at the $P \leq 0.10$ level.

CHAPTER 4

RESULTS

Climate Conditions and Streamflow

1999 and 2000 were drier than normal. Precipitation at the Bandy Ranch in 1999 was 254.5 mm and in 2000 was 169 mm with the 25-year average being 333.2 mm. At the weather station for Martinsdale, Montana, precipitation levels for 1999 were 275 mm and 225 mm for 2000. The 25-year average was 326.5 mm (Montana Ag. Stats 2001).

During the grazing months of July and August, the Bandy Ranch was 77% below average in precipitation in 1999 and 63% below in 2000. In 1999 accumulated precipitation by July was 150 mm and in 2000, the accumulated precipitation was 123 mm. The 25 year accumulated precipitation by July was 194 mm.

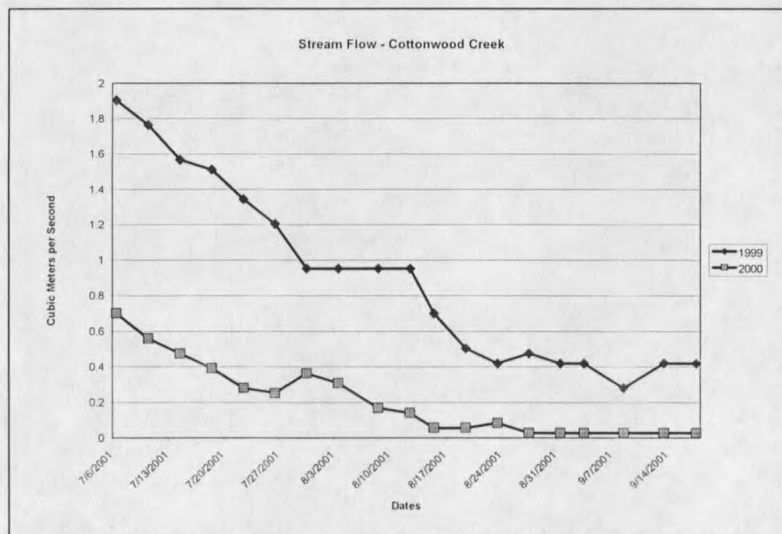


Fig. 3. Stream flow measured on Cottonwood Creek, Bandy Ranch Ovando, Montana in 1999 and 2000.

Stream flows over the two years reflected the dry conditions. The Bandy Ranch had a stream gage on Cottonwood Creek to record flow. Records indicate that stream flows

dropped below 0.7 CMS in mid-August of 1999, however the flows were below this level in early July of 2000 (Fig. 3). The Bair Ranch did not have a gage on the South Fork of the Musselshell so data from the closest gaging station at Harlowton was used for the analyses.

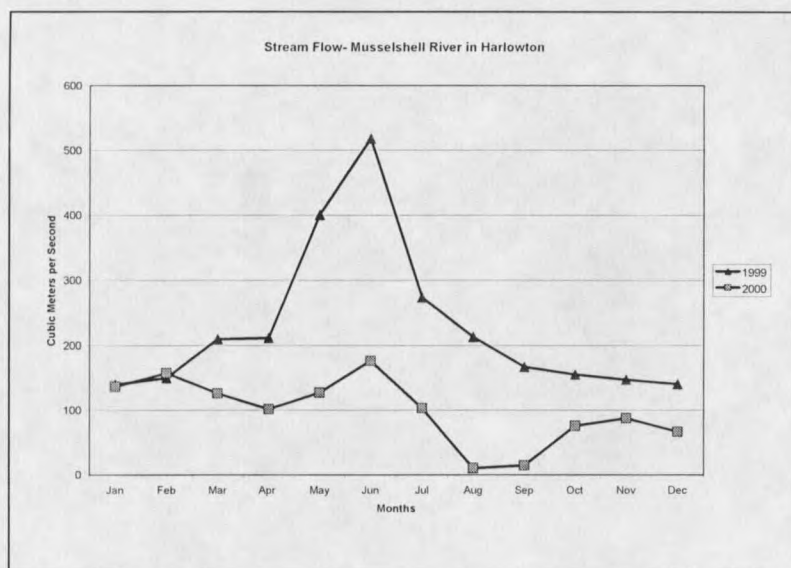


Fig. 4. Stream flow on the Musselshell River, Harlowton, Montana in 1999 and 2000. Harlowton is 36 km downstream from the Bair Ranch.

While this station does not precisely represent the Martinsdale site because of the influence of the North Fork of the Musselshell River, the information still shows a reduction in flow on the Musselshell over the two years of the study (Fig. 4). At both ranches, stream flow was below normal both years, and in 2000 water levels were very low.

Stream temperature is a problem because of the reduction in stream flows. Once water temperature exceeds 15.6 degrees C (60 degrees F) for streams in Montana, fecal coliform levels above 200 organisms/100 ml are considered a health risk. Water temperatures in Cottonwood Creek at the Bandy Ranch in both 1999 and 2000 never

In 1999 all fecal coliform levels were below the 200 organisms/100 ml standard (Table 3). In 2000, mean fecal coliform counts in the South Fork of the Musselshell below grazed pastures were excessively high.

Replications (pastures) at the Bandy Ranch in 1999 were not significantly different in regard to fecal coliform ($P=0.80$), ortho-phosphate ($P=0.78$), nitrate ($P=0.16$) or pH ($P=0.99$) levels. At the Bair Ranch in 1999, fecal coliform ($P=0.62$) was not different among pastures.

Table 3. Mean fecal coliform and ortho-phosphate levels at Bandy and Bair Ranches. All comparisons significant at $P=0.10$.

	Fecal Coliform				Ortho-phosphate			
	Bandy Ranch		Bair Ranch		Bandy Ranch		Bair Ranch	
	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed	ungrazed	grazed
1999	27 org/100ml	51 org/100ml	69 org/100ml	118 org/100ml	ns	ns	ns	ns
2000	ns	ns	199 org/100ml	41024 org/100ml	101µg/l	96µg/L	165µg/L	127µg/L

In year 2000, the replications (pastures) at the Bandy Ranch were non significant for fecal coliform ($P=0.81$), ortho-phosphate ($P=0.37$), nitrate ($P=0.14$) and pH ($P=0.41$). During the same year at the Bair Ranch, fecal coliform ($P=0.01$) and nitrate ($P<0.01$) did have a pasture effect, whereas ortho-phosphate ($P=0.40$), and pH ($P=0.64$) did not.

1999 Data

During the first year of grazing, fecal coliform differences between ungrazed and grazed stream sections were significant at both ranches (Table 2). Fecal coliform counts were significantly different ($P=0.03$) at the Bandy Ranch (Table 2), while all other

measured parameters such as nitrate ($P=1.0$), ortho-phosphate ($P=0.64$), pH ($P=0.83$), and temperature ($P=0.80$) were not significant.

When looking at Bandy fecal coliform levels in 1999, no samples came close to state standards. There was, however, considerable variability among ungrazed samples ranging from 5 to 72 org/100 ml in the water column (Fig. 5).

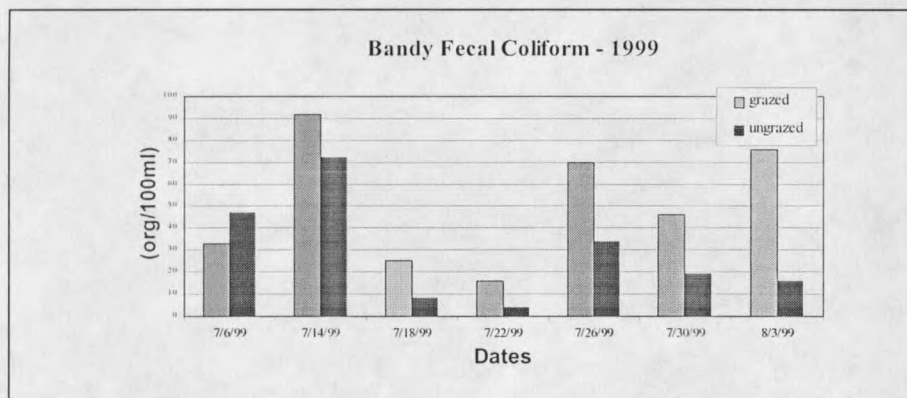


Fig.5. Fecal coliform counts in Cottonwood Creek during grazing at the Bandy Ranch in 1999.

Suspended sediment was measured at the same time as all other samples on both ranches at the up and downstream fencelines. However, no measurable suspended sediment was ever collected from either water column on the Bandy or the Bair Ranches.

After using the signed rank test to identify which parameters were significant, a simple linear regression analyses were computed to determine which management tools (stubble height, days in pasture, or stream temperature) were most closely related to fecal coliform and ortho-phosphate levels. Only significant effects (Table 2) were run through the regression analysis. The differences between ungrazed and grazed fecal coliform and ortho-phosphate levels were run against the stubble height average taken for that pasture

on the same day that water quality samples were collected. The differences were also regressed against the number of days cattle were in the pasture, and the stream temperature for the same day samples were taken.

Table 4. Summarization of regression analysis of significant effects reported in Table 3. Simple linear regression was used. Non-significant effects were not analyzed.							
Fecal Coliform -vs-		Stubble Ht		Days in Pasture		Stream Temperature	
		R ²	P-value	R ²	P-value	R ²	P-value
Bandy							
1999		0.23	0.28	0.25	0.25	0.33	0.18
Bair							
1999		0	0.99	0.02	0.72	0.41	0.08
2000		0.03	0.77	0.15	0.52	0.85	0.02
Ortho-phosphate vs-		Stubble Ht		Days in Pasture		Stream Temperature	
		R ²	P-value	R ²	P-value	R ²	P-value
Bandy							
2000		0.06	0.55	0.31	0.15	0.28	0.18
Bair							
2000		0.79	0.04	0.36	0.28	0.02	0.81
The difference of fecal coliform and ortho-phosphate numbers were derived by subtracting downstream (grazed) samples from the upstream (ungrazed) fenceline. The difference was then compared to stubble height, days in pasture and stream temperature for the same dates as the water quality samples were collected.							

When looking at the regression analysis values, for Bandy Ranch fecal coliform in 1999 (Table 4), it was apparent that stubble height was not significantly correlated (P=0.28), nor was the number of days livestock were in a pasture (P=0.25) or stream temperature (P=0.18).

Water quality patterns on the Bair Ranch in 1999 were similar to those on the Bandy. Fecal coliform increases were significant (P=0.05), with no significant increases in ortho-phosphate (P=0.76), nitrate (P=0.68), pH (P=0.44) or temperature (P=0.85) (Table 2). Here only one sample (Fig. 6) exceeded the state standard of 200 organisms/100 ml, and

after this sample there seemed to be a trend downward in fecal coliform levels.

For the Bair Ranch in 1999, had the regression analysis indicated that fecal coliform was unrelated to stubble height ($P=0.99$), and the number of days that livestock were in the pasture ($P=0.72$). However, the relationship between stream temperature and fecal coliform was significant ($P=0.08$).

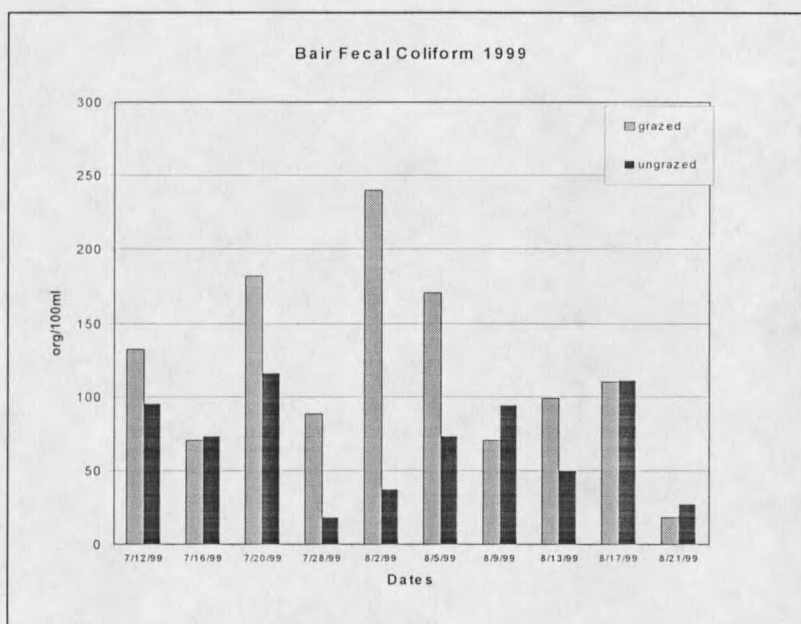


Fig. 6. Fecal coliform counts in the South Fork of the Musselshell River at the Bair Ranch in 1999.

2000 Data

As in 1999, data from individual ranches were evaluated using a signed rank test (Table 2). During the second year of the study, the Bandy Ranch had a significant difference in ortho-phosphate ($P=0.08$) between ungrazed and grazed reaches (Table 2), but not in fecal coliform ($P=0.65$), nitrate ($P=0.63$) or temperature ($P=1.0$). Ortho-phosphate levels seemed to stay relatively constant throughout the grazing period (Fig.

7). However, samples on the downstream side (grazed) had lower ortho-phosphate levels than those on the upstream (ungrazed) sites.

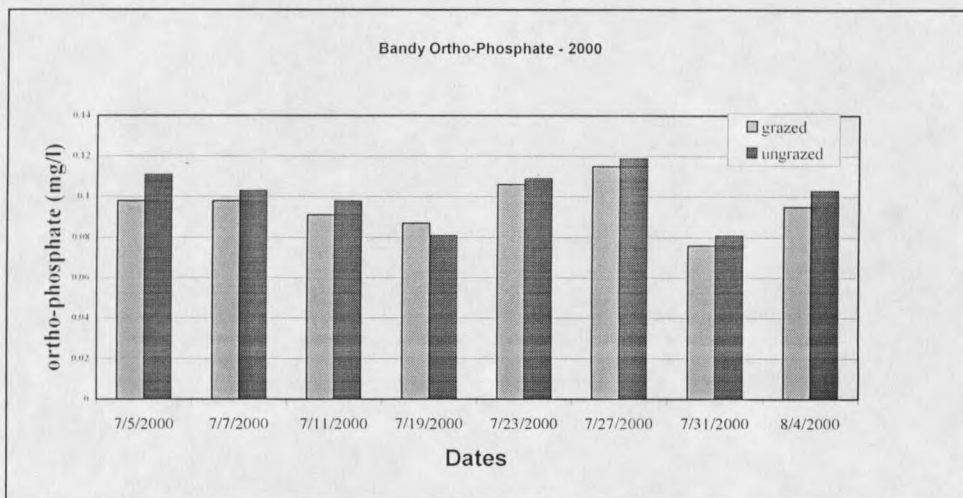


Fig. 7. Ortho-phosphate concentrations in Cottonwood Creek at the Bandy Ranch 2000.

In 2000 at the Bair Ranch, there appeared to be little difference in ortho-phosphate levels between grazed and ungrazed reaches (Fig. 8) and substantiated differences in fecal coliform levels (Fig. 9).

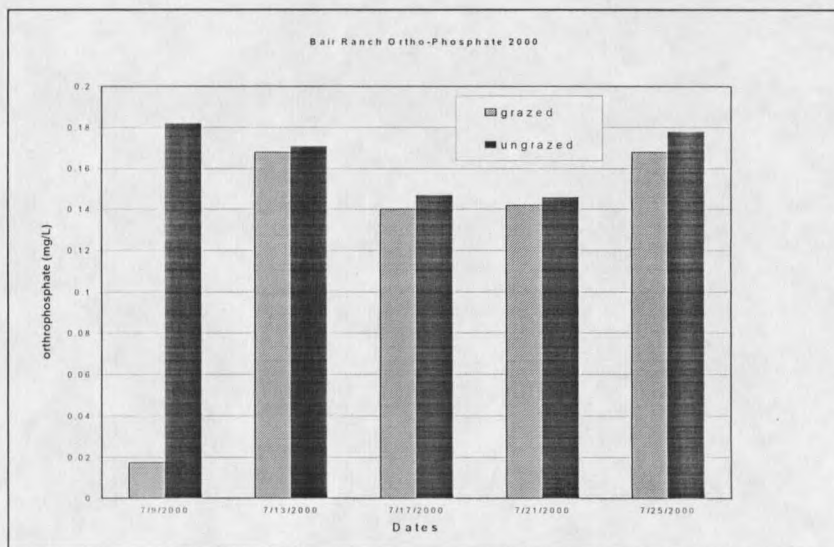


Fig. 8. Ortho-phosphate concentrations in the South Fork of the Musselshell River at the Bair Ranch 2000.

When comparing the three significant measurements in 2000 through regression analysis, Bandy Ranch ortho-phosphate was not significantly related with stubble height ($P=0.55$), days in pasture ($P=0.15$) or stream temperature ($P=0.18$).

At the Bair Ranch, ortho-phosphate ($P=0.06$) was less in grazed pastures, fecal coliform was greater ($P=0.06$), but nitrate ($P=0.81$) and stream temperature ($P=0.75$) did not differ between grazed and ungrazed treatments (Table 2).

Regression analysis for the Bair Ranch 2000 data indicated fecal coliform and stubble height were unrelated ($P=0.77$), as were fecal coliform and days in pasture ($P=0.52$). However, stream temperature ($P=0.02$) was again significant and thought to be caused by the low flow amounts in the stream. Ortho-phosphate levels for Bair 2000 were significantly related ($P=0.04$) to stubble height, but not days in pasture ($P=0.28$) or stream temperature ($P=0.81$).

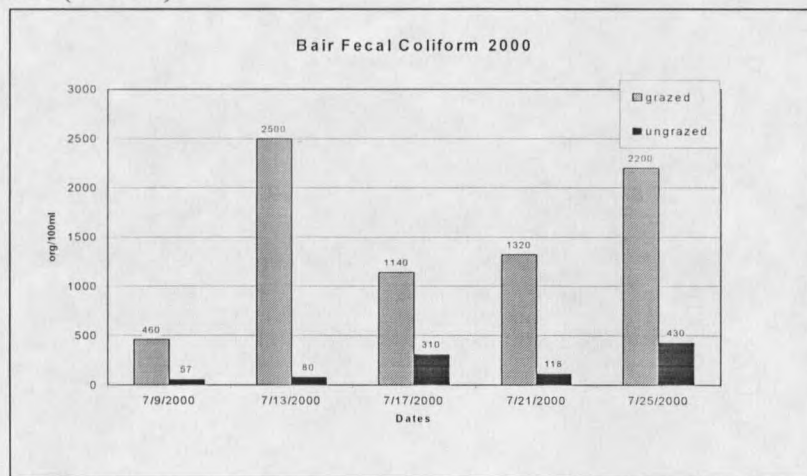


Fig. 9. Fecal coliform concentrations in the South Fork of the Musselshell River at the Bair Ranch 2000. On 7/13/2000 the amount actually equaled 41,000 org/100ml, but this actual value would distort the graph.

Temperature of the Musselshell both years was indicative of a warm water stream (>16.6 degree C). This could most likely be attributed to the extreme dewatering of the

Musselshell due to irrigation. Consequently, flows may be a major indicator of fecal coliform increases.

Comparison of 1999 and 2000 data

With the year 2000 being much drier than 1999, fecal coliform counts at the Bair Ranch were significantly higher ($P=0.02$) than the previous year. In 1999, the Bair Ranch fecal coliform levels were significantly higher ($P=0.07$) than those at the Bandy Ranch and in 2000 the difference between the two ranches was again significant ($P<0.01$). With lower flow and drier conditions in 2000, it stands to reason that fecal coliform concentration would increase within the study reach of the Musselshell.

CHAPTER 5

DISCUSSION

Grazing to a 7.5 cm stubble height did not degrade the water quality at either of the ranches in Montana. Thus, the new concept of looking at specific stubble height along the greenline to protect water quality did hold true, even when there were significant changes in fecal coliform and ortho-phosphate levels in grazed pastures. Except for ortho-phosphate at the Bair Ranch in 2000, stubble height was found to have no effect on the water quality parameters monitored during the course of this study (Table 2).

While fecal coliform changed significantly during this study, the 1999 fecal coliform levels only exceeded the Montana standard (200org/100ml) once during the grazing season and then only on the Bair Ranch. However, in 2000, the state standard was exceeded in all grazed pastures at the Bair Ranch. It is important to note that 2 out of 5 fecal coliform samples in the ungrazed pastures on the Bair Ranch also exceeded the state standard.

Ortho-phosphate levels in grazed and ungrazed pastures differed significantly ($P < 0.10$) on both ranches in 2000. Review of biweekly ortho-phosphate levels (Fig. 7 and 8) reveals a consistent pattern; ungrazed levels were higher than those taken in pastures being grazed, except for a single measure on 7/19/2000 at the Bandy Ranch. The apparent improvement is difficult to explain but could be due to rapid incorporation of ortho-phosphate in stream sediments of grazed pastures.

Nitrate levels were never elevated under livestock grazing in this study. The Montana standard for nitrate of <10 ppm for drinking water and 100 ppm for stock water (Montana Surface Water Quality Standards nda) were never exceeded during this study. This compares favorably to what Tiedemann et al. (1989) found in Oregon.

Days cattle were in the pasture had no bearing on fecal coliform levels (Table 4) but temperature was correlated to elevated fecal coliform at the Bair Ranch in 1999 and 2000. Consequently, the findings of this study show that the primary effect cattle had on water quality was to elevate fecal coliform levels. Higher stream temperatures caused by lower stream flows (Fig. 3 and 4) possibly enhanced bacterial growth in surface waters of the grazed pastures.

Even though there was no difference in stream temperature from downstream fenceline (grazed) to upstream fenceline (ungrazed) at the Bair Ranch (Table 2), some other parameter such as reduced flow or exposed soil may have been the cause of the significant relationship between stream temperature and fecal coliform (Table 4). However, this relationship is the same as that noted by Howell et al. (1996). Bandy Ranch water quality relationships appeared unaffected by stream temperature. Depressed flow levels measured at the Bandy Ranch gaging station were also evaluated as a potential cause for higher fecal coliform counts and the results showed that discharge in Cottonwood Creek had little effect on the fecal coliform levels in 1999 or the ortho-phosphate levels in 2000 (Table 4). Hence, at the Bandy Ranch, other parameters need to be studied to know the cause of the significant increases in fecal coliform in 1999 and ortho-phosphate in 2000, while at the Bair Ranch the only related parameter through the

regression tests was the stream temperature. The lack of grazing effects on stream temperatures in this study contradict the improvements in water temperature following cattle removal as reported by Van Velson (1979). The stream temperature at the Bandy Ranch never exceeded 15.6 degrees C in either year. Stream temperature at the Bair Ranch averaged 17.8 degrees C in 1999 and 18.9 degrees C in 2000 during the grazing season. The Bandy Ranch averaged 11.1 degrees C in 1999 and 10.6 degrees C in 2000 for the grazing season. Differences between grazed and ungrazed reaches of the same streams at the Bandy and Bair Ranches were never significant (Table 2).

The glaciated topography may provide more groundwater in flows on Cottonwood Creek at the Bandy Ranch than on the unglaciated South Fork of the Musselshell River at the Bair Ranch. Consequently, greater groundwater exchange with surface waters would have kept water temperatures low at the Bandy Ranch. Following the arguments of Howell (1996) this could explain lower fecal coliform levels in 1999 and 2000 at the Bandy Ranch than at the Bair Ranch.

Without a stream gage at the Bair Ranch, it was difficult to evaluate stream flow as a cause for elevated fecal coliform levels, but the South Fork of the Musselshell River can be assumed to react the same as mountain streams where irrigation draws down water levels in the summer months. This idea is backed up by other studies (Morrison and Fair 1966, Kunkle and Meiman 1967, Kunkle and Meiman 1968 and Skinner et al. 1974) in which fecal coliform and fecal streptococci were at the highest levels in late summer.

With lower discharge, water temperature increased because of less water volume and quicker warming. Even though discharge and stream temperature may interact, further

research on grazing levels and water temperature is necessary. The interesting fact is that these two study sites were grazed intensively and even with the increased pressure, no relationship between stubble height on the greenline other than ortho-phosphate at the Bair Ranch in 2000 or days livestock spent in the pasture and water quality was detected. It is important to note, however, that several of the original reports discussing the use of a 7.5 cm grazed stubble criterion (Hall and Bryant 1995, Abt et al. 1994) based their recommendations on observations in plant communities dominated by the low growing Kentucky bluegrass (*Poa pratensis*). Taller graminoids, timothy, orchardgrass, beaked sedge and Nebraska sedge, dominated the greenline along Cottonwood Creek, and the South Fork of the Musselshell. Hence a 7.5 cm stubble would have removed less plant material from a Kentucky bluegrass dominated riparian zone than on sites like those on the Bair and Bandy Ranches. This suggests that it is important to consider the plant community to be grazed before applying a stubble height standard along a greenline. Stream flow may end up being the major consideration when planning livestock grazing because low flows can lead to higher stream temperatures and ultimately elevated fecal coliform levels. Nonetheless, current recommendations look at health of riparian zone and vegetation, but rarely address water quality. Current recommendations (Clary and Leininger 2000, Clary et al. 1989, Hall and Bryant 1995) are based on the concept that increased attention to the amount of forage removal as a prescribed management tool will improve water quality. This study found that a vegetation attribute such as a fixed stubble height standard on the greenline does little to improve water quality. Additionally, grazing had no effects on stream temperature. These findings differ with those of Rhodes

et al. (1995) because water quality on two separate geographic areas was affected by grazing in a similar fashion. However, the study by Rhodes et al. (1995) only addressed bank stability not water quality. This suggests that the relationship between bank trampling, more exposed soil, and water temperature should be investigated.

CHAPTER 6

CONCLUSION

A grazing standard of a 7.5 cm stubble height on the greenline generally had no effect on water quality (fecal coliform, ortho-phosphate, nitrate, pH, temperature and sediment) on the two study streams in Montana. Nitrate levels were not elevated by livestock grazing at either ranch, and remained well below the state standards. Stream temperature, pH, and sediment levels were not impacted in any way by livestock grazing to a 7.5 cm greenline stubble height. Even though fecal coliform was elevated by grazing at the Bandy and Bair Ranches in 1999 and at the Bair Ranch in 2000, neither stubble height nor cattle days in pasture was related to the change.

At the Bandy Ranch, water temperature was not related to elevated ortho-phosphate or fecal coliform, but on the Bair Ranch, stream temperature was significantly related to increased fecal coliform numbers. Irrigation withdrawals that increased stream temperature may have been more responsible for elevated fecal coliform levels than livestock grazing.

Several authors (Belsky et al. 1999, Duff 1979, Carothers 1977) have suggested that grazing livestock may be the primary cause of non point source pollution on western rangelands. This may be true in some areas, but under heavy grazing at two locations in Montana, only fecal coliform and ortho-phosphate were affected by cattle. The issues of recreation, summer homes, and wildlife on western rangelands should also be examined to determine their effects on water quality. An entire watershed needs to be taken into

account and not just a single user. This study shows that stubble height is not a good indicator of water quality on grazing lands. Stream discharge and temperature appear to be more reliable indicators of grazing impacts to water quality than stubble height. It is apparent from this study that during drought conditions or on streams with high irrigation withdrawals, livestock grazing could lead to unacceptable levels of fecal coliform. With this understanding, managers could utilize off-stream water or pasture deferment to limit water quality degradation on grazing lands.

REFERENCES CITED

- Abt, S.R., W.P. Clary, and C.I. Thornton. 1994. Sediment deposition and entrapment in vegetated streambeds. *J. Irrigation and Drainage Engineering* 120:1099-1111.
- Bailey, D.W., J.E. Gross, E.A. Laca, L.R. Rittenhouse, M.B. Coughenour, D.M. Swift, and P.L. Sims. 1996. Mechanisms that result in large herbivore grazing distribution patterns. *J. Range Manage.* 49:386-400.
- Bayley, P.B and H.W. Li. 1992. Riverine Fishes. Pg 251-281 in P. Calow and G.E. Petts, editors. *The Rivers Handbook*. Blackwell Scientific Publication, London.
- Beetle, A.A. 1956. Range survey in Wyoming's Big Horn Mountains. *Wyo. Agr. Exp. Sta. Bull. #341*. 40pp.
- Beaverhead N.F. 1997, Final EIS Beaverhead National Forest. Dillon, Mont.
- Belsky, A.J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. *J. Soil and Water Cons.* 54:419-431.
- Biskie, J.L., B.M. Sherer, J.A. Moore, J.C. Buckhouse and J.R. Miner. 1988. Behavior of indicator bacteria in rangeland streams- Manure spike experiments. *Journal Paper No. 8437, Oregon Ag. Exp. Stat, Corvallis. ASAE Paper No. 88-2081*.
- Brown, G.W. 1983. Forestry and water quality. College of Forestry, Oregon State University. Publ. OSU Bookstores, Inc. Corvallis, OR. 142 pp.
- Bryant L.D. 1982. Response of livestock to riparian zone exclusion. *J. Range Manage.* 35:780-785.
- Buckhouse, J.C. and G.F. Gifford. 1976. Water quality implications of cattle grazing on a semiarid watershed in southeastern Utah. *J. Range Manag.* 29:109-113.
- Carothers, S.W. 1977. Importance, preservation, and management of riparian habitats: and overview. In: *Importance, Preservation, and Management of Riparian Habitat: A Symposium*. USDA Forest Serv. Gen. Tech. Rep. RM-43. P. 2-4. Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Co.
- Chaney, E., W. Elmore, and W.S. Platts. 1990. Livestock grazing on Western riparian areas. North west resource Info. Cen., Inc.: Eagle, Ida.
- Chow, VenTe. 1959. Open channel Hydraulics. McGraw-Hill, Inc, New York.

- Clary, W.P. and W.C. Leininger. 2000. Stubble height as a tool for management of riparian areas. *J. Range Manage.* 53:562-573.
- Clary, W.P. and B.F. Webster. 1989. Managing grazing of riparian areas in the intermountain region. Intermountain Res. Sta. Gen. Tech. Rep. INT-263. U.S. Department of Agriculture, Forest Service.
- Clesceri, L.S., A.E. Greenberg, and A.D. Eaton. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition. American Public Health Association, Washington, D.C.
- Cooper, J.R., J.W. Gilliam, R.D. Daniels, and W.P. Robarge. 1987. Riparian areas as filters for agricultural sediment. *Soil Sci. Soc. Am. J.* 51:416-420.
- Daniels, R.B. and J.W. Gilliam. 1996. Sediment and chemical load reduction by grass and riparian filters. *Soil Sci. Soc. Am. J.* 60:246-251.
- Darling, L.A. 1973. Effects of livestock grazing on the water quality of mountain streams. *Water-Animal Proceedings*. USDA-ARS-Western Region. Snake River Cons. Res. Center, Kimberly, Idaho.
- Davis, J.W. 1982. Livestock vs. riparian habitat management- there are solutions. P. 175-184. In: *Wildlife-livestock relationships symposium: Proc. 10*. Univ. of Idaho Forest, Wildlife and Range Exp. Sta. Moscow.
- DeBano, L.F. and B.R. Heede. 1987. Enhancement of riparian ecosystems with channel structures. *Water Resources Bulletin*, American Water Resource Association 23:463-470.
- DeBano, L.F. and L.J. Schmidt. 1989. Interrelationship between watershed condition and health of riparian areas in southwestern United States. In: Gresswell, R.E., B.A. Barton, and J.L. Kershner, eds. *Practical Approaches to Riparian Resource Management: An Educational Workshop*. Billings, MT: USDI Bureau of Land Management.
- Dixon, J.E., G.R. Stephenson, A.J. Lingg, D.V. Naylor, and D.D. Hinman. 1979. Stocking rate influence upon pollutant losses from land wintering rangeland cattle: A preliminary study. *Amer. Soc. of Ag. Engineers. Livestock Waste: A Renewable Resource*. 261-264. St. Joseph, Michigan.

- Duff, D.A. 1979. Livestock grazing impacts on aquatic habitat in Big Creek, Utah. Paper presented at the symposium on livestock interactions with wildlife, fish and their environments, May 1977, Sparks, Nevada. University of California, Davis, California.
- Elliott, L.F. and J.R. Ellis. 1977. Bacterial and viral pathogens associated with land application of organic wastes. *J. Environ. Qual.* 6:245-251.
- Ellis, W.C., J.P. Telford, H. Lippke, and M.W. Riewe. 1984. Forage and grazing effects on intake and utilization of annual ryegrass by cattle. P. 223-234. In: G.W. Horn (ed) *Proc. of the Nat. Wheat Pasture Symposium*. Okla. Agr. Exp. Sta. MP-115.
- Fajardo, J.J., J.W. Bauder, and S.D. Cash. 2001. Managing nitrate and bacteria in runoff from livestock confinement areas with vegetative filter strips. *J. of Soil and Water Conservation*. 56:184-190
- Gary, H.L., S.R. Johnson, and S.L. Ponce. 1983. Cattle grazing impact on surface water quality in a Colorado Front Range stream. *J. Soil Water Conserv.* 38:124-128.
- Grey, C.L., Q.D. Skinner, and R. J. Henszey. 1997. The effects of three residual vegetation heights on streambed sediment deposition and vegetation production. Abstracts, 50th Annual Meeting, Society for Range Manage, Feb. 16-21, Rapid city, SD.
- Gross, J.A. and J.E. Knight. 2000. Elk presence inside various-sized cattle exclosures. *J. Range Management*. 53:287-290.
- Hall, F.C. and Bryant, L.. 1995. Herbaceous stubble height as a warning of impending cattle grazing damage to riparian areas. Gen. Tech. Rep. PNW-GTR-362. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 9 p.
- Haan, C.T. and B.J. Barfield. 1978. Hydrology and sedimentology of surfaced mined lands. Office of Continuing Education and Extension, College of Engineering, University of Kentucky, Lexington.
- Hansen, P.L., R.D. Pfister, K. Boggs, B.J. Cook, H. Joy, and D.K. Hinckley. 1995. Classification and Management of Montana's Riparian and Wetland Sites. University of Montana. Misc. Pub. No. 54.
- Heitschmidt, R.K. 1990. The role of livestock and other herbivores in improving rangeland vegetation. *Rangelands* 12:112-115.

- Howell, J.M., M.S. Coyne, and P.L. Cornelius. 1996. Effect of sediment particle size and temperature on fecal bacteria mortality rates and the Fecal Coliform/Fecal Streptococci ratio. *J. Environ. Qual.* 25:1216-1220.
- Jawson, M.D., L.F. Elliott, D.E. Saxton, and D.H. Fortier. 1982. The effect of cattle grazing on indicator bacteria in runoff from a Pacific Northwest watershed. *J. Environ. Qual.* 11:621-627.
- Johnson, S.R., H.L. Gary, and S.L. Ponce. 1978. Range cattle impact on stream water quality in the Colorado front range. USFS Res. No. RM-359.
- Kauffman, J.B. 1982. Synecological effects of cattle grazing riparian ecosystems. M.S. Thesis. Oregon State University, Corvallis.
- Kauffman, J.B. and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications...A Review. *J. Range Manage.* 37:430-438.
- Kauffman, J.B., W.C. Krueger, and M. Vavra. 1983. Impacts of cattle grazing streambanks in northeastern Oregon. *J. Range Manage.* 36:683-685.
- Kondolf, M.G. 1993. Lag in stream channel adjustment to livestock. *Restoration Ecol.* 1:226-230.
- Kunkle, S. H. and J.R. Meiman. 1967. Water quality of mountain watersheds. Hydrology papers No. 21. Colorado State University, Fort Collins, Colorado.
- Kunkle, S.H. and J.R. Meiman. 1968. Sampling bacteria in a mountain stream. Hydrology papers No. 28. Colorado State University, Fort Collins, Colorado.
- Larson, L.L. and S. Larson. 1996. Riparian shade and stream temperature: A perspective. *Rangelands* 18:149-152.
- Lee-Campbell, K., J. Bloomquist, T.Bozarth, C. Cady, B. Hanson, W. Kellogg, C. Marlow, S. Noggles, J. Olivarez, and B. Shepard. 1999. Conservation District Bureau, Department of Natural Resources and Conservation. Helena, MT. 59620-1601.
- Leege, T.A., D.J. Herman, and B. Zamora. 1979. Effects of cattle grazing on mountain meadows in Idaho. *J. Range Manage.* 34:324-328.
- Marcuson, P.E. 1977. The effect of cattle grazing on brown trout in Rock Creek, Montana. Fish and Game Fed. Aid Pro. F-20-R-21-11a.

- Marlow, C.B. and T.M. Pogacnik. 1985. Time of grazing and cattle induced damage to streambanks. USDA For. Serv. Gen. Tech. Rep. RM-120. Pp. 270-284.
- Marlow, C.B., T.M. Pogacnik, and S.D. Quinsey. 1987. Streambank stability and cattle grazing in southwestern, Montana. *J. Soil and Water Conserv.* 42:291-296.
- Marlow, C.B., K. Olson-Rutz, and J. Atchley. 1989. Response of a Southwest Montana riparian system to four grazing management alternatives. Practical approaches to riparian resource management: an educational workshop, May 8-11, 1989, Billings, Montana.
- Meehan, W.R. and W.S. Platts. 1978. Livestock grazing and the aquatic environment. *J. Soil and Water Conserv.* 33:274-278.
- Montana Agricultural Statistics. 2001. Montana Department of Agriculture and U.S. Department of Agriculture.
- Montana Surface Water Quality Standards (17.30.620 through 17.30.637) – of the Administration Rules of Montana [ARM].
- Morrison, S.M. and J.F. Fair. 1966. Influence of environment on stream microbial dynamics. Hydrology papers No. 13. Colorado State University, Fort Collins, Colorado.
- Myers T.J. and S. Swanson. 1995. Impact of deferred rotation grazing on stream characteristics in central Nevada: A case study. *North American J. of Fisheries Manage.* 15:428-439.
- Osborne L.L. and D.A. Kovacic. 1993. Riparian vegetated buffer strips in water quality restoration and stream management. *Freshwater Biol.* 29:243-258
- Platts, W.S. 1979. Livestock grazing and riparian stream ecosystems- An overview. *Proceeding Forum: Grazing and riparian stream ecosystems.* P. 39-45. Trout Unlimited, Inc.
- Platts, W.S. 1982. Livestock and riparian fishery interaction: What are the facts? *Trans. North Amer. Wildl. Nat. Res. Conf.* 47:507-515.
- Platts, W.S. and R.L. Nelson. 1985a. Impacts of rest-rotation grazing on stream banks in forested watersheds in Idaho. *North American J. Fisheries Manage.* 5:547-556.
- Platts, W.S. and R.L. Nelson. 1985b. Will the riparian pasture build good streams? *Rangelands* 7:7-11.

- Platts, W.S. and F.J. Wagstaff. 1984. Fencing to control livestock grazing on riparian habitats along streams: Is it a viable alternative? *North Amer. J. Fisheries Manage.* 4:266-272.
- Redmon, L.A., T.F. Mccollum, G.W. Horn, M.D. Cravey, S.A. Gunter, P.A. Beck, J.M. Mieres, and R.S. Julian. 1995. Forage intake by beef steers grazing winter wheat with varied herbage allowances. *J. Range Manage.* 48:198-201.
- Rhodes, B.J., C.B. Marlow, and H.W. Sherwood. 1995. Monitoring streambank stability: Grazing impacts or stream variability. *Montana Ag Research Agri. Exp. Stat.* Vol 12. Issue 2 Final Issue.
- Rinne, J.N. 1988. Grazing effects on stream habitat and fishes: Research design considerations. *North American J. Fisheries Manage.* 8:240-247.
- Rumsey, C.J. 1996. The effect of three residual vegetation heights on streambank sediment deposition and vegetative production. M.S. Thesis, University of Wyoming, Laramie.
- Savory, A. 1980. The Savory grazing method. *Rangelands* 2:234-237.
- Sherer, B.M., J.R. Miner, J.A. Moore, J.C. Buckhouse. 1988. Resuspending organisms from a rangeland stream bottom. *Amer. Soc. of Ag Eng.* 31:1217-1222.
- Skinner, Q.D. 1998. Stubble height and function of riparian communities. Stubble height and utilization measurements: uses and measurements. *Sta. Bull.* 682. May 1998. *Ag. Exp. Sta.* Oregon State University.
- Skinner Q.D., J.C. Adams, P.A. Rechard, and A.A. Beetle. 1974. Effects of summer use of a mountain watershed on bacterial water quality. *J. Environ. Qual.* 3:329-335.
- Skinner Q.D., H.E. Speck, M. Smith, J.C. Adams. 1984. Stream water quality as influenced by beaver within grazing systems in Wyoming. *J. Range Manage.* 37:142-146.
- Stephenson, D.G., and L.V. Street. 1978. Bacterial variation in a stream from a southwest Idaho rangeland watershed. *J. Environ. Qual.* 8:150-157.
- Swanson, F.J., S.V. Gregory, J.R. Sedell, and A.G. Campbell. 1982. Land water interactions: the riparian zone. *US-IBP Synthesis Series* 14:267-291.
- Thelin, R. and G.F. Gifford. 1983. Fecal coliform release patterns from fecal material of cattle. *J. Environ. Qual.* 12:57-63.

- Tiedemann, A.R., J.M. Quigley, and H.R. Sanderson. 1989. Managing Interior Northwest rangelands: The Oregon range evaluation project. May 1989. Pacific Northwest Research Station. Gen. Tech. Rep. PNW-GTR-238. U.S. Department of Agriculture, Forest Service.
- Trlica, M.J., E.A. Nibarger, W.C. Leininger, and G.W. Frasier. 1999. Runoff water quality from a grazed montane riparian ecosystem. VIth International Rangeland Congress Proceedings Vol. 2. July 19-23, Townsville, Queensland, Australia. P.699-701.
- USEPA. 1986. Quality criteria for water. EPA 440/5/86/001. United States Environmental Protection Agency, Washington, DC.
- USEPA. 1989. National primary and secondary drinking water regulation, proposed rule. Fed. Reg. 54:97. United States Environmental Protection Agency, Washington, DC.
- Van Donsel, D.J. and E.E. Geldreich. 1971. Relationships of salmonella to fecal coliforms in bottom sediments. Water Research 5:1079-1087.
- Van Velson, R. 1979. Effects of livestock grazing upon rainbow trout in Otter Creek p. 53-56. In: Proc., Forum-Grazing and Riparian/Stream Ecosystems. Trout Unlimited, Inc.
- Voisin, A. 1959. Grassland Productivity. Island Press, 353pp.
- Weller, M.W. 1996. Birds of rangeland wetlands. pp. 71/82. In: P.R Krausman (ed.), Rangeland Wildlife. The Society for Range Manage., Denver Colo.
- Winward, A.H. 2000. Monitoring the vegetation resources in riparian areas. Gen. Tech. Rep. RMRS-GTR-47. Odgen, Ut: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49p.
- Wright, I.A., T.K. Whyte, and K. Osoro. 1990. The herbage intake and performance of autumn-calving beef cows and their calves when grazing continuously at two sward heights. Anim. Prod. 51:85-92.

APPENDIX A:
NON SIGNIFICANT CHARTS

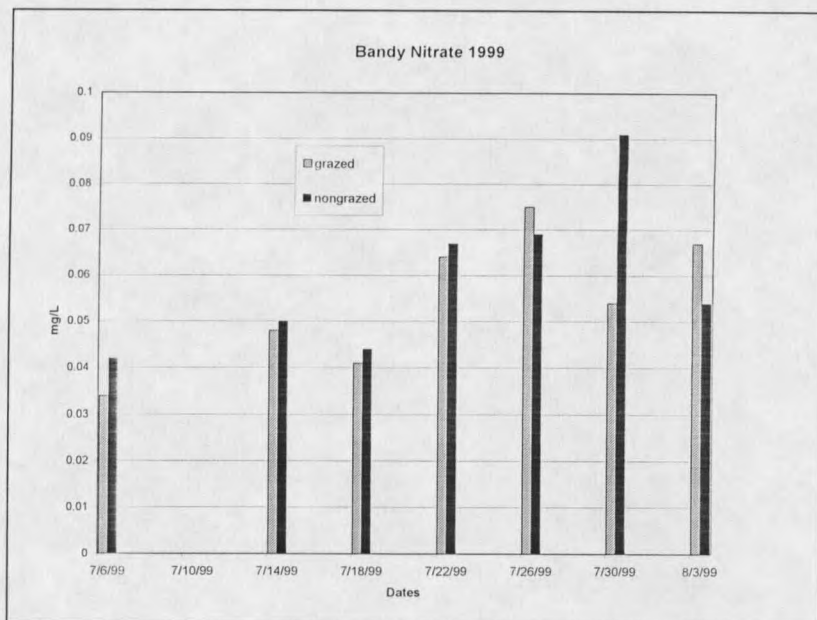


Fig. 10. Non-significant nitrate concentrations in Cottonwood creek at the Bandy Ranch 1999.

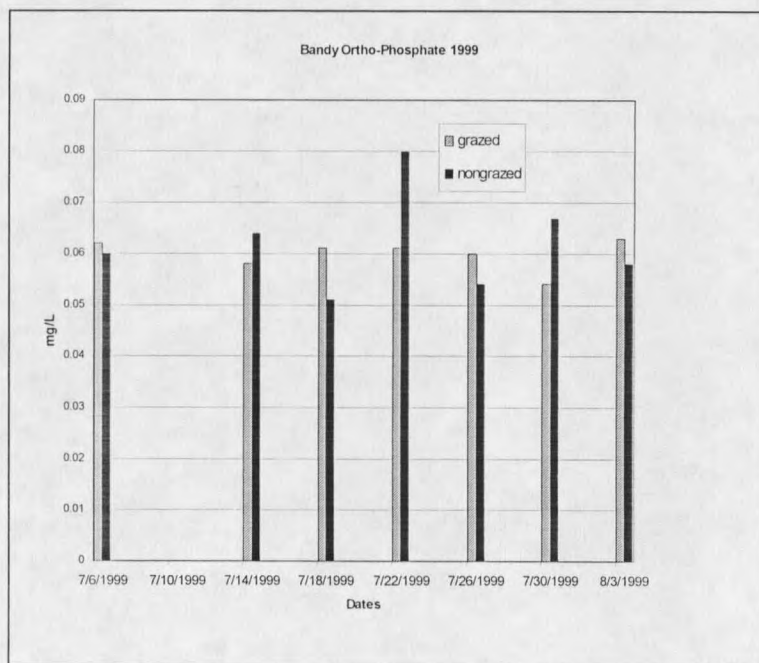


Fig. 11. Non-significant ortho-phosphate concentrations in Cottonwood Creek at the Bandy Ranch 1999.

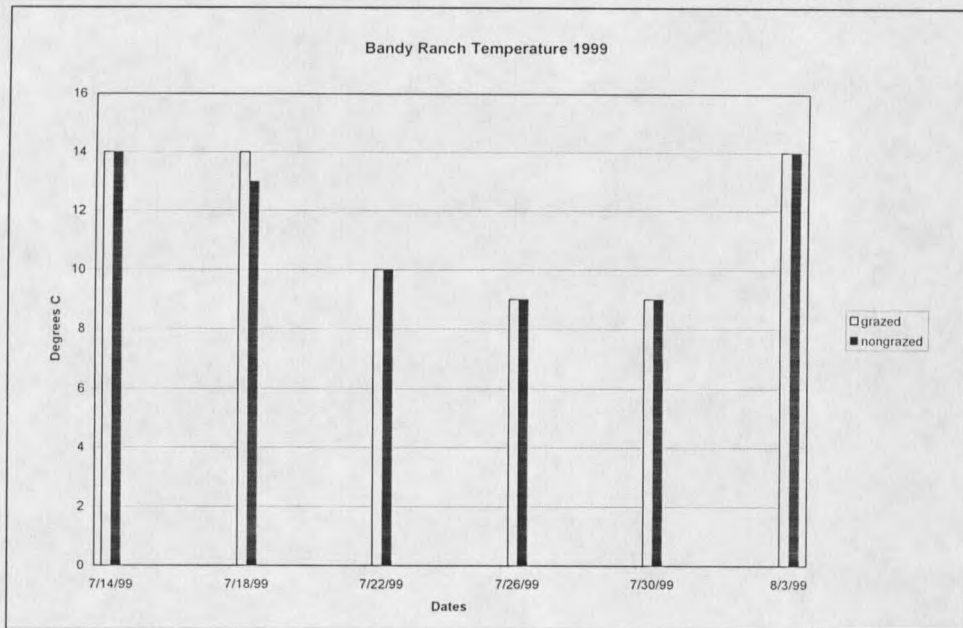


Fig. 12. Non-significant temperature in Cottonwood Creek at the Bandy Ranch 1999.

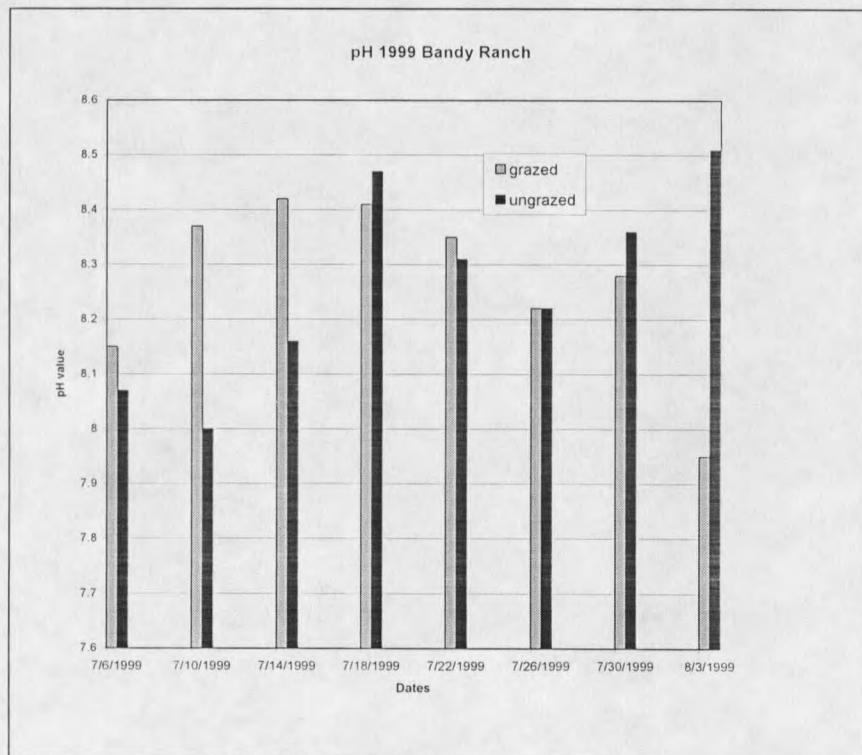


Fig. 13. Non-significant pH in Cottonwood creek at the Bandy Ranch 1999.

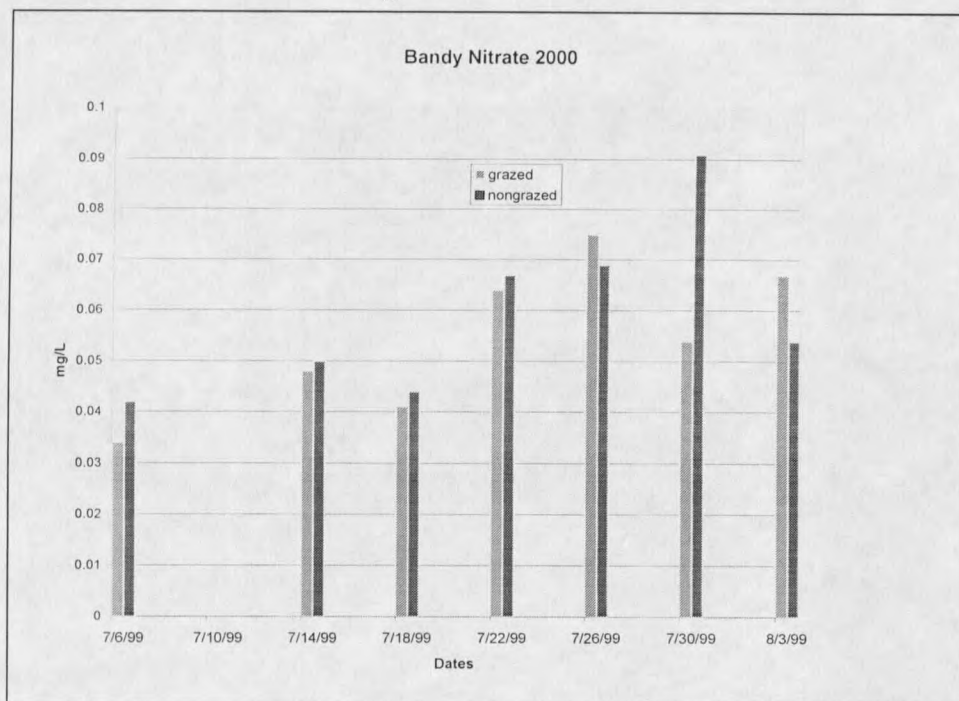


Fig. 14. Non-significant nitrate concentrations in Cottonwood Creek at the Bandy Ranch 2000.

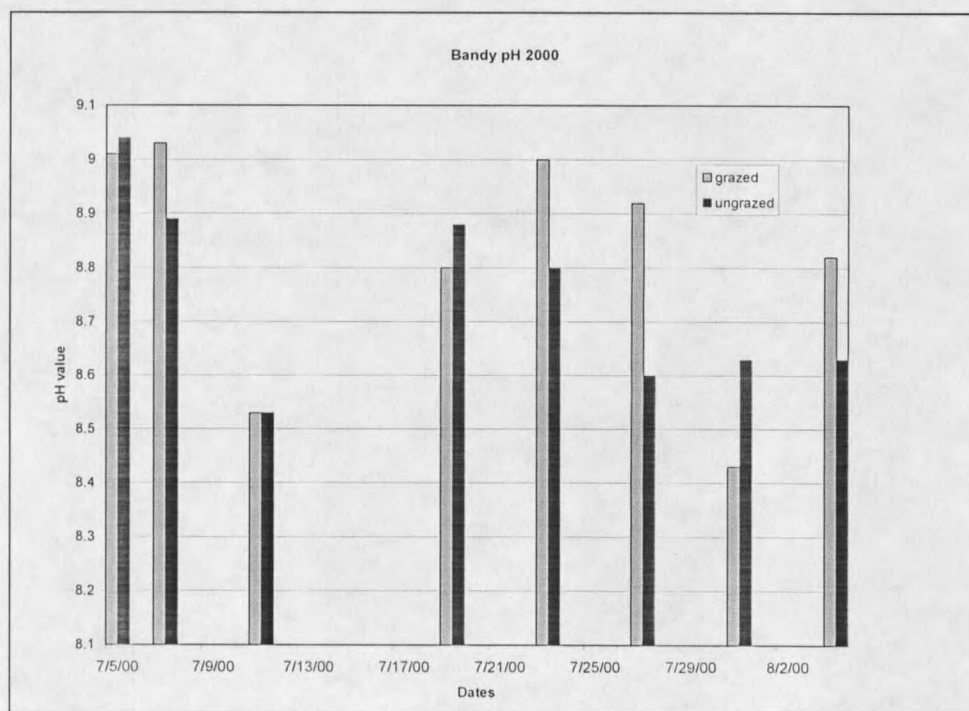


Fig. 15. Non-significant pH concentrations in Cottonwood Creek at the Bandy Ranch 2000.

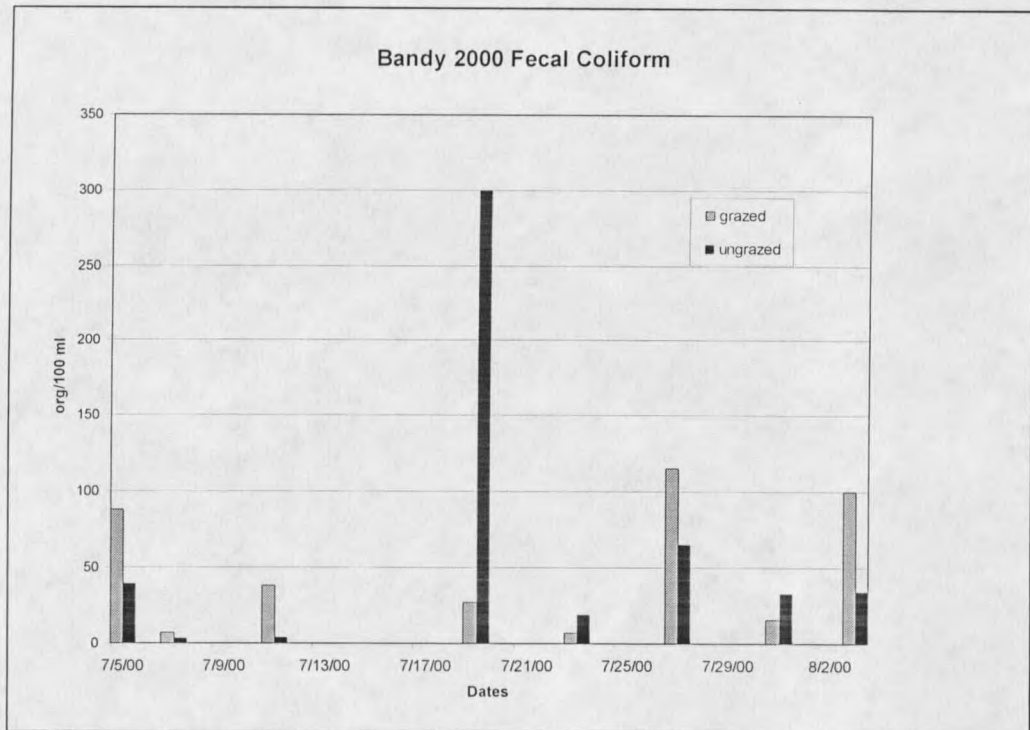


Fig. 16. Non-significant fecal coliform concentrations in Cottonwood Creek at the Bandy Ranch 2000.

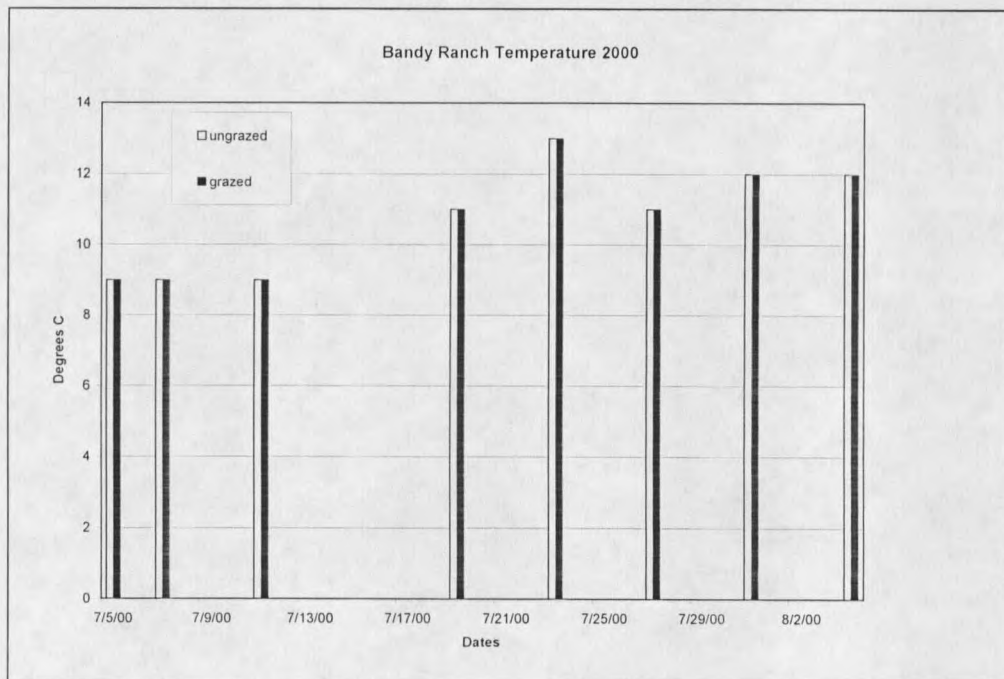


Fig. 17. Non-significant temperature in Cottonwood Creek at the Bandy Ranch 2000.

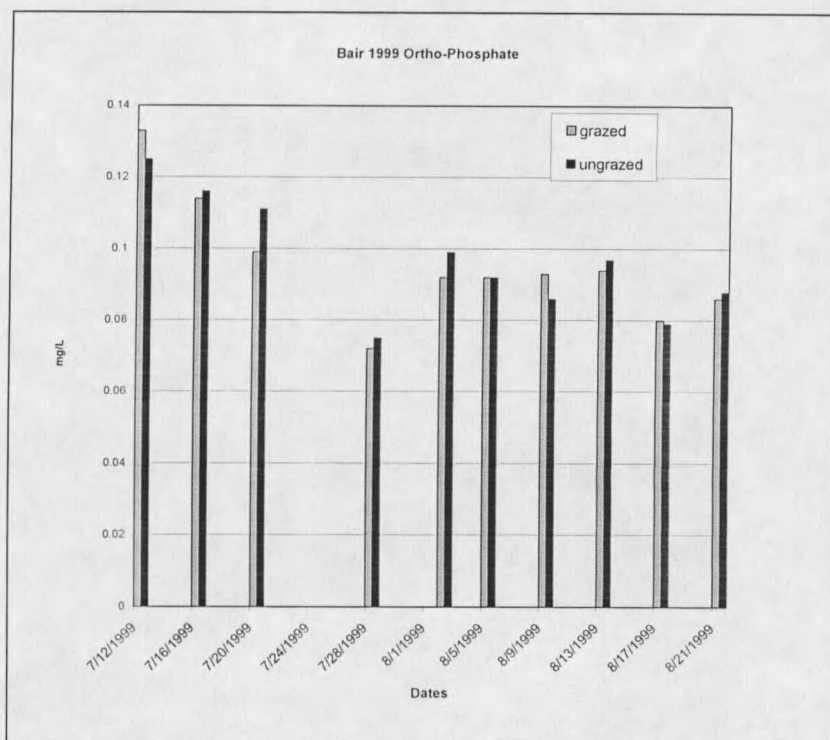


Fig 18. Non-significant ortho-phosphate concentrations in the South Fork of the Musselshell River at the Bair Ranch 1999.

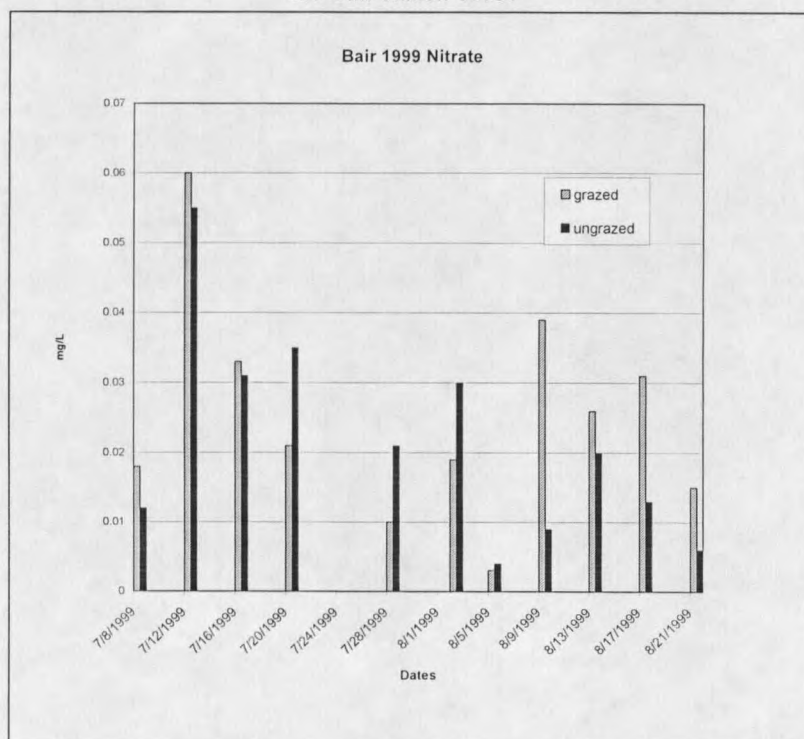


Fig. 19. Non-significant nitrate concentrations in the South Fork of the Musselshell River at the Bair Ranch 1999.

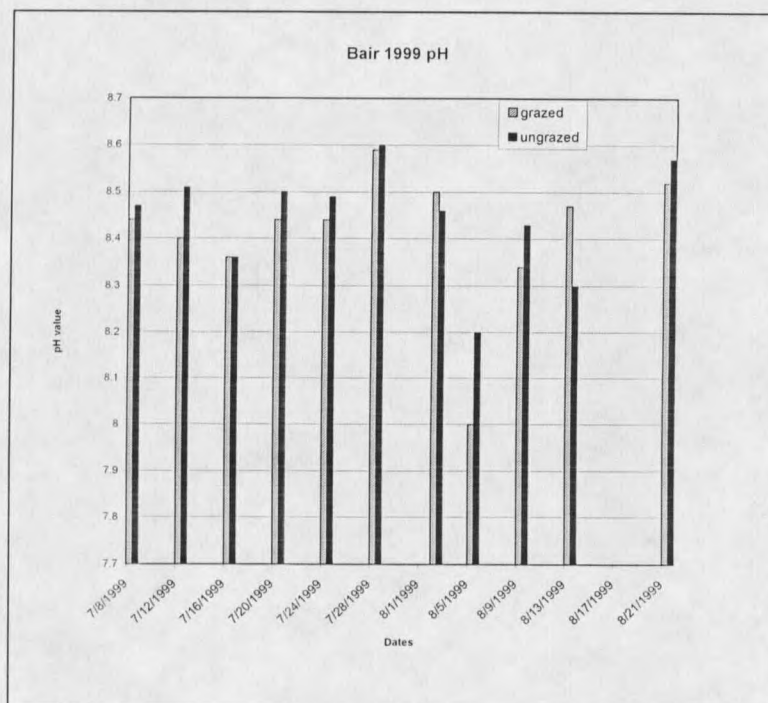


Fig. 20. Non-significant pH concentrations in the South Fork of the Musselshell River at the Bair Ranch 1999.

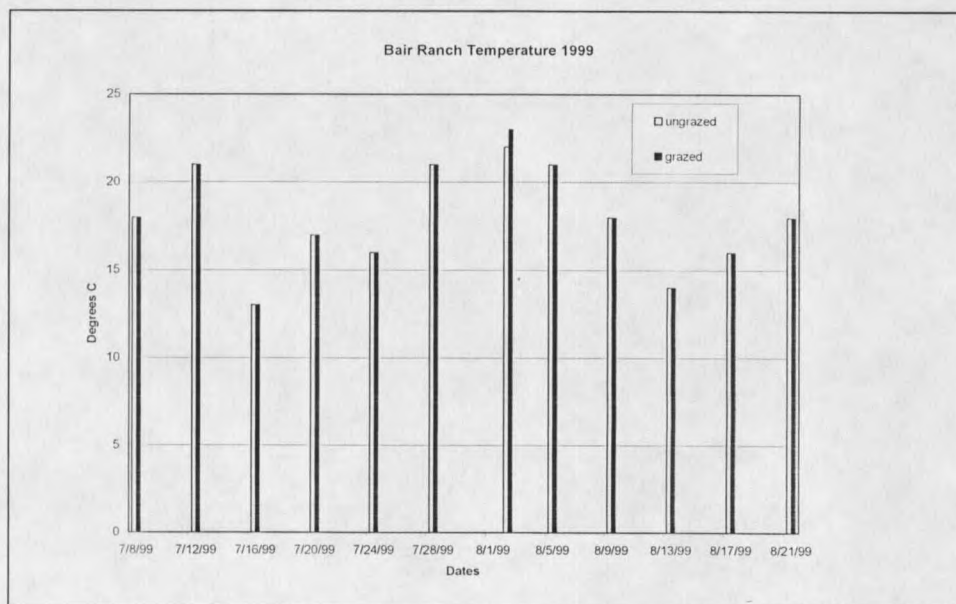


Fig. 21. Non-significant temperature in the South Fork of the Musselshell River at the Bair Ranch 1999.

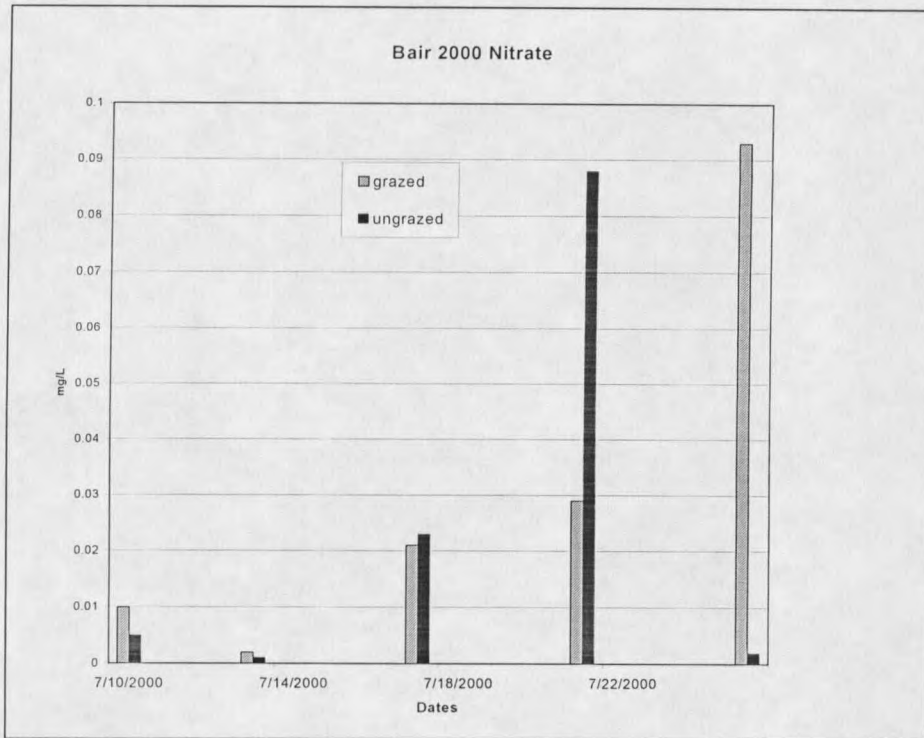


Fig. 22. Non-significant nitrate concentrations in the South Fork of the Musselshell River at the Bair Ranch 2000.

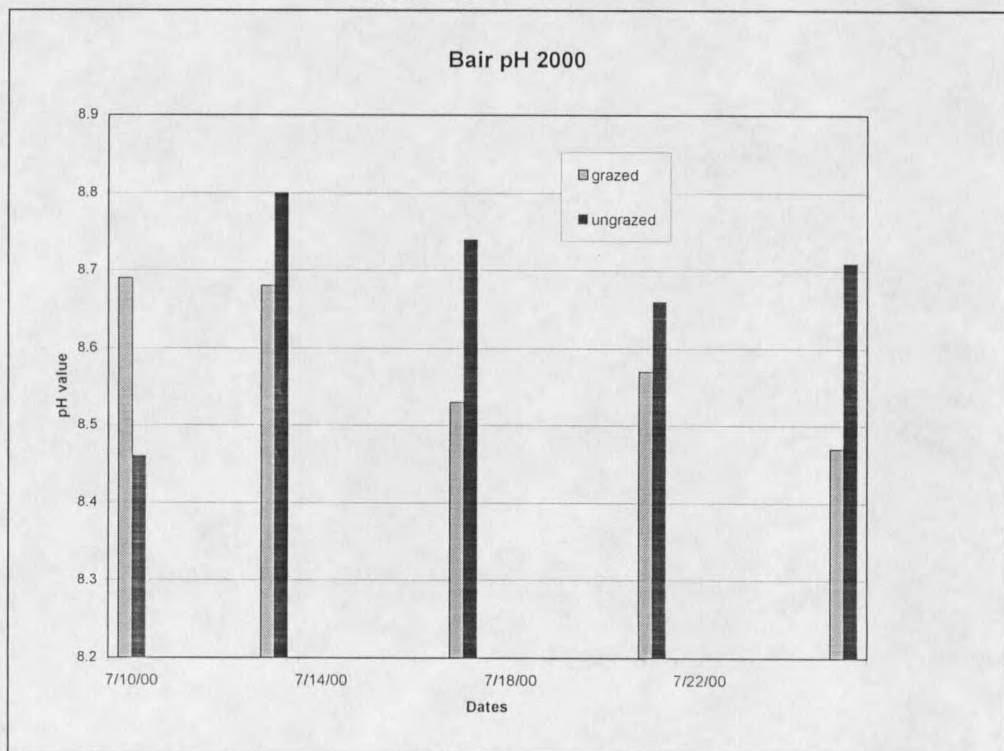


Fig 23. Non-significant pH concentrations in the South Fork of the Musselshell River at the Bair Ranch 2000.

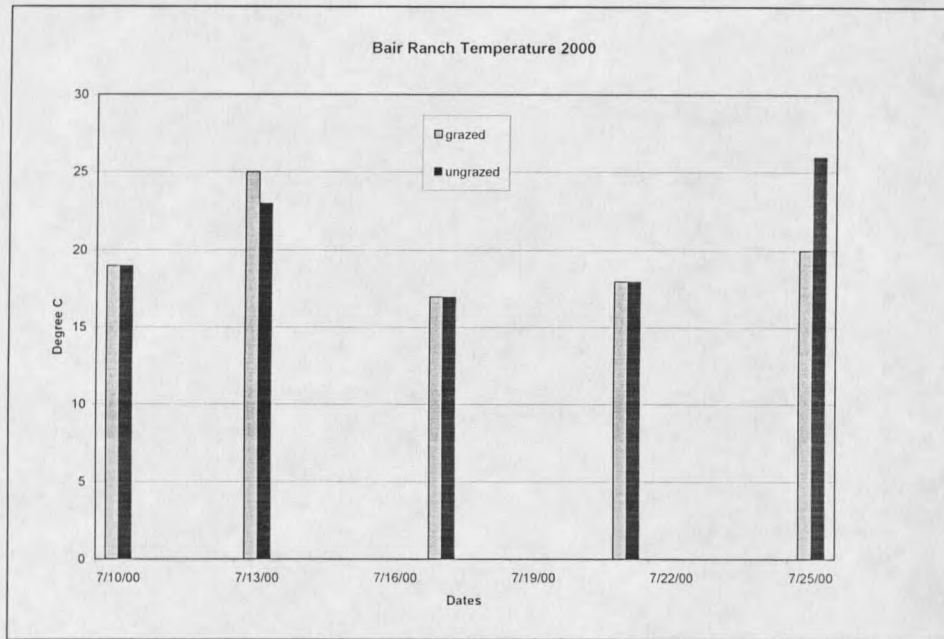


Fig. 24. Non-significant temperature in the South Fork of the Musselshell River at the Bair Ranch 2000.

MONTANA STATE UNIVERSITY - BOZEMAN



3 1762 10382369 4