The Impact of Livestock Grazing on Riparian Water Quality

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Abstract Numerous studies have shown that uncontrolled livestock grazing impacts stream bank stability, stream water quality, and can change, reduce, or eliminate vegetation in riparian ecosystems. This study, located at the California Sierra Foothills Research and Extension Center in Yuba County, extends prior research to determine if and how three grazing treatments, which have been continuously applied to the same watersheds from 1993 to 2005, affect water quality. Three different grazing treatments (no grazing, light-intensity grazing, and moderate intensity grazing) were applied randomly to the sites within three watersheds. Water quality was monitored over the course of six months water quality and the results were compared to the 1997 study in order to assess the long-term impacts of livestock grazing on water quality. Results established no significant differences in measured parameters among grazing treatments. This study demonstrates similar results to the 1997 study indicating that livestock grazing intensities at levels applied in this study does not greatly impact water quality.

Introduction

Uncontrolled livestock grazing can have serious ecological consequences in western North America. Range management is practiced throughout the west, and livestock grazing is considered to be one of the largest land uses (Fleischner 1994). Of the 641 million acres of federal lands managed by the Bureau of Land Management and the U.S. Forest Service in the west, approximately 268 million acres (forty-two percent) are used for grazing (Fleischner 1994, BLM). Riparian systems, which include springs, seasonal and perennial streams, and their associated vegetation, comprise an important and unique part of ecosystems and are therefore crucial components of many land management plans (Allen-Diaz and Campbell 1997). Livestock tend to congregate in riparian ecosystems because of cooler summer temperatures and the availability of feed, water, and shade. Grazing can alter the species composition of riparian communities, impact stream channel morphology, water quality and the structure of streambanks (Kauffman and Krueger 1984; Fleischner 1994).

Riparian vegetation provides allochtonous inputs and influences the physical conditions in the stream environment. Vegetation provides shade, influencing stream temperature, and can also reduce water velocity and the erosive nature of stream flow (Kauffman and Krueger 1984). Fernandez-Gimenez and Allen-Diaz (1999) note that livestock grazing influences species composition directly through defoliation and trampling and indirectly by nutrient enrichment. They speculated that elevated nutrient concentrations near water sources resulted from livestock waste. They also speculated that livestock grazing may affect plant community composition, biomass, and cover indirectly through the deposition of nutrients. Grazing pressure increases the proportion of grazing-tolerant species inversely to the proportion of palatable species.

The EPA recognizes sediment, pathogens, nitrogen and phosphorus, biochemical oxygen demand, and turbidity as possible non-point source pollutants originating from cattle (Allen-Diaz and Campbell 1997). At the watershed level, changes in water quality and runoff quantity may indicate non-point sources of water pollution (Allen-Diaz and Campbell 1997). Water quality can be impacted by increasing temperatures, nutrients, suspended sediments and water flow (Platts 1979; Allen-Diaz and Campbell 1997). Stout et al. (2000) showed that intensive grazing could have significant negative impacts on water quality downstream from pastures. He attributed increased nitrate levels downstream to animal urine and feces. Increases in nitrogen and phosphorous levels can also result in algae blooms leading to eutrophication of water systems (Allen-Diaz and Campbell 1997). Platts (1979) states that livestock grazing affects stream channel morphology as well as water quality. There are many studies focusing on the impacts of grazing on erosion and streambank stability. Erosion can be initiated and aggravated by grazing animals and occurs throughout the nation's rangelands. Heavy grazing can compact soil thereby reducing infiltration, increasing runoff and erosion (Evans 1998; Rauzi and Hanson 1996; Trimble et al. 1995; Kauffman et al. 1983). Storm characteristics and seasonal trends were also considered to be a factor in the production of runoff.

It is difficult to study the effects of grazing. Few riparian systems have grazing records detailing the length of time and grazing intensities, leaving no baseline for comparison. To deal with this problem, many studies of livestock grazing effects on riparian and aquatic habitats have compared grazed and ungrazed areas using livestock exclosures which provide reference areas, and also can also provide protective measures to minimize impacts of livestock on riparian habitats (Starr 2002). There are, however, problems with common designs of livestock exclosure/inclosure studies. Most studies do not include pre-treatment data and begin the experiment when the exclosure is set up, producing circumstantial data (Larsen et al. 1997; Starr 2002). Many studies of grazing effects on riparian zones lack adequate description of the grazing method and type of livestock (Fleischner 1994). Grazing intensity, livestock species, seasonality of grazing, type of vegetation, and degree of active management can influence the impact of grazing on riparian zones (Fleischner 1994; Kauffman et al. 1983). Trimble et al. (1995) noted that light and moderate grazing have less significant effects then heavy grazing, thus there is a need for future research where the grazing intensity is controlled. Any research on the effects of grazing must clearly address the different management variables and their impact on the results.

The importance of determining the effects of grazing on riparian ecosystems is clear. Riparian ecosystems are generally considered to be the most biologically rich areas in arid and semiarid regions of the western United States (Fleischner 1994). The purpose of this study is to investigate the effects of livestock grazing on the water quality of spring-fed watercourses originating in oak woodlands located in the foothills of the Sierra Nevada Mountains in California. This study will investigate the impacts of grazing intensities on nitrate, pH, temperature, and conductivity. This study is important because it uses a controlled experimental design, where both grazing history is known, grazing intensities are controlled, and methods are consistent with a previous study. The results of this study will be compared to the 1997 study done by Allen-Diaz and Campbell on the same system with the same parameters. The hypothesis of this study is there will be significant differences in the measured parameters among the different grazing intensities. Greater grazing intensities will result in a greater impact on the water quality. The Allen-Diaz and Campbell study demonstrated no significant differences in the measured parameters among the treatments. The compounding effect of the grazing treatments being applied continuously for eight years may result in a difference in results between this study and the Allen-Diaz and Campbell study.

Methods

The study site is located at the University of California Sierra Foothill Research and Extension Center (SFREC) (Figure 1). The SFREC is located on the eastern side of the central valley in the Sierra foothills near Browns Valley, California, and covers 2,300 hectares between 90 and 600 meters in elevation (Allen-Diaz and Campbell 1997). The site has annual precipitation averages of 72 cm/yr and an average temperature of 75ºF. It is dominated by blue oak (*Quercus douglasii*)/grey pine (*Pinus sabiniana*) woodlands and savannas with introduced annual grasses and forbs (Allen-Diaz et al 1998).

Figure 1: SFREC Location

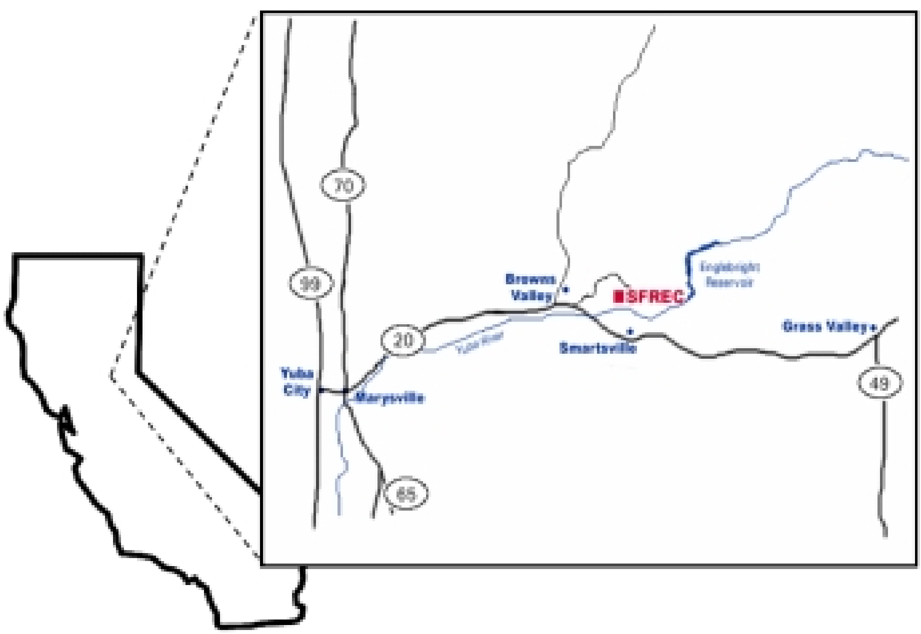

Figure 1

The 1997 study established nine 1-2.5 ha sites (Figure 2). All sites contain an undeveloped spring and creek, and have similar livestock grazing histories. Beginning in 1992, three cattle grazing treatments were applied randomly to the sites within the three watersheds using a completely randomized block design. Watersheds served as blocks such that watershed-to-watershed variation was separated from error variance. Each spring-creek system within the watershed (block) was randomly assigned one of three grazing treatments (Allen-Diaz et al. 1998): no grazing, light-intensity grazing leaving 1000-1200 kg/ha of residual dry matter (RDM) in the annual grassland, and moderate/heavy-intensity grazing leaving 600-750 kg/ha of RDM in the uplands (Allen-Diaz and Campbell 1997). Grazing treatments are applied every three months for short periods of time to simulate yearlong grazing, and to achieve the appropriate RDM levels (Allen-Diaz et al. 1998). The grazing treatments are applied by SFREC range managers and have been maintained from 1992 to the present (2005).

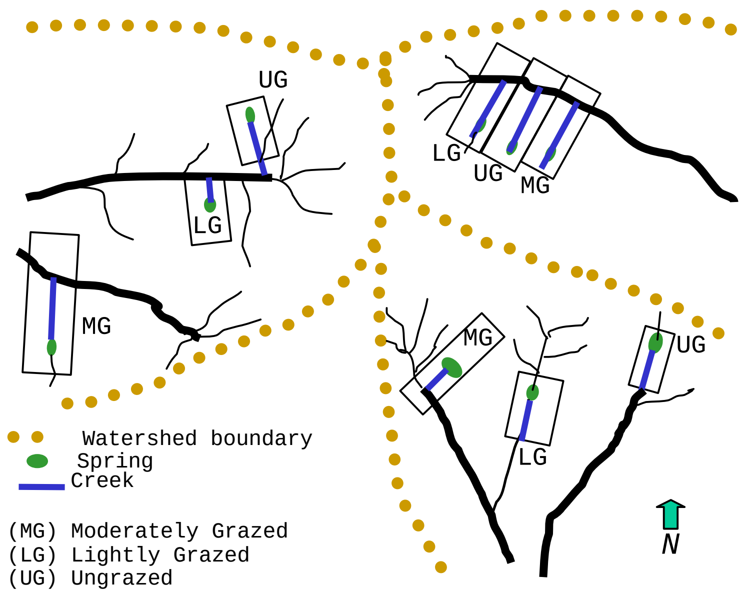

Figure 2: Experiment design diagram located in Sierra Foothill Research & Extension Center, Browns Valley, CA (Allen-Diaz and Campbell 1997). Treatments were randomly applied in each watershed or block.

The same nine sites used in the Allen-Diaz and Campbell (1997) study were utilized and sampled in this study. Samples were taken once a month, from October 2004 to March 2005 to capture variability associated with seasonal variation and pressures from livestock grazing. Each month, four water samples were taken from each site from the top and bottom of each spring and creek and were analyzed in sito using the YSI Model 63 Water Testing Meter (YSI Inc., Yellow Springs, OH) to measure temperature, pH, and conductivity. Samples were also collected for nitrate analyses and sent to the DANR lab at UC Davis using a flow injection analyzer. The results in 1997 serve both as base-line data sets and as preliminary results. The preliminary results have an important correlation to the final data. The base-line study provided an idea of how many samples needed to be collected, and also was used to provide data before the grazing treatments were applied.

The water quality parameters were analyzed using a randomized block design with analysis of variance (ANOVA) to account for the variability among the different watersheds in the experiment (Zar 1999). To identify the grazing treatment effects, the randomized block ANOVA was used to analyze a mixed model two-way interaction with treatment as the fixed factor and watershed as the block. An alpha-value of less than 0.05 was as an indicator of statistical significance. The differences of the means of the sample measurements were tested against the null-hypothesis. The results of this study were then paired with the results from the 1997 study to determine if there were any significant differences between the two studies. One water year from the 1997 study was used for comparison. The 1993/1994 water year was chosen based on similar sampling dates to this study.

Results

The means and standard error over the six months by treatment are displayed in Table 1.

Spring	***Moderate Grazing***	***SE***	***Light Grazing***	***SE***	***No Graze***	***SE***	***P-Value***
Nitrate (mg/L)	0.96	0.16	0.98	0.17	1.52	0.19	0.22
Temperature (°C)	13.8	0.3	14.3	0.34	16.2	0.41	0.17
Conductivity (µs/cm)	347	26.2	294	19.6	251	10.9	0.30
pH	7.59	0.09	7.37	0.07	7.34	0.07	0.46
Creek							
Nitrate (mg/L)	1.39	0.15	0.93	0.14	1.43	0.23	0.31
Temperature (°C)	14.4	0.37	13.8	0.25	15.18	0.56	0.71
Conductivity (µs/cm)	373	23.9	326	23.3	227	9.88	0.23
pH	7.68	0.09	7.84	0.05	7.83	0.05	0.73

Table 1: Summary of Spring and Creek Means and Standard Error (SE) by Grazing Treatment Dec 2004 –March 2005 using randomized block ANOVA.

Over the course of the six month study there was no significant differences detected between treatments. Figure 3 shows the lack of differences between treatments over the course of the six months. The analysis determined that any differences were the result of variation between sites. The results over the six month period show seasonal trends. Nitrate levels are higher in December after a higher rainfall and temperature appears to decrease across all treatments during the colder months of December through February

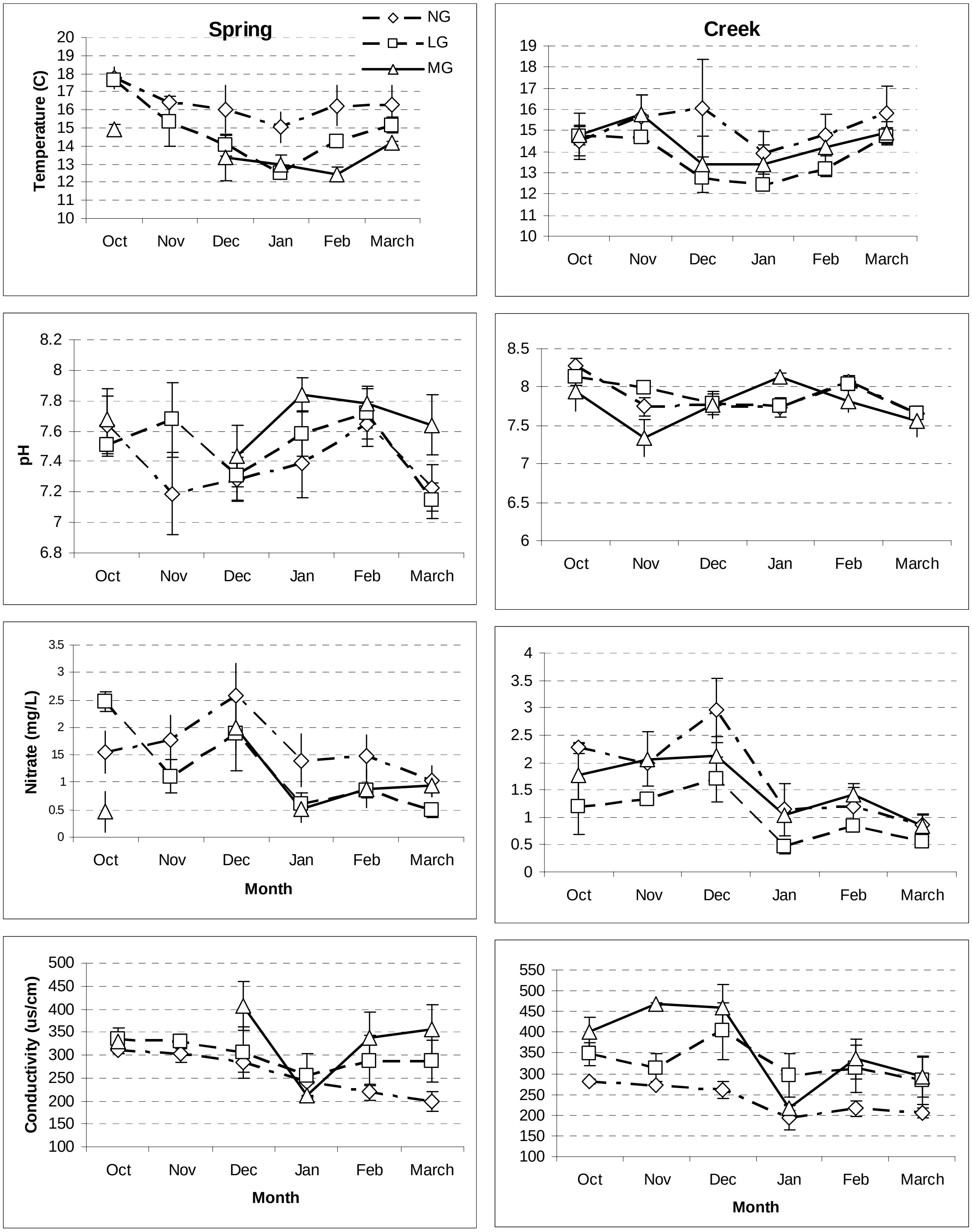

Figure 3: Monthly Water Quality Parameters for the Spring and Creek Averaged Over the Three Watersheds and Grazing Treatments.

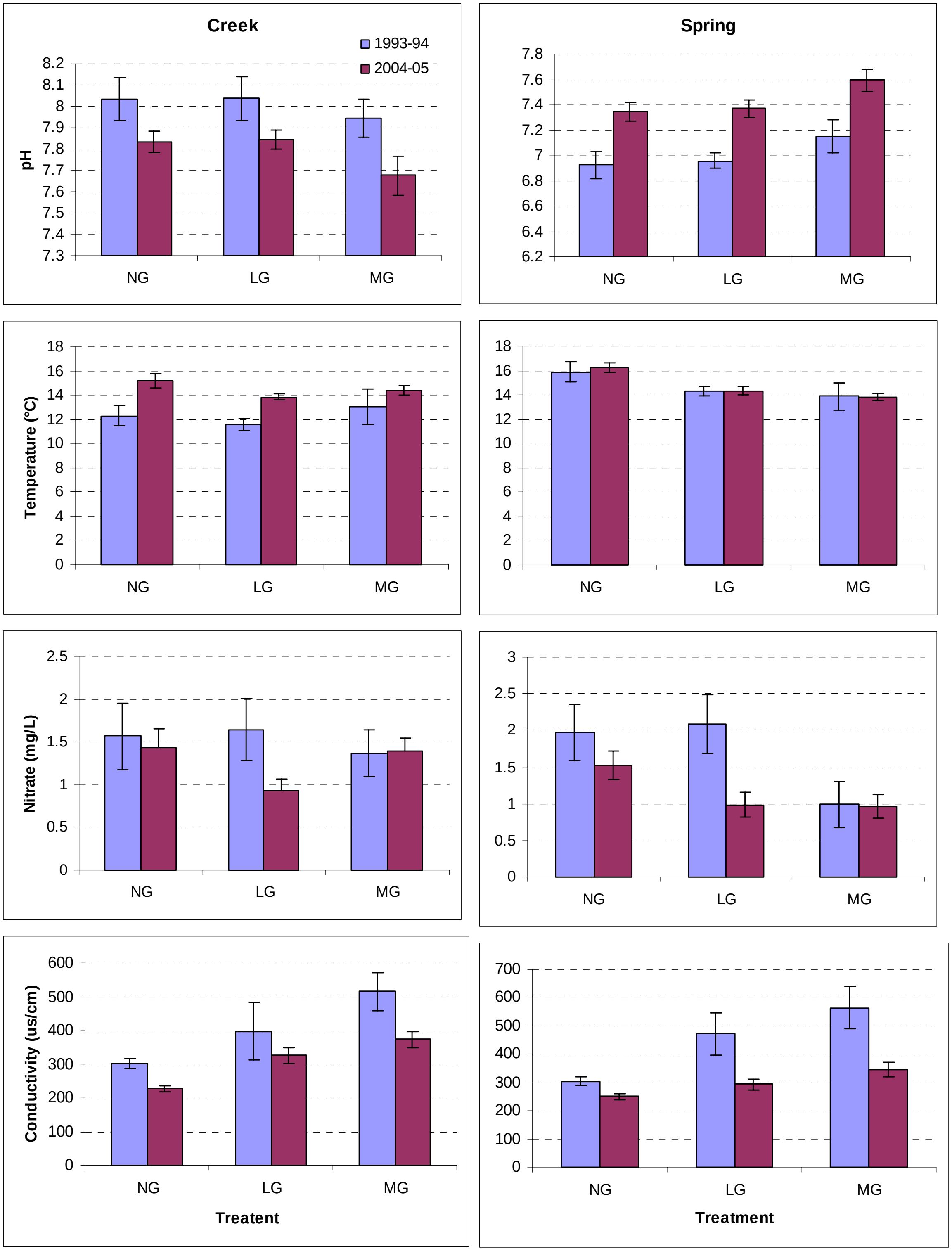

Figure 4: The Means and Associated Standard Errors of the Water Quality Parameters for the Spring and Creek Sites Measured During 1993-94 versus the 2004-05 Water Years.

		1993-94		2004-05		
Spring/Creek	Treatment	pH	SE	pH	SE	P-value
Creek	No Graze	8.03	0.10	7.83	0.05	0.44
Creek	Light Graze	8.04	0.10	7.84	0.05	0.29
Creek	Medium Graze	7.94	0.09	7.68	0.09	0.23
Spring	No Graze	6.92	0.11	7.34	0.07	0.06
Spring	Light Graze	6.96	0.06	7.37	0.07	0.06
Spring	Medium Graze	7.15	0.13	7.59	0.09	0.16
Spring/Creek	Treatment	Temperature (°C)	SE	Temperature(°C)	SE	P-value
Creek	No Graze	12.3	0.80	15.2	0.56	0.02
Creek	Light Graze	11.6	0.52	13.8	0.25	0.17
Creek	Moderate Graze	13.0	1.42	14.4	0.37	0.17
Spring	No Graze	15.9	0.84	16.2	0.41	0.46
Spring	Light Graze	14.3	0.40	14.3	0.34	0.88
Spring	Moderate Graze	13.9	1.15	13.8	0.30	0.82
Spring/Creek	Treatment	Nitrate (mg/L)	SE	Nitrate (mg/L)	SE	P-value
Creek	No Graze	1.57	0.37	1.43	0.22	0.22
Creek	Light Graze	1.64	0.36	0.93	0.14	0.13
Creek	Moderate Graze	1.37	0.27	1.39	0.15	0.93
Spring	No Graze	1.97	0.39	1.52	0.19	0.21
Spring	Light Graze	2.09	0.40	0.98	0.17	0.17
Spring	Moderate Graze	0.99	0.32	0.96	0.16	0.95
Spring/Creek	Treatment	Conductivity(µs/cm)	SE	Conductivity(µs/cm)	SE	P-value
Creek	No Graze	302	14.6	227	9.80	0.05
Creek	Light Graze	397	85.6	325	23.3	0.24
Creek	Moderate Graze	515	56.3	373	23.9	0.08
Spring	No Graze	303	14.9	251	10.9	0.02
Spring	Light Graze	472	75.6	294	19.6	0.27
Spring	Moderate Graze	565	76.1	347	26.2	0.12

Table 2: Comparison of Spring and Creek Means and Standard Error (SE) by Grazing Treatment Between 1993-94 and 2004-05 water years using randomized block ANOVA.

The results of this study were then compared to the 1997 study. In general, a means comparison did not reveal significant difference among water quality parameters between years. Significant differences in conductivity occurred between the two water years in the ungrazed spring and creek samples. Significant differences in temperature occurred between the two water years in the ungrazed creek samples. Significant differences among sites were determined. Table 2 and figure 4 above show the results of this comparison.

Discussion

The purpose of this study was to investigate the effects of livestock grazing on the water quality of spring fed watercourses originating from rangelands. The impacts of livestock grazing on spring and creek water quality were determined using different grazing intensities and sampling for nitrate, pH, temperature, and conductivity. The results demonstrate no significant difference in parameters between the three grazing treatments at an alpha-value equal to 0.05. The results of this experiment correlate with the results of the 1997 study done by Allen-Diaz and Campbell on the same system with the same parameters. The 1997 study also demonstrated no significant differences between treatments.

The hypothesis of this study stated that the parameters would demonstrate differences between grazing treatments. Other studies have shown that intense grazing can negatively impact stream water quality and alter the species composition of riparian communities. Previous studies have also noted that water quality can be impacted by increasing temperatures, nutrients, sediments and water flow (Platts 1979; Fleischner 1994; Kaufman and Krueger 1984). However, many of the studies do not quantify grazing intensities. This study showed the results of controlled grazing on water quality producing important information for range mangers on the effects of different grazing intensities. The results of this study demonstrate that grazing at these intensities on spring-fed wetlands do not have a detrimental impact on water quality.

Site characteristics had a greater influence on water quality than the grazing treatments. The results indicate that there is no difference in conductivity and pH parameters in the treatments. The pH is a critical component of biological systems and measures the ion activity. Conductivity is a measure of the amount of dissolved solids in water and is related to the total concentration of ions. Both parameters showed differences between sites, but were not influenced by grazing intensities.

The differences in nitrate between treatments were not significant. Slightly higher nitrate levels were observed in the ungrazed treatments. Jackson et al. (2005) suggest that removal of livestock grazing from springs allows dead plant material to accumulate preventing nitrate uptake by the vegetation and results in elevated stream-water nitrate concentrations. Different levels of nitrates could also be attributed site characteristics or precipitation. It may be possible that nitrate levels may become more diluted with increased flows during storms (Allen-Diaz and Campbell 1997). Sampling dates in October, January, and March were taken directly after times of high precipitation. These dates indicated slightly lower levels of nitrate.

Temperature is a good indicator of the general conditions of an aquatic biota. The results from this study again indicated no difference in treatment levels. The ungrazed treatments had a slightly higher temperature than the moderately and lightly grazed treatments. This could be a result of site characteristics. Sites with overstories of vegetation generally have lower temperatures than sites without cover. One specific ungrazed site was located in a south facing slope that had higher average temperatures than that of other sites. The temperature results do not indicate that the moderately grazed treatments had a negative effect on water quality.

The results of this study are similar to the 1997 study. The results indicate that there has been no change in the parameters by treatment over time. Differences between the two studies were only noted in the no graze treatments for both temperature and conductivity. This could be attributed to the differences in precipitation and air temperature on collection days. Both studies had similar levels of precipitation during the months of December and January. There was significantly lower precipitation in March of 1993 than in 2005. This may have attributed to differences in the conductivity parameters. Significant differences were also the result of differences in site. Both the 1997 study and this study indicate that grazing at intensities conducted in this study do not have a harmful affect on water quality. This has important ramifications for range mangers, suggesting that light to moderate grazing of California's extensive oak woodlands will not have a detrimental impact on down steam water users.

There were many difficulties with this study. The first few sampling months had limited data points because flow level at many of the spring and creek sites were so low, samples count not be taken. This led to unequal replication across grazing treatments and sites. After January, all of the spring and creek sites had enough water for samples to be taken. Other problems included equipment error. Dissolved oxygen data collected for this study could not be analyze because of a faulty probe. Phosphorus data was also not suitable for analysis because the DANR laboratory was unable to make readings less than 0.05 mg/L. All of the phosphate results were less than this value.

Site characteristics and flow may have played a role in the differences in grazing treatments. Time and space constraints on the study prevented larger sampling sizes. Collecting continuous concentration and flow data would have helped reduced differences from the specific time points.

Problems with common designs of livestock exclosure/enclosure studies were mitigated in this study. The 1997 study included pre-treatment data and began the experiment when the exclosure was set up. Many studies of grazing and riparian zone impacts lack an adequate description of the grazing method and type of livestock (Fleischner 1994). Grazing intensity, livestock species, and type of vegetation were all known in this study. In addition, this study is significant because the controlling variables (grazing treatments, etc) were isolated. However, our downside to this study and its application to extensive livestock grazing is the way animals were allowed to graze the springs for short periods of time and then removed. This allowed the vegetation and site to recover before grazing was allowed again. Research on grazing impacts must clearly address the different management variables and their impact on the results, and expansion of these results to more extensive, yearlong grazing access to spring sites must be done with caution.

This study has produced important results that can be used to better understand the effects of grazing on water quality. Studies should continue beyond the course of a year to understand the long term effects of grazing. Ideally these studies should continue for several years reflecting the long term impacts of California's fluctuating climate. It is hoped that this study will encourage range mangers to mange these rangeland resources on a sustainable basis without fear of impacting downstream water resources.

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References

Allen-Diaz, Barbara. 1991. Water table and plant species relationships in Sierra Nevada meadows. American Midland Naturalist **126**:30-43.

Allen-Diaz, Barbara, Randall D. Jackson, Jeffery S. Fehmi. 1998. Detecting channel morphology change in California's hardwood rangeland spring ecosystems. Journal of Range Management **51**:514-518.

Allen-Diaz, Barbra, Chris G. Campbell. 1997. Livestock grazing and riparian habitat water quality: an examination of oak woodland springs in the Sierra Foothills of California. USDA Forest Service Res. Paper PSW-GTR-160.

Bureau of Land Management. 2003. Bureau of Land Management Facts. http://www.blm.gov/nhp/facts/acres.htm. 12 March 2005.

Fernandez-Gimenez, M.E., and B. Allen-Diaz. 1999. Testing non-equilibrium models of rangeland vegetation dynamics in Mongolia. Journal of Applied Ecology **36**:871-885.

Fleischner, Thomas L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology **8**: 629-644.

Jackson, Randall, Barbara Allen-Diaz, Lawrence Oates and Kenneth Tate. 2005. Spring-water nitrate increased with removal of livestock grazing in a California oak savanna. Accepted Ecosystems 3/2005.

Kauffman, J.B., and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management **37**:430-437.

Kauffman, J.B., W.C. Krueger, and M. Vavra. 1983. Effects of late season cattle grazing on riparian plant communities. Journal of Range Management **36**:685-691.

Larsen, Royce E., William C. Krueger, Melvin R. George, Mack R. Barrington, John C. Buckhouse, and Douglas E. Johnson. 1997. Viewpoint: livestock influences on riparian zones and fish habitat: literature classification. Journal of Range Management **51**:661-664.

Platts, W.S. 1979. Livestock grazing and riparian/stream ecosystems–an overview. Proceedings of the Forum-grazing and riparian/stream ecosystems. Trout Unlimited, Denver, Colorado.

Starr, Daniel A. 2002. Riparian livestock exclosure research in the western United States: a critique and some recommendations. Environmental Management **30**:516-526.

Stout, W.L., S.L. Fales, C.D. Muller, R.R. Schnabel, G.F. Elwinger and S.R. Weaver. 2000. Assessing the effect of management intensive grazing on water quality in northeastern United States. Journal of Soil and Water Conservation **55**:238.

Trimble, Stanley W. and Alexandra C. Mendel. 1995. The cow as a geomorphic agent-a critical review. Geomorphology **13**: 233-253.

Rauzi, F. and C.L. Hanson. 1966. Water intake and runoff as affected by intensity of grazing. Journal of Range Management **19**: 351-356.

Zar, Jerrold H. 1999. Biostatistical analysis. Prentice Hall. Upper Saddle River, New Jersey.