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RESPONSE OF STREAMBANKS TO DIFFERENT INTENSITIES AND SEASONS OF CATTLE GRAZING IN TWO MONTANE RIPARIAN AREAS IN WESTERN NEW MEXICO

WRRI Miscellaneous Report No. 29

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Response of Streambanks to Different Intensities and Seasons of Cattle Grazing in Two Montane Riparian Areas in Western New Mexico

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ABSTRACT

Streambank morphology plays an important role in the ecosystem functions of stream and riparian areas. Livestock can potentially have large impacts on streambanks. Understanding the effects of grazing on streambank morphology is important for making good management decisions. Little work has been done to examine the effects of livestock grazing on southwestern stream channels. The purpose of this study was to evaluate the effects of different grazing intensities and different seasons of use on streambank morphology in two montane riparian areas in western New Mexico. No significant larger-scale changes to streambanks were detected over the duration of the study. In contrast, many smaller-scale changes were noted to have taken place following cattle grazing. The smaller-scale changes observed were not associated with other indicators of streambank alteration such as bank collapse, widening of the active channel, plant community change, or other larger-scale changes. It was concluded that the smaller-scale changes observed were part of the normal geomorphological adjustments made by streambanks and did not ultimately contribute to lasting streambank morphological change. The resource management and scientific community should be aware that results of streambank morphological studies may depend on which data analysis strategy or response variable is employed.

Keywords: stream cross-section, season of use, grazing intensity, riparian, w/d ratio, percentage change

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INTRODUCTION

The impact of livestock grazing on riparian and stream ecosystems in the western United States has been and continues to be a contentious topic (Larsen et al. 1998). Cattle grazing has been implicated in the degradation of streams and riparian areas throughout North America (Carothers 1977; Davis 1977; Behnke 1979; Armour et al. 1994; Fleischner 1994; Li et al. 1994; Belsky and Blumenthal 1997; Belsky et al. 1999; Donahue 1999), despite the fact that many different factors, such as road construction and maintenance (Jones et al. 2000), mining (Sidle and Sharma 1996), logging (Kauffman et al. 1996), and recreation (Goodwin et al. 1997) have also contributed to the decline.

Streambank morphology is often used as an indicator of the condition of a stream system (Marlow et al. 1987; Trimble and Mendel 1995; Clary 1999) and is of great concern to land managers because eroding streambanks may be unable to perform important ecosystem functions (Kauffman et al. 1996). These functions include flood attenuation and dissipation of peak streamflow energy (Beschta and Platts 1986); regulation of water flow regime and groundwater recharge (Heede 1980); provisioning of a vital habitat for fish, wildlife, and other terrestrial and aquatic organisms (Skovlin 1984; Beschta and Platts 1986; Platts 1991); and providing a medium through which terrestrial and aquatic nutrients and energy exchange takes place (Likens and Bormann 1974; Dent and Grimm 1999).

Understanding how streambanks respond to various livestock grazing pressures is useful, because it gives all members of the land management community insight into how to best ameliorate any less desirable effects and take advantage of any positive effects of livestock grazing on streambank and riparian systems. This is especially true in semi-arid areas where livestock grazing is a common activity. Preliminary work has been done in the southwestern United States, but large gaps remain in understanding the effects of cattle grazing on streambank morphology in this highly diverse area. Due to the intrinsically complicated nature of stream and riparian systems as well as the numerous influences that have contributed to the current streambank morphology of a system, it is often difficult to ascribe a single cause to any observed changes in streambank morphology. The use of well-designed experiments, however, can greatly facilitate elimination of potential causes of the observed phenomenon and greatly contribute to the knowledge of how these complicated systems work.

The primary objective of this study was to evaluate the effects of different levels of cattle grazing intensity during different seasons of use on streambank morphology in two montane riparian areas in western New Mexico. The hypothesis was that areas receiving greater levels of cattle grazing would experience greater changes to streambank morphology. Additionally, since grazing during the dormant season is often proposed to minimize grazing impacts in riparian areas because vegetation is dormant and soils are frozen, it was hypothesized that areas grazed during the dormant season would experience less change to streambank morphology than areas grazed during the cool and warm seasons.

METHODS AND MATERIALS

Study Site

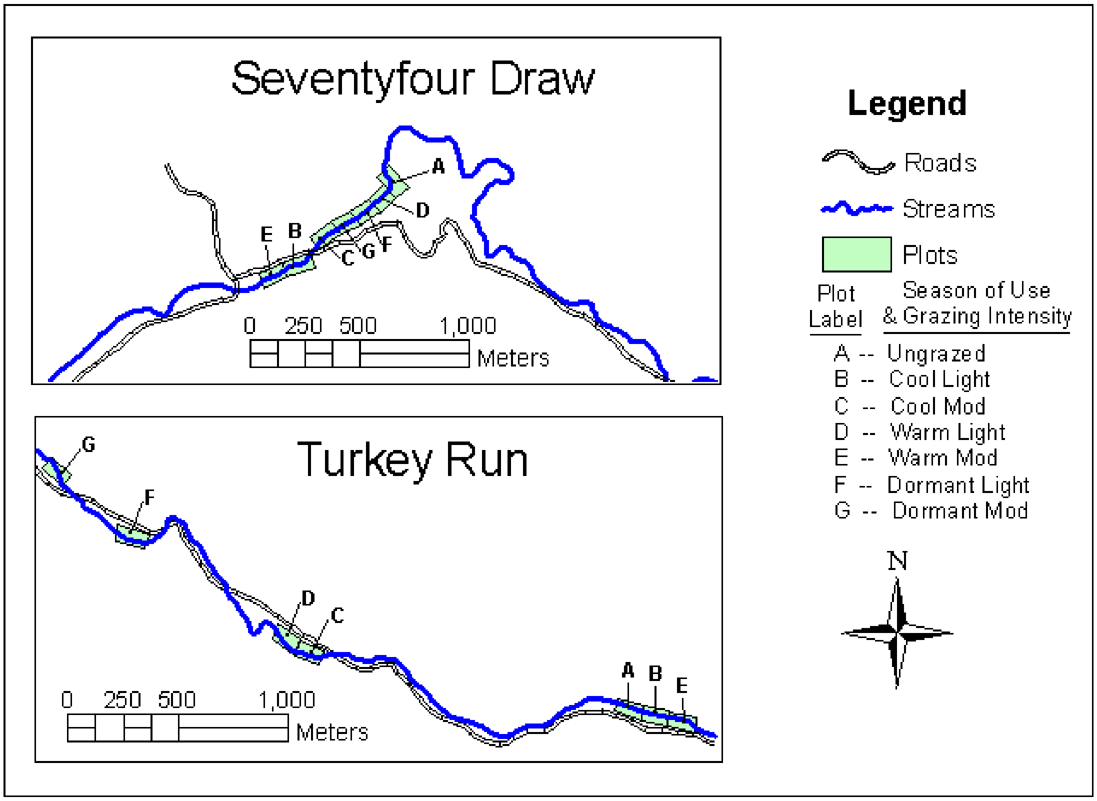
The study areas were two adjacent watersheds, Seventyfour Draw and Turkey Run, on the western slope of the Black Range Mountains in western New Mexico, about 230 km northwest of Las Cruces (Fig. 1). The streams drain 35 and 25 km^2, respectively, and both are second order, rural, unregulated streams lined with cobbles and boulders. Median particle size of streambed material for Seventyfour Draw and Turkey Run was 9 cm and 7 cm, respectively. Due to variable precipitation, streamflow is intermittent, but generally occurs during the rainy season in the late summer and fall (July-October), although snowmelt may also create streamflow during the winter months. These watersheds were chosen because they are in close proximity to one another and are very similar (Souders and Subirge 1984) in terms of vegetation, soils, geology, hydrology, mean elevation (2255 m), mean annual precipitation (350 mm), and land use history. There has been some cattle grazing in these watersheds, but no crop agriculture, mining, or other major land-disturbing activities since at least the 1950s when the current ranching family began their cattle operation. There was no evidence of recent or ongoing large-scale forestry operations. Mean annual summer temperature (June – Aug) is 18°C and mean annual winter temperature (Dec – Feb) is –1°C. Soils in both watersheds are Cumulic Haploborolls (Souders and Subirge 1984). Using the hydrometer method (Gee and Bauder 1986), soils along the streambank in Seventyfour Draw were found to be primarily sand and loamy sand with clay contents between 1% and 5%. Soils along the streambank in Turkey Run were found to be primarily loamy sand and sandy loam with clay content between 6% and 8%.

Dominant vegetation in the riparian corridor of both watersheds consists of ponderosa pine (*Pinus ponderosa* Laws.), narrowleaf cottonwood (*Populus angustifolia* James), Arizona alder (*Alnus oblongifolia* Torr.), and associated understory species that include Kentucky bluegrass (*Poa pratensis* L.), blue grama (*Bouteloua gracilis* [Kunth] Griffiths), nodding brome (*Bromus anomalus* Fourn.), Louisiana sage (*Artemesia ludoviciana* Nutt.), western yarrow (*Achillea millefolium* L.), cinquefoil (*Potentilla hippiana* Lehm.), annual muhly (*Muhlenburgia ramulosa* [Kunth] Swallen), trailing daisy (*Erigeron flagellaris* Gray), and comenlina (*Comenlina dianthifolia* Nutt.). Upland vegetation is dominated by ponderosa pine, Gambel's oak (*Quercus gambelii* Nutt.), alligator juniper (*Juniperus deppeana* Steudel), pinyon pine (*Pinus edulis* Engelm.), mountain mahogany (*Cercocarpus montanus* Raf.), blue grama, and New Mexican muhly (*Muhlenbergia pauciflora* Buckl.). The geology is complex and was described by Ericksen and Wedow (1976). Briefly, the area is dominated by igneous rock resulting from active andesitic lava flows during the early Tertiary era. Rocky outcrops are common throughout the study area.

Study Design

Three grazing intensity treatments were evaluated (none, light, and moderate) during three seasons of use (dormant, cool, and warm). Grazing intensity and season of use treatments were randomly assigned within each watershed at the beginning of the experiment in a 2 x 3 factorial treatment structure (Fig. 1) and remained unchanged throughout the duration of the experiment. One enclosure in each watershed served as the ungrazed control for all three seasons of use. Due to administrative concerns by the U.S. government agency responsible for the administration of this land, additional control enclosures or more intensive grazing treatments were not possible. Each 0.4-ha enclosure was located along a stream based on three criteria: 1) presence of similar length of stream reach running through the middle of each enclosure; 2) presence of similar herbaceous species, both riparian and upland inside each enclosure; and 3) similar basal area of dominant tree species inside each enclosure. Each stream was treated as a separate block. Enclosures were constructed of 4 strands of barbed wire and a single strand of electrified wire and were not built to exclude wild ungulates or other wildlife.

Figure 1.
Layout of study plots (enclosures) in Seventyfour Draw and Turkey Run, New Mexico. Streamflow is from east to west in both watersheds.



Following Holechek and others (1998), light grazing was defined as the use of 20%-30% of available standing biomass (dry mass) and moderate grazing as the use of 40%-50% of available standing biomass. Grazing seasons corresponded to the phenological stage of cool and warm season grasses. Dormant season grazing was conducted in February and March, cool season grazing was conducted in May and June, and warm season grazing was conducted in August and September.

Grazing Intensity

Two-year old heifers were used as the grazing animal in each case. The cage comparison method (Pieper 1978; Cook and Stubbendieck 1986) was used to estimate grazing intensity in each enclosure. Three 4-sided welded-panel cages (4 gauge, 10 x 10 cm galvanized panels) enclosing 2.3 m^2 were randomly located inside each enclosure to prevent the removal of herbaceous plant material during the grazing period. Grazing intensity was initially judged by ocular estimation against the three reference cages in each plot (Cook and Stubbendieck 1986). When a plot appeared to have sustained the target grazing intensity, cattle were removed and herbaceous material within the three cages was clipped immediately following the grazing period to obtain a more accurate estimate of grazing intensity. Two 0.19-m^2 quadrats (2 square feet) were located side-by-side in the center of each cage and all herbaceous vegetation was clipped at ground level and separated by species. Outside each cage, vegetation from two additional 0.19-m^2 quadrats was clipped from previously selected areas that had similar cover and species composition to the caged plant community (Pieper 1978; Cook and Stubbendieck 1986). Vegetation samples were oven-dried for 48 hours at 60°C and allowed to cool to room temperature before being weighed.

Streambank Morphology

Five permanent stream cross-section transects were established in each plot perpendicular to streamflow to evaluate streambank responses to treatments. Channel cross-section sampling methods followed those described by Harrelson and others (1994). Cross-section transect end points were located 2-3 m beyond the active channel banks and were marked with rebar end-stakes permanently driven into the ground. The active channel was determined primarily by a break in the bank slope but also by deposits of sand, silt, or other debris at the active scour mark, rock discoloration, and by changes in perennial vegetation (Harrelson et al. 1994). Depth-to-channel measurements were recorded using a surveyor's transit and stadia, recording measurements from an arbitrary reference depth to the channel floor. All transects were referenced to the same level. Because of the highly variable water depth from season to season (i.e., the lack of streamflow in the cool season), measurements were taken from end-stake to end-stake every 30 cm along each of the cross-section transects. Cross-sections were sampled before and after all grazing events for two consecutive years.

Two indices of channel morphology were used to describe stream channels. The first index, the width/depth ratio (w/d) of stream cross-sections, is widely used as a relative index of general stream shapes (Heede 1980; Beschta and Platts 1986). The w/d ratio is an indicator of larger-scale patterns in streambank morphology. Despite its common use, the w/d ratio is not exceptionally sensitive to small changes within a channel. Under certain conditions it is possible for the w/d ratio to remain unchanged even though changes have occurred within the channel. For instance, no change would be registered if the left bank loses soil and if the right bank gains an equal amount of soil. In order to avoid such a situation, the use of a second, more responsive metric of channel morphology change was included. Width, in this case, is the width of the active stream channel and depth is the mean depth across the channel (Heede 1980). The difference in w/d (post treatment - pre treatment) was calculated to describe any changes in channel shape. Negative values for the difference in w/d ratios indicate the channel has become deeper or the active channel has become wider.

The second index of stream morphology used was the mean percentage change of cross-sectional area (*PC*) as estimated from the various depth measurements. This index provides a finer-scale estimate of how much change takes place along a given cross-section (Olson-Rutz and Marlow 1992; Allen-Diaz et al. 1998). *PC* is defined as:

$$PC = \frac{\sum_{i=1}^{n} \left| Y_{ibefore} - Y_{iafter} \right|}{\sum_{i=1}^{n} Y_{ibefore}} \qquad \text{(Equation 1)}$$

where $Y_{ibefore}$ = channel depth at i^{th} point along a cross-section before grazing, Y_{iafter} = channel depth at i^{th} point along a cross-section after grazing, and n = the number of Y_i values measured along a cross-section. If there are no changes in the cross-sectional area of a stream, then the *PC* value will be 0. If there are changes to the cross-sectional area of a stream, then the *PC* value will be greater than 0. This value does not indicate whether the stream is becoming narrower and deeper or wider and shallower, just that change is occurring.

Each index represents a slightly different characteristic of a stream channel and these indices used in concert provide a repeatable measure to ascertain if stream channels were experiencing change. Means of initial measures of cross-section transect width, depth, and channel morphology indices calculated prior to the commencement of grazing treatments are included in Table 1.

Table 1.
Initial mean widths, depths, and width/depth (w/d) ratios prior to the application of grazing treatments in the Black Range of western New Mexico. Treatment means were not significantly different at $\alpha = 0.05$.

	Grazing Intensity Treatments		
Variable	No Grazing mean (SE)	Light Grazing mean (SE)	Moderate Grazing mean (SE)
Active Channel Width (cm)	817 (31)	781 (31)	945 (63)
Mean Channel Depth (cm)	47.1 (0.8)	44.7 (0.9)	51.1 (0.7)
w/d ratio	19.2 (1.2)	21.0 (1.3)	20.2 (1.4)
N	10	30	30

	Season of Use Treatments		
Variable	Cool Season mean (SE)	Warm Season mean (SE)	Dormant Season mean (SE)
Active Channel Width (cm)	860 (49)	833 (40)	849 (49)
Mean Channel Depth (cm)	51.2 (0.8)	46.5 (0.7)	43.8 (0.9)
w/d ratio	19.3 (1.2)	20.5 (1.1)	21.1 (1.8)
N	30	30	30

Analyses

Impacts of grazing and season of use treatments on streambank morphology for two years were quantified by calculating stream morphology indices and making comparisons between the initial values (calculated from data collected from the first grazing period) and the final values of the indices (calculated from data collected during the final grazing period). Analyses were conducted on the numeric differences of w/d ratios in addition to the calculated *PC* index values. A three-way ANOVA was used to detect treatment effects using grazing intensity, season of use, and block as the main sources of variation in an additive model, which in this case assumes that no interactions exist between stream system (each stream was treated as a separate block) and either of the main effects of grazing intensity or season of use treatments (Quinn and Keough 2002). The assumption that there are no interactions with the block factor is not often valid in natural systems; but due to the streams proximity and their similarity, this assumption may be valid in this case. Examining interactions of each main effect with stream by graphing the response variables of each stream on the ordinate and the treatment levels on the abscissa confirmed the additive model assumption was reasonable. Block was treated as a random effect. Analyses were done using PROC GLM within the SAS statistical programming package, version 8.2 (SAS 2001). Significant differences among means in the ANOVA tests were identified using Fisher's protected LSD test (Zar 1999). Normality of all response variables was checked using PROC UNIVARIATE (SAS 1996). Differences between initial and final measurements were found to be normally distributed with the Shapiro-Wilke test for normality (Zar 1999). Results on all variables were considered significant if *P*-values were less than or equal to 0.05.

RESULTS AND DISCUSSION

Over the duration of this study, target grazing intensity levels were met. Grazing periods in each enclosure ranged from 1 to 8 days (Table 2). Mean utilization in the moderately grazed plots was 42% (3.4% SE) of the above ground standing phytomass, which was significantly greater ($P = 0.0132$) than the mean utilization of 26% (2.6% SE) observed in the lightly grazed plots. Mean observed utilization in the ungrazed plots was 0.2% (3.0% SE), which was significantly lower than utilizations in both the moderately and lightly grazed plots ($P < 0.0001$, $P = 0.0006$). Grazing intensity treatments were significantly different between each treatment ($P < 0.0001$), but were not significantly different among seasons of use ($P = 0.1685$). Utilization occurring in the ungrazed plots was attributed to deer, elk, turkey, or other wildlife.

Table 2.
Number of cattle grazed and duration of grazing period in each enclosure to achieve desired grazing intensity treatments in the Black Range of western New Mexico. (TR = Turkey Run, SF = Seventyfour Draw, Mod = Moderate grazing intensity).

	Grazing	Number of cattle grazed		Number days in enclosures	
Stream	Treatment	2000	2001	2000	2001
TR	Dormant Mod	4	4	4	5
TR	Dormant Light	3	5	4	4
SF	Dormant Mod	3	4	3	4
SF	Dormant Light	3	4	1	2
TR	Cool Mod	3	3	3	6
TR	Cool Light	3	3	1	3
SF	Cool Mod	3	4	3	4
SF	Cool Light	4	2	1	2
TR	Warm Mod	3	2	6	8
TR	Warm Light	3	2	4	4
SF	Warm Mod	3	4	4	6
SF	Warm Light	3	4	3	2

Significant larger-scale changes to the streambanks were not observed over the duration of this study. The widths of the active channel remained unchanged in all treatments (Table 1). Only the mean channel depth varied, indicating that cattle grazing at light and moderate intensities in all seasons of use did not result in large erosion events or bank failure. Differences in w/d ratios over the duration of the study were not significant as a result of grazing intensity or season of use treatments and in fact were not even significantly different from 0 (Table 3). Given that active channel widths remained unchanged, positive differences in the w/d ratio would have indicated that the channel became shallower, while negative differences would have indicated that the channel became deeper.

Table 3.
Differences in stream morphology after two years of grazing in response to grazing intensity (moderate: 40%-50% use, light: 20%-30% use, control: 0% use) and season of grazing treatments (warm: Aug-Sept, cool: May-June, dormant: Feb-Mar) in the Black Range of western New Mexico. Changes in width/depth ratio (Δw/d) and percentage change of cross-sectional area were calculated using data collected prior to the commencement of grazing and after the last grazing event. Treatment means sharing the same uppercase letter within rows were not significantly different between grazing treatments at α = 0.05.

	Grazing Intensity Treatments		
Variable	No Grazing mean (SE)	Light Grazing mean (SE)	Moderate Grazing mean (SE)
Δw/d ratio	0.56 (0.77) A	0.35 (0.74) A	-0.06 (0.74) A
Percentage change (%)	9.7 (2.9) A	26.7 (2.8) B	24.8 (2.8) B
N	28	29	29
	Season of Use Treatments		
Variable	Cool Season mean (SE)	Warm Season mean (SE)	Dormant Season mean (SE)
Δw/d ratio	-0.49 (0.76) A	1.04 (0.77) A	0.30 (0.73) A
Percentage change (%)	36.6 (2.9) A	18.6 (2.9) B	6.1 (2.8) C
N	28	28	30

Contrary to the larger-scale results, significant smaller-scale changes to streambanks occurred (Tables 3 and 4). The lightly and moderately grazed plots and the plots grazed during the cool season experienced between 25 and 37% change as indicated by the *PC* index (Table 3). The *PC* index indicates changes taking place over smaller-scales, because it is more sensitive to alterations in the streambank between the initial and final measurement periods than other indices of streambank morphology (Allen-Diaz et al. 1998). This index does not indicate the direction of change: for example, if the stream is aggrading or degrading, it simply registers that a change has taken place. Finding significant changes in the *PC* index lends some support to both study hypotheses, that areas experiencing greater intensities of cattle grazing will experience greater streambank change and that areas grazed during the dormant season will experience less change. Responses of streambanks are, however, typically associated with a lag time as small, incremental changes over short periods of time build up and may equate to larger changes over greater periods (Kondolf 1993; Sidle and Sharma 1996). Larger-scale changes may not have been observed because the experiment's response time may not have been long enough. Conversely, the smaller-scale changes may be part of the normal geomorphological adjustments of the streambank and may be ultimately unimportant to overall streambank morphology. More long-term data are needed to resolve this issue.

Table 4.

Analysis of variance tables on differences in stream morphology indices in response to grazing intensity (moderate: 40%-50% use, light: 20%-30% use, control: 0% use) and season of grazing treatments (warm: Aug-Sept, cool: May-June, dormant: Feb-Mar) in the Black Range of western New Mexico. W/d ratio and *PC* were calculated from data collected prior to the commencement of grazing events and after the last grazing event.

		w/d		*PC*	
Source	df	MS	P-value	MS	P-value
Grazing intensity trt	2	3.921486	0.6576	0.243412	0.0499
Season of use trt	2	16.459320	0.2171	0.703157	0.0048
Block	1	0.021884	0.9616	0.001422	0.8841
Trt*season	4	33.313111	0.0519	0.139675	0.1565
Trt*season*block	8	8.844543		0.054564	

Although cattle grazing can be a direct agent of geomorphological change (Trimble and Mendel 1995), grazing is more often *indirectly* involved in the alteration of streambanks. Peak flows and flood events are the main catalysts of change in many riparian and stream systems (Waltemeyer 1996; Webb and Leake 2006), especially in the Southwest where flash floods are frequent and violent (Webb and Leake 2006). Cattle grazing can modify the response of streambanks to peak flows through the removal of plant material from streambanks and the eventual alteration of vegetation communities (see below), compaction of the soil leading to increased overland flow and runoff (Li et al. 1994), or the rearrangement or shifting of cobbles lining the streambank (Trimble and Mendel 1995). Additionally, these indirect effects of grazing do not generally produce immediate changes to the streambank (Kondolf 1993; Sidle and Sharma 1996). Instead, the change generally follows high discharge events. In this system, stream flow was not measured. In the future, a better test of the effects of cattle grazing on streambank morphology may need to include the interaction with peak stream flow by maintaining a number of different grazing systems and documenting the changes to streambank morphology following peak discharge events.

Vegetation communities remained relatively unchanged over the duration of the experiment. Lucas and others (2004) did not find significant changes to the woody or herbaceous communities or disproportionate vegetation removal along streambanks relative to other areas of the enclosures following cattle grazing, suggesting that streambanks were able to maintain their capacity to withstand erosive forces of high stream flows. Preferential grazing of vegetation along streambanks over vegetation growing in other parts of an area may result in the removal of more vegetation along streambanks and leave them unprotected and more susceptible to the scouring effects of high stream flows. Depending how much vegetation is removed by grazing, the plants' response to disturbance, and the growth characteristics of the remaining or potential colonizing plant species, different plant communities may develop as vegetation regrows following grazing events (Friedel 1991). Altering the plant community composition of a streambank may have long-term effects because different plants have different root morphologies and different capacities to protect streambanks from scouring. This did not appear to be the case here. It must be noted that since the enclosures are not located on separate streams, they were not wholly independent from each other, and changes that occurred in one enclosure may have been due partially to changes upstream.

There have been conflicting reports as to the effects of cattle grazing on streambanks, some groups reporting that grazing resulted in significant changes to streambanks (Marlow et al. 1987; Clary and Webster 1989; Platts 1991; Myers and Swanson 1992; Swanson and Myers 1994; Trimble 1994; Myers and Swanson 1995) and others reporting no changes following grazing (Kondolf 1993; Smith et al. 1993; Allen-Diaz et al. 1998; George et al. 2002). Despite their lack of agreement, some important points can be learned from these studies. Collectively, these studies indicate that fine textured and wet streambank soils are more susceptible to erosion. Additionally, the most common mode of streambank change resulting from grazing is channel width increase as a result of the failure of undercut banks, a likely consequence of trampling and hoof action. In this system, grazing took place when the soils were drier (moisture contents of streambank soils were between 18 and 25% by volume during grazing periods), and the sandy soils and larger particle size of the streambed material likely reduced the vulnerability of the streambanks to change and erosion; an interpretation supported by this result that active channels did not widen following grazing treatments.

Members of the resource management and scientific community should exercise care when selecting a response variable(s) and a data analysis strategy to evaluate streambank morphology change and be aware that their selections may influence their conclusions. For that reason, the use of multiple indicators is suggested. When considering changes occurring to a streambank, the selection of appropriate response variables has not been standardized – the range management, the hydrologic, and the engineering communities all using slightly different responses. It is important to highlight that a single response variable or analysis was employed in this study. Conclusions reached from study results would have depended on which analytical method had been chosen for use in the study. Stream cross-section data can continue to provide useful information to assess morphologic change in stream systems (but see Allen-Diaz et al. 1998), but it is recommended that any comparison of long-term changes in streambank morphology be done so in the context of smaller-scale changes, thus providing greater understanding regarding morphological changes.

SUMMARY AND CONCLUSIONS

Significant changes to streambank morphology were observed resulting from grazing intensity or season of use treatments in only one of two indices, thus failing to provide strong support for the two hypotheses that greater intensities of grazing will result in greater degrees of streambank change and that grazing during the dormant season would result in the least amount of streambank change. Given that the significant differences were observed in the index that is more sensitive to smaller-scale changes, the widths of the active channels remained unchanged, no bank sloughing or failure events occurred, the vegetation communities remained unchanged in grazed and ungrazed areas, and the coarse-textured soils and cobble-lined streambanks are resistant to change and may be able to withstand or absorb a certain amount of disturbance (Beschta and Platts 1986), it was concluded that light or moderate cattle grazing in cool, warm, or dormant growing seasons had little effect on overall streambank morphology in these two watersheds, which are representative of many montane riparian areas in the southwestern United States. As additional experiments and analyses are carried out, understanding of the complicated effects of cattle grazing on stream and riparian areas will continue to improve.

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