Response of a Southwest Montana Riparian System to Four Grazing Management Alternatives

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Abstract.—The effects of deferred rotation, time control (Savory Grazing Method), season-long, and livestock exclusion on streambank stability and trout habitat condition in a southwestern Montana riparian zone has been monitored since 1986. Although livestock exclusion appeared to improve channel conditions in 1986, there was no significant difference among any of the treatments thereafter. The decline in trout habitat condition appeared to be more a function of stream discharge and channel aggradation than grazing management. The lack of significant differences ($P < 0.10$) in bank stability among the various treatments during three consecutive drought years suggests that it is the interaction between grazing and stream discharge events that dictate the magnitude of streambank alteration. Downward shifts in livestock numbers will probably not limit streambank degradation and loss of trout habitat. Decreasing the length of time cattle have access to a stream reach and adjusting the grazing period to coincide with low streambank moisture levels shows promise for the improvement of riparian zone condition.

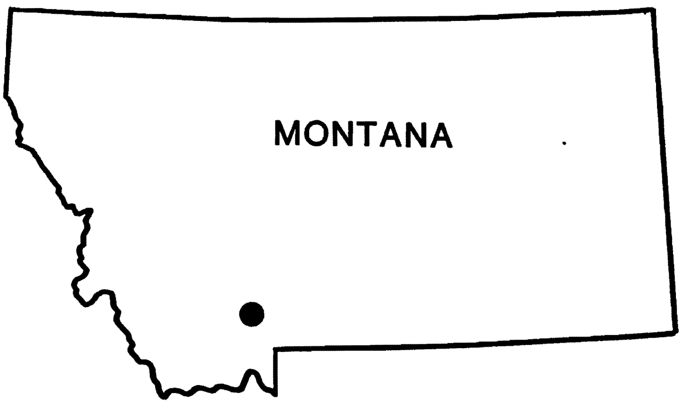
Wildlife and land managers seldom have to defend the importance of riparian ecosystems since the 1978 Callaway Gardens Symposium (Johnson and McCormick 1978). Now efforts are directed to finding the most effective management alternatives for rehabilitating or protecting local wetland, floodplain, and streamside communities. This is especially so in the semi-arid and arid regions of the western USA where livestock grazing on public lands is a common practice. Successful rehabilitation or protection of riparian communities on livestock grazing allotments is thought to be unlikely without first placing the allotment under a resource sensitive level of stocking and management intensity (Davis 1986). Resource sensitive stocking intensity may be interpreted as a reduction in livestock numbers. Although such a decision appears logical, a reduction in numbers does not eliminate the problem, it only restricts impact to smaller areas within the allotment pastures. Since the stream and its watershed function as a unit (Platts and Rinne 1985), those areas still being impacted will continue to limit the likelihood of riparian improvement along the stream course. This occurs because cuts in animal numbers do not mean an automatic modification in animal grazing behavior; individuals will still feed in preferred sites and forage primarily on preferred plant species. Resource sensitive stocking rates and management requires that livestock grazing behavior be sufficiently modified to limit negative impacts to the riparian community. In light of this need, we describe the response of certain riparian components to several grazing management methods that can be used to modify livestock grazing behavior.

Study Site

Site Description

We are studying a first order stream, Cottonwood Creek, on the Red Bluff Research Ranch near Norris, Montana (Figure 1). The stream was classified according to Rosgen (1985) (Table 1). Landform and vegetation are typical of lower elevational mountain slopes in southwestern Montana. Quaking aspen *Populus tremuloides*, Bebb's willow *Salix bebbiana*, and beaked sedge *Carex rostrata* dominate the riparian zone. A more detailed description of physiography and vegetation type is given in Marlow et al. (1987). Streambanks had less than 10% of their upper 1.0-m profile filled with rock or gravel. Bank soil texture was predominately a loamy sand.

Figure 1.—Location of Cottonwood Creek study site on the Montana Agricultural Experiment Station's Red Bluff Research Ranch in southwestern Montana.



Prior to the initiation of the present study, most of the area under investigation had been grazed under moderate stocking rates (measured utilization was 40-60%) at set periods of use (Marlow et al. 1987). Earlier, 1967 to 1980, the area had been grazed by 30-40 head of horses or 50-100 cow/calf pairs for approximately 90 d each year. From the late 1930s until 1967, when the Montana Agricultural Experiment Station bought the ranch, the Cottonwood drainage was intermittently grazed by 1,000 to 2,000 domestic sheep. The impact from sheep grazing on the drainage is difficult to determine because of nonexistent range condition data from the period of private ownership. However, by 1974, a Soil Conservation Service survey of the Red Bluff Research Ranch indicated that about 80% of the Cottonwood drainage was in good range condition. Unfortunately, the survey provided no information on the health or condition of the riparian areas.

Stream Discharge Conditions

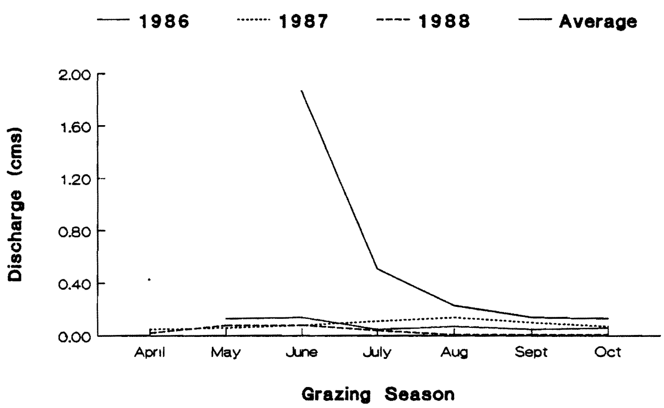
Since the initiation of this project in 1986, the study area has experienced below normal stream discharge during the period extending from May to August (Figure 2). According to U. S. Geological Survey water survey data, 1987 stream-

Table 1.—Characterization of Cottonwood Creek according to Rosgen (1985).

	Characteristics					
Type	Gradient	Sinuosity	Ratio	Particle size	Entrenchment	Landform
C^5	≤0.1	2.5+	5+	Silt/clay, medium to fine sands (little bed armour)	Moderate to slight confinement	Alluvial terraces with fine to medium textured soils. Predominately noncohesive materials.

flows in the portion of the Missouri River drainage occupied by the study site were 62% of normal (Shields et al. 1987). Not only was annual stream discharge down, but streamflow during the month of June 1987 was substantially lower than normal. The low flow was attributed to the less than normal snowpack and warmer than usual temperatures during 1986 and early 1987 (Shields et al. 1987). This pattern is critical to the results of this study because of the apparent close interaction between high flow events, cattle use, and streambank alteration (Marlow et al. 1987).

Figure 2.—Monthly stream discharge in cubic meters per second (cms) for Cottonwood Creek. The solid line represents the 4-year average for the same stream for the years 1981 to 1984.



Methods

Grazing Management Strategies

Realistically, managers can only control when livestock graze an area, how long they stay in the area, and how many individuals are present during the scheduled grazing period. Consequently, the grazing management methods used in this study represent several combinations of animal numbers, length of stay in a particular pasture, and the season of grazing.

Season-long.—Under this management strategy the manager attempts to control livestock impact by adjusting livestock numbers within a paddock. This is usually accomplished by calculating a stocking rate for the paddock or allotment in question. These rates, expressed as a cow/calf pair or animal unit per month (AUM), are based on the amount of forage in the paddock which can be utilized by livestock without impairing forage plant vigor. Following this approach, 127 cow/calf pairs were grazed in the Cottonwood Creek pasture for 90 d. This is equivalent to a 0.25 AUM/hectare stocking rate. To modify cattle behavior, salt was placed 0.75 km away from Cottonwood Creek to encourage cattle use of upland areas and to reduce the amount of time they spent in the riparian zone.

Deferred rotation.—This grazing strategy gives the manager more control over livestock behavior by adjusting the number of animals using the pasture and then scheduling grazing for periods when grazing induced changes can be minimized. For example, deferment of grazing until preferred forage plants have nearly matured improves the health and vigor of the vegetation, thereby improving overall range condition (Wamboldt 1974). In terms of riparian zone condition, grazing deferment was based on the moisture level of streambanks rather than plant phenology in an effort to limit or reduce bank alteration (Marlow et al. 1987). A further refinement of the traditional deferred rotation grazing method for use in this study was the movement of cattle from a paddock when 40 to 50% of the riparian forage base had been used. The level of forage utilization in the adjacent uplands was not considered in deciding when the cattle were to be moved. Consequently, cattle had access to the riparian areas of each paddock for a shorter length of time than the cattle grazing under season-long management.

Under deferred rotation, four cow/calf pairs grazed the designated deferred rotation paddocks on Cottonwood Creek for 14 to 28 d or at a stocking rate of 9 AUMs/hectare. Grazing began in a different paddock each year to achieve the necessary deferment until streambank moisture levels were low enough to limit trampling damage.

Time control (Savory Grazing Method).—This management strategy provides the most intense control of livestock behavior. By concentrating large numbers of livestock in relatively small paddocks, the manager has finally reached a point where the desired level of livestock use for certain areas or vegetation can actually be controlled. Plant vigor and soil surface conditions are protected by allowing the animals to stay in each paddock for a relatively short period of time, usually a week or less. Range or riparian condition is improved by scheduling these short, intense grazing periods at approximately 60- to 90-d intervals.

Because of the short stay and high number of cattle using the designated time control paddocks, the stocking rate under this grazing strategy was equivalent to that used in the deferred rotation treatments, 9 AUMs/hectare. The actual length of stay in each time control paddock was based on the time it took the cattle to utilize 40 to 50% of the riparian forage base.

Livestock exclusion.—The need for livestock control is eliminated by removing livestock grazing from the area. In this study it also provided a means of monitoring the interactive processes between streamflow, channel dynamics, and precipitation.

Summary.—The grazing management strategies applied on Cottonwood Creek differed according to the length of time and livestock density used. Length of time spent grazing a single paddock ranged from 0 d in the livestock exclosures, to 3 - 4 d under time control management, 14 - 28 d under deferred rotation, and 90 d under season-long management. Animal density (numbers per hectare) was nearly the reverse of this pattern. There were 14 head/hectare in the time control paddocks, 3 head/hectare in the deferred rotation paddocks, and 0.2 head/hectare in the season-long pasture. Consequently, results of this study should be viewed in light of livestock density and length of time cattle had access to the riparian area rather than as a recommendation of any particular grazing management method.

Study Design

In June 1986, approximately 12 hectares of Cottonwood Creek and its adjacent uplands were fenced into paddocks for application of deferred rotation, time control, and livestock exclusion management methods. The season-long treatment was represented by the grazing management for the remaining 1,550-hectare pasture surrounding the smaller deferred, time control, and exclusion treatments. Time control paddocks, each about 1.25 hectares, were interspersed among the larger (2.5 hectare) deferred paddocks to achieve some measure of equal variation among all the treatment paddocks (Hurlbert 1984). There were three deferred rotation, eight time control, and two livestock exclusion paddocks (0.75 hectare) lying along Cottonwood Creek. Two monitoring sites, one below and one above the enclosed paddocks, represent the season-long grazing treatment. One riparian exclosure had not been grazed for five years, prior to 1986, and the remaining exclosure was constructed in early 1986.

After the treatment paddocks were constructed, permanent stream channel cross-sectional transects were located in each paddock and pasture to monitor streambank stability. Transects were placed by moving a random number of meters (1 to 10) upstream from the paddock boundary. Thereafter, transects were placed at 15-m intervals. Transects were not located where they would intercept the outside curve of a stream meander. Due to differences in paddock size, the number of transects within paddocks ranged from 3 to 7. There were a total of 62 permanent stream channel transects along the approximately 1 km of stream reach within the study area. Data were collected from each transect following the procedures described by Platts et al. (1983) prior to the grazing season (late May), immediately following completion of grazing within a paddock, and in late October at the conclusion of the grazing season. Because of problems with monitoring schedules and the identification of permanent transects, the data from the newest (1986) exclosure are not included in this paper. Cross-sectional data were first summarized by transect for percent area change by subtracting the post-grazing measurements from the pre-grazing values, summing the resulting differences, and dividing by the summed pregrazing values of the respective transect. In this summary, negative values indicated the channel had experienced erosion while positive values suggested deposition. Then, to account for erosion and deposition events under the same transect which tended to cancel each other out and create a no change signal, absolute values were used in the summary calculations to produce an absolute percent change in channel area. This percentage only indicted whether there had been erosion and/or deposition. It could not indicate whether there had been a change in channel cross-sectional area. To compensate, a third evaluation method, the gini coefficient (Weiner and Solbrig 1984) was also used. This method produced a measure of the channel shape for further interpretation of changes in channel cross-sections. Specifically, a particular cross-sectional area could reflect little or no change in area but having considerable change in shape. The "gini" was used to detect this potential discrepancy (C. Marlow, K. Olson-Rutz, and J. E. Taylor, unpublished). Gini values approaching 0 indicate the channel cross-section is flat and uniform in shape, and values close to 1 indicate a narrow, irregular cross-section.

Streambank moisture levels were measured at 2-week intervals throughout the grazing season to monitor bank susceptibility to trampling deformation (Marlow et al. 1987). A 2-cm × 30-cm soil core was extracted from the streambank within 1 m of each permanent transect stake within each paddock or pasture. Cores were placed in resealable, plastic sandwich bags, returned to the laboratory, weighed to the nearest 0.1 g, dried at 80° C for 24 h and reweighed. Percent moisture was calculated according to Taylor and Ashcroft (1972). An ANOV summarization indicated significant differences ($P = 0.05$) in bank moisture levels among paddocks within treatments, so the data were only used as a covariate in the analysis of streambank stability.

Trout habitat was annually rated in each paddock and pasture following conclusion of the grazing season. The rating was carried out by an independent party (Zone Fisheries Biologist, Gallatin National Forest) using the COWFISH Habitat Capability Model (Lloyd 1986). Habitat suitability criteria for monitoring grazing strategy effects on the stream was used because low flows and shallow conditions precluded a fishery.

Streamflow was continuously measured from early May until late October at two locations, one immediately below and one immediately above the enclosed portion of the study area. Parshall type flumes were placed in the channel so they captured the entire flow. Stevens recorders with a 7-d clock were mounted on the flume and the floats suspended inside a stilling well attached to the side of the flume. The average stage height recorded over each 7-d period was used to calculate stream discharge from the following equation:

$$Q = 2.06 \times H_{1.58}$$

Q represents the stream discharge in cfs (cubic feet/s) and H represents stage height. Cubic feet per second was converted to cubic meters per second by multiplying by 0.028.

Statistical analysis of all data was performed through ANOV and Waller-Duncan *T*-test (Chew 1980) for differences among treatments (grazing methods) within year. The significance level set for this study was $P = 0.10$ (Gill 1981). As previously mentioned, streambank moisture and stream discharge were used as covariates to improve the potential for detecting differences due to stocking rate and livestock density. Means are reported, followed by standard error of the mean in parentheses.

Results

Streambank Stability

We could not detect a difference ($P = 0.30$) in stream channel morphology among the deferred rotation, time control, and livestock exclusion paddocks at the beginning of the study (Ginipre, Table 2). However, at the close of the 1986 grazing season, the channel shape was different among treatments ($P = 0.09$, Ginipost, Table 2). The channel within the exclosure had become deeper and narrower, but the grazed paddocks retained their shape ($P < 0.01$, Ginidiff, Table 2). The percent change in cross-sectional area was minimal and equal among all treatments ($P = 0.21$, net-change-area, Table 2); however, the exclosure experienced more absolute percent change in area ($P = 0.06$, gross erosion+deposition, Table 2) that resulted in a more narrow and deep channel than in the grazed paddocks.

The channel within the various grazing treatments did not change shape from the end of the grazing season in 1986 to early June 1987 (1986 Ginipost, Table 2 versus 1987 Ginipre, Table 3). We began collecting information on channel stability in the season-long pasture in June 1987 and found that the channel lying within this pasture was significantly ($P = 0.05$, Ginipre, Table 3) wider and flatter than the channel within the other grazing treatments. By the end of the 1987 grazing season, the season-long stream channel was somewhat flatter and more uniform than it had been previously ($P = 0.09$, Ginidiff, Table 3). However, this level of change was comparable to that in time control and exclosure paddock. The percent change in cross-sectional area was negligible and equal among treatments ($P = 0.23$), as was gross erosion+deposition ($P = 0.34$, Table 3). Unlike 1986 conditions when the livestock exclusion paddock experienced some downcutting (negative Ginidiff value), the channel in all grazing and nongrazing treatment paddocks and pasture experienced deposition during 1987.

The relative differences among the treatments remained largely unchanged from the post grazing values of 1987 to the pre-grazing values of 1988 (Ginipost, Table 3 versus Ginipre, Table 4). Channel shape changed very little among grazing treatments ($P = 0.36$, Ginidiff, Table 4) after the conclusion of grazing in 1988. Changes in channel cross-sectional area reflected by the net percent change index were all positive, indicating channel aggradation or deposition. However, neither the net change ($P = 0.18$) nor absolute change ($P = 0.29$) were significantly different among treatments. The pattern of the channel becoming more flat and wide in all grazing management treatments noted in 1987 continued in 1988.

Comparison of post grazing channel shape over the first 3 years of this study (Figure 3) indicate that the livestock exclusion and time control paddocks continued to flatten out while the channel in the deferred rotation and season long paddocks remained virtually the same. If narrow, irregular channel profiles are indicative of good riparian condition, then 8 consecutive years of livestock exclusion have not produced an upward or improving trend on Cottonwood Creek.

Trout Habitat Condition

Over the first 3 years of study, trout habitat quality appears to be declining under all of the grazing management methods (Table 5). However, two conditions limit the validity of this interpretation. First, there was a change in U. S. Forest Service fisheries biologists between the 1986 and 1987 habitat inventory which resulted in a major decline in the percentage ratings for all habitat components in 1987. Second, an early, heavy snowfall in 1988 interrupted the inventory process; leaving the last replicates of the grazed paddocks and both of the ungrazed

Table 2.—1986 mean treatment ginicoefficients pre- and post-grazing, within season difference in Gini coefficient, net % change in channel cross-sectional area, and absolute % change in cross-section area, standard error in ( ).

Treatment	Ginipre	Ginipost	Ginidiff	Net % change area	Absolute % change area
Deferred	.21 (.023)[a]	.21 (.022)[a]	.003 (.003)[a]	-2.5 (1.4)[a]	7.8 (1.4)[a]
Time-Control	.20 (.018)[a]	.20 (.017)[a]	.000 (.002)[a]	-0.8 (2.7)[a]	0.8 (1.1)[a]
Exclosure	.28 (.044)[a]	.32 (.043)[b]	-.037 (.006)[b]	1.0 (1.1)[a]	15.0 (2.6)[b]

Different letters within a column denote significance at $\alpha = 0.10$.

Smaller gini coefficient numbers describe flatter, more uniform cross-sectional shape.

Ginidiff = Ginipost - Ginipre, a negative value described a narrowing, deepening channel shape.

A negative net percent change area value represents erosion.

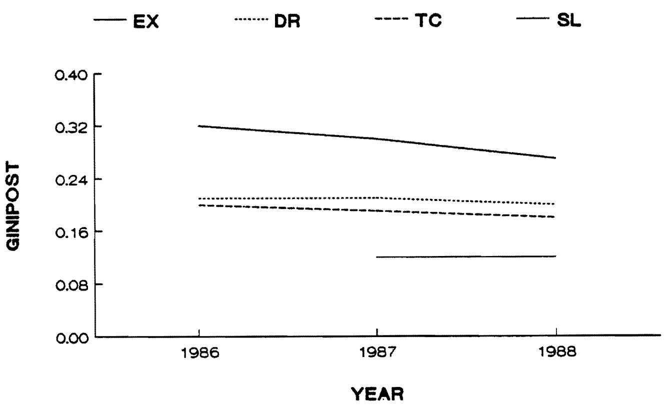
Table 3.—1987 mean treatment channel cross-section variables. See Table 1 for full description.

Treatment	Ginipre	Ginipost	Ginidiff	Net % change area	Absolute % change area
Deferred	.21 (.020)[b]	.21 (.020)[b]	.000 (.004)[a]	0.0 (1.1)[a]	9.0 (1.2)[a]
Time Control	.19 (.016)[b]	.19 (.016)[b]	.008 (.003)[ab]	-0.1 (0.9)[a]	8.4 (0.9)[a]
Season-Long	.13 (.036)[a]	.12 (.036)[a]	.010 (.008)[b]	3.1 (2.0)[a]	6.3 (2.0)[a]
Exclosure	.30 (.039)[c]	.30 (.039)[c]	.007 (.008)[ab]	-2.5 (2.2)[a]	9.1 (2.2)[a]

Table 4.—1988 mean treatment channel cross-section variables. See Table 1 for full description.

Treatment	Ginipre	Ginipost	Ginidiff	Net % change area	Absolute % change area
Deferred	.21 (.003)[b]	.20 (.002)[b]	+.005 (.002)[a]	0.4 (2.29)[a]	8.9 (1.65)[a]
Time Control	.18 (.013)[b]	.18 (.001)[b]	+.005 (.003)[a]	3.6 (1.63)[a]	9.0 (1.33)[a]
Season-Long	.13 (.001)[a]	.12 (.001)[a]	+.010 (.001)[a]	2.2 (1.05)[a]	5.8 (.30)[a]
Exclosure	.28 (.002)[c]	.27 (.002)[c]	+.008 (.001)[a]	.21 (1.22)[a]	5.5 (1.13)[a]

Figure 3.—Three year trend in post-grazing channel shape for livestock exclusion (EX), deferred rotation (DR), time control (TC), and season-long (SL) paddocks. Lower gini values indicate a more flat and uniform channel cross-sectional profile.



paddocks unsampled. Nonetheless, examination of the 1987 and 1988 data for two-thirds of the treatment replicates indicates a downward trend in percent undercut banks, percent vegetation cover, and habitat optimum (Table 5). Those habitat parameters showing an increase were percent embeddedness and width/depth ratio. Both of these last habitat parameters match the pattern detected while monitoring streambank stability.

Deposition as the predominate agent of change matches the increase in channel gravel and cobble embeddedness and an increasing width/depth ratio follows the trend towards a wider, flatter channel noted with the "gini" analysis of channel cross-sectional area. These changes, coupled with the decrease in percent undercut banks, probably account for most of the apparent decline in trout habitat quality.

Review of the 1987 ratings suggests that livestock exclusion had better values for vegetation cover and bank alteration than did the grazed treatments. Unaltered streambanks did not, however, mean more undercut banks in 1987 (Table 5). During this period, the ungrazed channel had as much embedded material as the channel in the grazed paddocks.

Discussion

After 3 years of below normal stream discharge, the channel of Cottonwood Creek is taking on a wider and more flat cross-sectional profile than had existed previously. This pattern of change will probably reduce the channel's ability to contain high flow events and may lead to the alteration of the floodplain and riparian vegetation (Heede 1986). Cattle use of the riparian zone could tend to hasten this process by accelerating channel aggradation through trampling. This was not supported by the results from this study because the deposition which occurred in the ungrazed paddock was similar to that occurring in the grazed paddocks. The lack of significant differences in channel shape and cross-sectional area among the various grazing treatments combined with the abnormally low stream discharge supports our earlier statements regarding cattle induced damage to streambanks (Marlow et al. 1987).

During periods of high streambank moisture content, cattle use can deform banks, making them more susceptible to erosion during high flow events or causing channels

Table 5.—Mean observed or measured trout habitat values associated with the COWFISH model.

Grazing treatment	Percent undercut banks			Percent vegetation cover			Percent bank alteration			Percent embeddedness (sediment)			Width: depth ratio			Habitat Optimum		
(year)	86	87	88	86	87	88	86	87	88	86	87	88	86	87	88	86	87	88
Deferred rotation	62	19	17	87	43	39	35	28	43	10	47	57	24	14	17	73	53	45
Time control	40	19	11	56	38	45	34	38	35	12	50	64	25	17	25	59	42	33
Season-long	NM	12	8	NM	13	9	NM	69	70	NM	59	57	NM	16	19	NM	37	25
Exclosure	91	6	NM	100	87	NM	3	0	NM	20	67	NM	22	12	NM	84	57	NM

NM = not measured.

to become more flat and wide. Both conditions can upset the dynamic equilibrium of the riparian zone leading to changes in water quality and fisheries habitat. Conversely, grazing when bank moisture levels and stream discharge is low appears to cause no significant changes in either streambank stability or channel shape. Based on the responses during the drought years of 1986 to 1988, grazing did not appear to accelerate channel aggradation above that being caused by low stream discharge. Consequently, the timing of cattle use is critical to the protection and improvement of riparian areas. In addition, on Cottonwood Creek, during periods of low stream discharge, there does not appear to be any significant short-term advantage gained from the removal of livestock.

Low stream discharge may have also contributed to the reduction in undercut banks along Cottonwood Creek. It is difficult to reconcile the loss of undercut banks observed in the trout habitat inventory with the limited change in channel cross-sectional area recorded while monitoring streambank stability without taking the low stream discharge into account. Sediment deposition and a reduced wetted area may have filled in some undercuts while leaving others above the water line. This would have led to a lower estimate of undercut banks within the water column. Loss of undercuts to trampling should have produced a measurable change in channel shape or the level of channel filling. Because we could not detect significant differences in either parameter under livestock grazing, abnormally low stream discharge appears to be the primarily cause of the current decline in trout habitat quality on Cottonwood Creek.

Protection and rehabilitation of riparian areas in semi-arid and arid environments may not necessitate automatic reductions in stocking rates or the exclusion of grazing. Instead, managers should schedule grazing of riparian areas for periods of low streamflow and streambank moisture conditions to limit bank degradation. Additional improvement can be attained by basing the stocking rate on the forage availability and utilization of the riparian area rather than holding livestock in the pasture long enough to obtain a pre-determined level of use in the uplands.

Even though the channel in the season long pasture did not experience levels of change significantly greater than that under time control and deferred rotation, it consistently had the greatest amount of change. This suggests that under normal discharge patterns the season-long grazed pasture may experience significant change. In light of this possibility and the low levels of change detected under high cattle densities for short grazing periods (time control), the longer cattle have access to a particular stream stretch, the more likely the occurrence of accelerated channel alteration. Consequently, shortening the grazing period may lead to improvements in riparian zone condition without creating controversy over the elimination of grazing.

At this point in our research, it appears that resource sensitive stocking rates mean the adjustment of the length of the grazing period to coincide with the level of forage utilization in the riparian zone. Resource sensitive management would mean scheduling of grazing for periods when stream discharge is low and banks relatively dry for 2 of 3 years. If there are concerns about potential reductions in the grazing season because of stocking rates being based only on utilization of the riparian forage base, there are at least two management alternatives. First, the riparian zone can be fenced into a special use pasture and grazed according to bank moisture conditions and forage utilization. Second, the pasture or allotment could be subdivided into smaller subunits and grazed under time control management. Each case should improve the opportunity to protect and enhance the riparian zone without causing major reductions in the length of the grazing season. Lastly, it would appear that grazing exclusion should be the management alternative of last resort.

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