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Stream channel and vegetation responses to late spring cattle grazing

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Abstract

A 10-year riparian grazing study was conducted on a cold, mountain meadow riparian system in central Idaho in response to cattle grazing-salmonid fisheries conflicts. Six pastures were established along Stanley Creek to study the effects on riparian habitat of no grazing, light grazing (20-25% utilization), and medium grazing (35-50%) during late June. Stream channels narrowed, stream width-depth ratios were reduced, and channel bottom embeddedness decreased under all 3 grazing treatments as the area responded to changes from heavier historic grazing use. Streambank stability increased and streamside willow communities (*Salix* spp. L.) increased in both height and cover under all 3 treatments. Plant species richness increased on both streamside and dry meadow areas during the years of grazing and moderate drought. The numbers of species receded to near original levels in the ungrazed and light grazed pastures in 1996, a wet post-grazing year, primarily due to a decrease in forb species. Streamside graminoid height growth was similar among treatments after 1 year of rest. Most measurements of streamside variables moved closer to those beneficial for salmonid fisheries when pastures were grazed to 10 cm of graminoid stubble height; virtually all measurements improved when pastures were grazed to 14 cm stubble height, or when pastures were not grazed. Many improvements were similar under all 3 treatments indicating these riparian habitats are compatible with light to medium late spring use by cattle.

Key Words: riparian, mountain meadow, streambank stability, width/depth ratio, willow, species richness, salmonid, fisheries, livestock management

Riparian areas are among the most important features of natural landscapes. Their biotic productivity and diversity stand out within the surrounding mosaic of terrestrial habitats (Kondolf et al. 1996). They typically function to moderate flood intensity, store water, and maintain water quality by acting as nutrient and sediment sinks (Hawkins 1994). These ecological attributes make riparian areas and the included

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Resumen

Se condujo un estudio de apacentamiento de áreas ribereñas con una duración de 10 años. El estudio se llevó a cabo en la región central de Idaho en un sistema ribereño frío de pradera de montaña y fue motivado por los conflictos surgidos entre el apacentamiento de ganado y las pesqueras de salmones. Se establecieron 6 potreros a lo largo del arroyo Stanley para estudiar los efectos que el no apacentamiento, apacentamiento ligero (20-25% de utilización) y apacentamiento moderado (35-50%) a fines de junio tienen sobre el hábitat ribereño. Los canales del arroyo se estrecharon, las relaciones ancho-profundidad de los arroyos se redujeron y los depósitos en el fondo del canal decrecieron, esto ocurrió bajo los 3 tratamientos de apacentamiento conforme el área cambió de un uso histórico de pastoreo fuerte. La estabilidad del banco del arroyo se incrementó y las comunidades de "willow" (*Salix* spp. L.) presentes a los lados del arroyo se incrementaron tanto en altura como cobertura, esta respuesta se obtuvo en los 3 tratamientos de apacentamiento. Durante los años de apacentamiento y sequía moderada, la riqueza de especies vegetales se incrementó tanto a lado del arroyo como en las áreas de pradera seca. En 1996, un año húmedo después de la estación de apacentamiento, el número de especies vegetales de los potreros que recibieron apacentamiento ligero o no apacentamiento regresó a niveles cercanos a los originales, esta respuesta se debió principalmente a una disminución de las especies de hierbas. Después de un año de descanso, el crecimiento en altura de las gramináceas de los lados del arroyo fue similar entre tratamientos. Cuando los potreros se apacentaron a 10 cm de altura del rastrojo remanente, la mayoría de las mediciones de las variables tomadas a los lados del arroyo se movieron a niveles cercanos de los que son benéficos para las pesqueras de salmones. Cuando los potreros se apacentaron a 14 cm de altura del rastrojo remanente o no se apacentaron, virtualmente todas las mediciones mejoraron. Muchas de las mejorías fueron similares bajo todos los tratamientos, indicando que estos hábitats son compatibles con el uso ligero o moderado por el ganado durante la primavera.

streams highly valued for many human uses. One of these uses is livestock grazing. Major concerns about the impacts of grazing on riparian areas have been raised in the last 2 decades (Swanson 1988, US GAO 1988, Armour et al. 1994).

In earlier years, livestock grazing practices rarely addressed

the needs of riparian areas (Winward 1994). Conflicting reports over the effects of livestock grazing on riparian areas have pointed to a critical need to examine grazing practices that can potentially permit livestock production while simultaneously preserving the riparian characteristics needed for wildlife habitat, native fisheries, and water quality (Waters 1995). Despite the need for objective management strategies, most current recommendations for improvement of riparian grazing are based on collective experiences and case studies. Experimental examination of specific management hypotheses has occurred at only a limited number of sites, including locations in Colorado (Schulz and Leininger 1990), Montana (Marlow and Pogacnik 1986), Oregon (Bryant 1985, Green and Kauffman 1995), and Wyoming (Siekert et al. 1985).

The need for more grazing management information has been apparent in the Pacific Northwest as concern for the dwindling numbers of anadromous salmonids heightened riparian habitat issues. A review of the Sawtooth National Recreation Area by the Chief of the Forest Service and representatives of The Wildlife Society, American Fisheries Society, and other concerned parties defined several courses of action to improve fish reproduction and migration, including development of improved riparian grazing systems (Peek and Gebhardt 1980). The present study was initiated in response to the identified concerns about grazing-fisheries conflicts in the Sawtooth National Recreation Area. This study spanned a 10-year period and examined the response of a cold mountain meadow riparian system to 3 intensities of controlled late June cattle grazing.

Study Area

The grazing study was initiated on Stanley Creek, Sawtooth National Recreation Area, Sawtooth National Forest, central Idaho in 1987. The study area is about 6 km northwest of Stanley, Ida., in portions of sections 19, 29, and 30 T11N, R13E (Lat 44°15'46"N, Long 114°59'02"W) where Stanley Creek flows through a broad, flat valley with a westerly aspect at an elevation of 1,950

m. Stanley Creek is a 3rd order, C4 stream (Rosgen 1994). Soils are Typic Cryaquepts formed in alluvium and lacustrine sediments derived from granite. They have moderately slow to moderate permeability. The upper 23 cm is typically a silty clay loam overlying a sandy to coarse sandy clay loam. Below 76 cm the profile contains 60% pebbles, cobbles, and stones (Personal communication, D.R. Gilman). National Weather Service records are incomplete, but annual precipitation during the treatment years (1987–1995) appeared to have been approximately 20–25% below the 389 mm average. This below average precipitation period is referred to as a drought in the current study. The post-grazing year (1996), when final measurements were taken, precipitation was 570 mm or approximately 46% above average. Average temperature during the June grazing period is 11°C; average annual temperature is 2°C (Personal communication, Idaho Climate Services).

The area is representative of the mountain meadows ecosystem in the forest zone of the mountain West containing wet to intermittently wet sites (Garrison et al. 1977). Typical streamside plant species included: Kentucky bluegrass (*Poa pratensis* L.), tufted hairgrass (*Deschampsia cespitosa* [L.] Beauv.), water sedge (*Carex aquatilis* Wahl.), beaked sedge (*C. rostrata* Stokes), Baltic rush (*Juncus balticus* Willd.), foxtail (*Alopecurus* spp. L.), timber dantonion (*Danthonia intermedia* Vasey), thick-stemmed aster (*Aster integrifolius* Nutt.), cinquefoil (*Potentilla* spp. L.), gentian (*Gentiana* spp. L.), Lemmon's willow (*Salix lemmonii* Bebb), and Drummond willow (*S. drummondiana* Barratt). The streamside area, 7% of the pastures (Clary and Booth 1993), was incised an average of 0.38 m below the surrounding drier meadow and averaged 16 m in width.

Idaho fescue (*Festuca idahoensis* Elmer), western needlegrass (*Stipa occidentalis* Thurb.), and mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle) were common in the portion of the area away from the stream. These areas, referred to as the "dry meadow," were typically dry from about mid July into fall, but bog-like areas and other areas of excess moisture were present in all years.

Stanley Creek and the surrounding meadows have had a long history of use

and disturbance by European man. Placer gold was discovered in Stanley Basin in 1863 (Van Noy et al. 1986). Mining in the upper portion of Stanley Creek began in the early 1870's by ground sluicing. Dredge mining was conducted from 1900 to 1914. Various forms of placer mining occurred from 1933 to 1938 (Choate 1962). Obvious signs of mining activity are still present immediately upstream from the study pastures. Other indications are also present that suggest heavy use by early settlers. Water diversion ditches and trail roads are apparent in a number of locations. A log-supported stream crossing is still present within the boundaries of 1 study pasture.

Sheep grazing began by 1879 and up to 200,000 sheep grazed during summers in the Sawtooth Valley, although there is no current sheep use of the study area. Cattle grazing in Stanley Basin apparently started in 1899, but records of grazing use are not available earlier than 1939 and little attention was given to grazing management until the 1970s (Sawtooth mountain area study: history. 1965. Copy on file Sawtooth National Recreation Area, Ketchum, Ida.) (Environmental analysis report: Stanley Basin revegetation and rehabilitation project. 1974. Copy on file Sawtooth National Recreation Area, Stanley, Ida.). Until fenced at the beginning of this study, the study area was grazed as part of the Stanley Basin cattle allotment. Limited utilization records suggested a 60–65% utilization rate of the dry meadow, tufted hairgrass sites, but no information was available on utilization rates for streamside locations (Personal communication, L. Burton). Streamside utilization rates were assumed to have been high because some cattle usually had access to Stanley Creek throughout the summer (Personal communication, B. Webster). No significant utilization by wild herbivores was apparent during the study.

Methods

Field Procedure

Six experimental pastures, 3.7 to 9.0 ha, were established along Stanley Creek in fall 1986 (Fig. 1). Grazing was conducted annually with cow-calf pairs in the last half of June from 1987 to 1995; except for 1993 when concerns

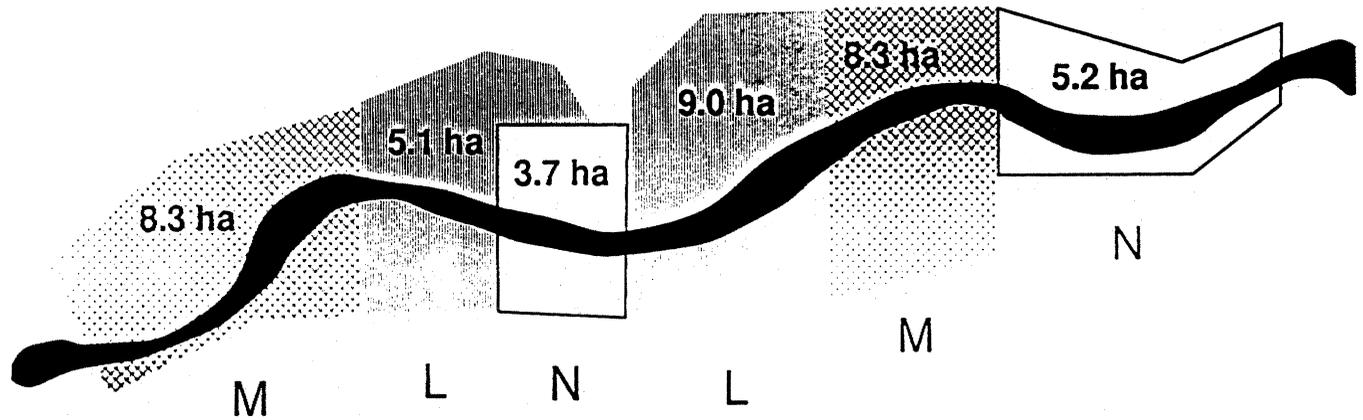


Fig. 1. Layout of experimental pastures on Stanley Creek in central Idaho. Treatments are medium (M), light (L), and no grazing (N). Black area represents the slightly incised stream and streamside area.

about federal listing of chinook salmon as a threatened species precluded grazing. The last half of June corresponded in nearly all years to the period when the dry meadow vegetation had made substantial growth, and yet had sufficient soil moisture remaining to maintain forage succulence. Since the dry meadow pre-study utilization rates of 60–65% exceeded the recommended 55% maximum to maintain healthy tufted hairgrass communities (Reid and Pickford 1946) and the grazing appeared to have negatively impacted the riparian habitats, the target utilization rates on the dry meadow portions of the pastures were 50, 25, and 0% for the medium, light, and no grazing grazing treatments. Two pastures were assigned to each of 3 treatments: medium grazing (average of 2.20 animal unit months [AUM] ha⁻¹), light grazing (average of 1.27 AUM ha⁻¹), and no grazing. Stocking was adjusted so all pastures were grazed for a similar period (usually 14 days).

A 4-ha, 100-point sampling grid was established within 5 pastures with interpoint distances of 20 m; the 6th pasture had interpoint distances of 17 m. At each point a 0.25-m² plot was sampled for various vegetation and soil attributes. Distribution of the 100-plot grid between streamside and dry meadow locations varied among pastures because of the variable size and location of the streamside areas. A second set of forty 0.25-m² plots was concentrated near the stream to provide a more detailed sample of the streamside area in each pasture. Analyses were based on 140 plots per pasture (100-plot grid plus 40 additional plots) with 45 to 59 of the plots per pasture sampling the streamside area and 81 to 95 sampling the dry meadow area.

Plant canopy cover, by graminoids, forbs, and shrubs, and litter were visually estimated (Daubenmire 1959); herbaceous plant height was measured in centimeters, and number of species was recorded by plant life form. Plant attributes were determined in each 0.25-m² plot in 1987, 1990, 1994, and 1996. Height of the willow closest to each plot was measured in centimeters at the beginning and at the end of the study (1987 and 1996). Plant community-type classifications were made within a radius of 3 m from each 0.25-m² plot in 1988 and 1996 following the general approach of Tuhy and Jensen (1982). Plant and soil moisture contents and their relationship to grazing distribution on the study area were reported in Clary and Booth (1993).

Percentage utilization to the nearest 5% was determined by visual estimation (Pechanec and Pickford 1937) by graminoid, forb, and shrub categories based on comparison with 6 reference cages per pasture. The cages were relocated at the start of the grazing period each year. Beginning in 1988, mean residual stubble heights were measured to the nearest centimeter immediately after each grazing period. Autumn remeasurements were initiated in 1989 to determine season-end heights.

Thirty-one channel cross-sections were systematically located along the stream within the boundaries of the plot grid in each pasture and measured mid summer in 1986, 1990, 1994, and 1996. Variables measured included wetted width, average wetted depth, bank stability (based on estimated protection from erosion provided by vegetation or by boulders and rubble), bank alteration

(based on linear proportion of active banks estimated to be slumped, broken, or eroding), channel bottom embeddedness (rated as the proportion of the average perimeter of individual gravel, rubble, and boulder particles covered by fine (<4.7 mm diameter) sediment), and channel bottom textural composition (Platts et. al 1987, Zwegardt and Buckhouse 1996).

Analyses

Although the pastures appeared to have similar characteristics when fenced; it became apparent that each one was somewhat unique. Therefore, to partially compensate for these initial differences, analyses were based on comparisons between the initial reading for a variable (1986 or 1987) and later readings (1990, 1994, or 1996). Stream profile variables were analyzed as proportional changes because stream channel width and width/depth ratio were physically limited in their potential response. Other variables were analyzed based on numeric differences between initial and later readings.

Variables were transformed as necessary to normalize data distributions. Transformations used were logarithm, square root, and arc sine for continuous variables, counts, and percentages and angles. Average values presented in tables were transformed back into the original data form. Analyses of treatment effects were conducted by Analysis of Variance (ANOVA) using a General Linear Model. Repeated measures analysis was used when data included more than 1 response year. Plant community-type frequency of

occurrence was examined by Chi-square analysis. Significant differences among means in the ANOVA tests were identified using a protected Fisher's Least Significance Difference (LSD). Additional T-tests were conducted to determine if responses within individual treatments differed from the initial readings in 1986 or 1987. This was used as an aid in interpretations of treatment trends, even when no significant differences were defined among treatments. Probabilities of 0.05 or less were considered significant in all analyses. The analysis of changes for most data are presented in 2 periods: 1990 and 1994 during the grazed drought years compared with initial year (1986 or 1987); and 1996 the post-grazing, high precipitation year compared with the initial year.

Results

Graminoid utilization averaged 35.2% at streamside and 51.8% in the dry meadow for the medium grazing treatment; 21.6% at streamside and 25.0% in the dry meadow for the light grazing treatment. The residual stubble heights for graminoids immediately following grazing were 10.5 cm (4.1 in) at streamside and 7.1 cm (2.8 in) on dry meadow for medium grazing and 14.1 cm (5.6 in) at streamside and 13.4 cm (5.3 in) on dry meadow for light grazing. Season-end streamside stubble heights were 12.9 cm (5.1 in) for medium, 16.4 cm (6.5 in) for light grazing, and 26.2 cm (10.3 in) for no grazing. These utilization levels were less severe and the season of grazing more restricted than had been the situation on the study site for most of this century.

Stream Channel

Stream Channel Profile and Streambank Ratings

A decrease in stream width occurred under all treatment regimes from 1986 to 1996 (Table 1). The average amount of narrowing was inversely associated with grazing intensity. The change in depth was more erratic among years than the change in width. Depths decreased during the drouthy grazing years, but had increased in the wet post-treatment year. The ungrazed pastures, which displayed the greatest narrowing, showed the greatest increase in depth

compared to 1986. The width/depth ratio decreased under all treatments as compared to pre-study conditions at study end; the ungrazed treatment produced greater decreases than did either grazed treatment (Table 1).

Ratings of streambank stability improved at a similar rate for the 3 grazing treatments (Table 2). Ratings of streambank alteration decreased under all treatments by the end of the study; the ungrazed treatment showed the most reduction (Table 2).

Channel Bottom

Embeddedness changed differently among treatments. Embeddedness had decreased in all treatments at study end;

the least change occurred under medium grazing (Table 3). The surface area composed of fine textured sediments increased or showed no change with medium grazing. Both the light and ungrazed pastures showed little reduction in surface fines during the grazed years, although the lightly grazed pasture illustrated a significant reduction from initial conditions by the end of the study (Table 3).

Riparian Vegetation

Streamside Willows

Willows in the streamside area were scattered along most the length of Stanley Creek included within the study area. Willow heights increased during

Table 1. Proportional changes in channel profile characteristics, Stanley Creek pastures.¹

Grazing treatment	Stream profile characteristics					
	Width		Depth		Width/depth ratio	
	1990&1994	1996	1990&1994	1996	1990&1994	1996
	(Proportion of initial measurement ²)					
Medium grazing	0.821 Cb ³	0.856 Bb	0.812Ab	1.598 Ab	1.011 Ba	0.536 Bb
Light grazing	0.665 Bb	0.824 Bb	0.730 Ab	1.585 Ab	0.912 Ba	0.520 Bb
No grazing	0.591 Ab	0.687 Ab	0.861 Ab	2.336 Bb	0.686 Ab	0.294 Ab

¹1990 and 1994 measurements were taken during grazed, droughty years; 1996 measurements were taken in ungrazed, wet conditions 1 year following cessation of treatments.

²Data presented are the proportional changes from initial measurements, therefore, the units are dimensionless.

³Treatment means sharing an upper case letter within a characteristic and year are not different at P<0.05. Lower case letters indicate: a=not different from initial reading, or b=significantly different from initial reading.

Table 2. Changes in streambank ratings, Stanley Creek pastures.¹

Grazing treatment	Streambank characteristics			
	Streambank stability		Streambank alteration	
	1990&1994	1996	1990&1994	1996
	(Change from initial rating ²)			
Medium grazing	12.4 Ab ³	12.0 Ab	3.3 Bb	-17.4 Bb
Light grazing	11.2 Ab	11.8 Ab	-1.3 Ba	-22.6 Bb
No grazing	16.7 Ab	19.5 Ab	-11.0 Ab	-35.2 Ab

¹1990 and 1994 measurements occurred during grazed, droughty years; 1996 measurements occurred in ungrazed, wet conditions 1 year following cessation of treatments.

²Characteristics were rated on a scale of 0-100. Table values indicate direction and magnitude of rating change.

³Treatment means sharing an upper case letter within a characteristic and year are not different at P<0.05. Lower case letters indicate: a=not different from initial reading, or b=significantly different from initial reading.

Table 3. Changes in channel bottom characteristics, Stanley Creek pastures.¹

Grazing treatment	Channel bottom characteristics			
	Embeddedness		Fine sediments	
	1990&1994	1996	1990&1994	1996
	(Coverage of large particles)		(Proportion of channel bottom)	
Medium grazing	6.7 Bb ²	-16.5 Cb	15.0 Bb	6.9 Ba
Light grazing	-2.6 Ab	-33.3 Ab	-1.0 Aa	-14.0 Ab
No grazing	-8.6 Ab	-20.0 Bb	-2.8 Aa	-4.0 Ba

¹1990 and 1994 measurements occurred during grazed, droughty years; 1996 measurements occurred in ungrazed, wet conditions 1 year following cessation of treatments.

²Treatment means sharing an upper case letter within a characteristic and year are not different at P<0.05. Lower case letters indicate: a=not different from initial reading, or b=significantly different from initial reading.

Table 4. Streamside willow responses to grazing management from beginning to end of study, Stanley Creek pastures.

Willow characteristics		
Grazing treatment	Change in height	Change in cover ¹
	(m)	(%)
Medium grazing	0.35 Ab ²	28.89 Ab
Light grazing	0.28 Ab	37.13 Ab
No grazing	0.40 Ab	56.39 Bb

¹Based only on plots containing willows throughout the study.

²Treatment means sharing an upper case letter within a characteristic are not different at P≤0.05. Lower case letters indicate: a=not different from initial reading, or b=significantly different from initial reading.

the study period, but the changes did not differ among treatments (Table 4). Willow cover increased with all treatments; the greatest increase occurred in the absence of grazing.

Plant Species Richness

The grazed pastures increased in graminoid species in all years compared to the initial reading (Table 5). The grazed pastures also showed an increase in forb species during the grazed years. The year after grazing ceased and precipitation was high all pastures lost forb species richness. The average number of shrub species per plot increased slightly from the initial readings; the response was similar among treatments. Overall, the grazed treatments experienced a greater increase in total plant species during the period of grazing than did the ungrazed treatment. In the year following the end of grazing when a general reduction of forb species occurred, only the medium grazed treatment maintained a significant increase in total species richness compared to initial readings (Table 5).

Plant Community-Types

No significant changes occurred in frequencies of individual plant community-

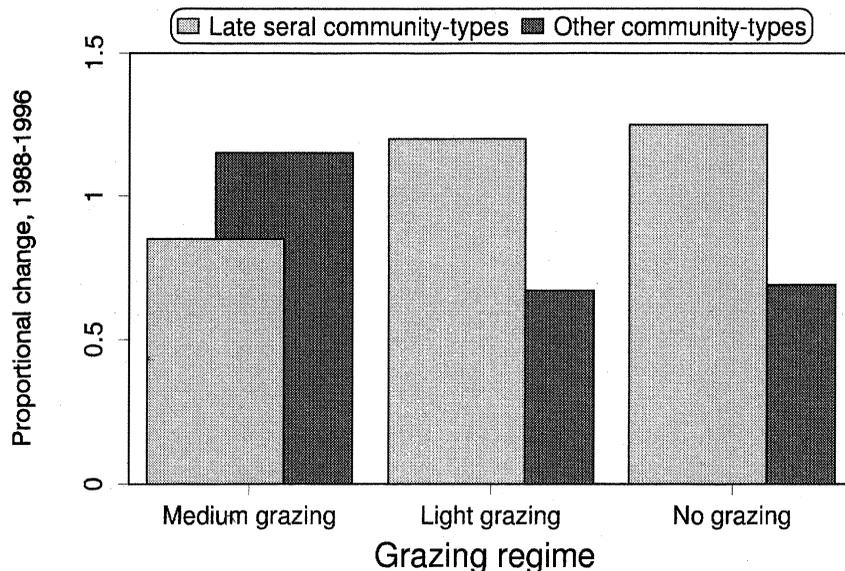


Fig. 2. Proportional change in several streamside plant community-type group frequencies during 1988 to 1996. The shift in community-types typified by strongly rooted, late seral graminoids compared to all other herbaceous plant community-types was significant at P=0.01.

types in the streamside locations. A significant change did occur in the frequency of the entire group of strongly-rooted, late seral species (beaked sedge, water sedge, bluejoint reedgrass [*Calamagrostis canadensis* (Michx.) Beauv.], and Baltic rush) (USDA-FS 1992)(P=0.01). An increase in this group occurred in the ungrazed and lightly grazed pastures (Fig. 2). This increase was nearly matched by a non-significant downward trend in the Kentucky bluegrass community-type (P=0.07).

Plant Cover and Litter

Little change in graminoid canopy cover occurred. No treatment differed significantly from the initial measurements at the end of the study (Table 6). The forb cover tended to increase variably in the grazed treatments and to decrease significantly in the ungrazed

treatment. Changes in total herbaceous plant cover did not differ among treatments in the grazed years. The no grazed treatment ended in 1996 with a lower total plant cover than the initial reading. Litter tended to decrease in the moderately grazed pastures, gain in the no grazing treatment, and change minimally in the light grazing treatment (Table 6).

Plant Height

Graminoid heights were similar among treatments after the cessation of grazing for 1 year (P=0.56). Average streamside graminoid heights were 28.2, 28.1, and 29.4 cm for medium, light, and no grazing treatments, respectively. These results suggest that similar growth rates of herbaceous plants were attained among treatments within 1 year after grazing stopped.

Table 5. Changes in numbers of streamside plant species, Stanley Creek.¹

Grazing treatment	Plant growth form							
	Graminoid		Forb		Shrub		Total Plant	
	1990&1994	1996	1990&1994	1996	1990&1994	1996	1990&1994	1996
	Change in no. 0.25-m ²							
Medium grazing	0.73 Bb ²	0.64 Bb	0.59 Bb	-0.01 Aa	0.08 Ab	0.09 Ab	1.40 Bb	0.72 Bb
Light grazing	0.65 Bb	0.35 ABb	0.47 Bb	-0.45 Ab	0.13 Ab	0.20 Ab	1.25 Bb	0.10 ABa
No grazing	0.14 Aa	0.06 Aa	0.04 Aa	-0.45 Ab	0.12 Ab	0.18 Ab	0.30 Ab	-0.21 Aa

¹1990 and 1994 measurements were taken during grazed, droughty years; 1996 measurements were taken in ungrazed, wet conditions 1 year following cessation of treatments.

²Treatment means sharing an upper case letter within a characteristic and year are not different at P≤0.05. Lower case letters indicate: a=not different from initial reading, or b=significantly different from initial reading.

Table 6. Changes in streamside litter and herbaceous plant cover, Stanley Creek pastures.¹

Grazing treatment	Plant growth form							
	Litter		Graminoid		Forb		Total herbaceous plant	
	1990&1994	1996	1990&1994	1996	1990&1994	1996	1990&1994	1996
	(Change in % cover)							
Medium grazing	-1.19 Aa ²	-3.39 Ab	-3.20 Aa	-2.91 Aa	0.82 Ba	4.28 Bb	-2.38 Aa	1.37 Ba
Light grazing	1.50 Bb	-0.66 Ba	-1.95 Aa	-4.89 Aa	3.62 Bb	0.02 Ba	1.67 Aa	-4.87 ABa
No grazing	2.82 Cb	2.77 Cb	8.44 Ab	1.93 Aa	-6.36 Ab	-7.83 Ab	2.08 Ab	-5.90 Ab

¹1990 and 1994 measurements were taken during grazed, droughty years; 1996 measurements were taken in ungrazed, wet conditions 1 year following cessation of treatments.

²Treatment means sharing an upper case letter within a characteristic and year are not different at P≤0.05. Lower case letters indicate: a=not different from initial reading, or b=significantly different from initial reading.

Dry Meadow Vegetation

Species Richness

The graminoids were greater in both the grazed period and in the post-grazing year in comparison to initial values (Table 7). The forb species richness exhibited a general increase across treatments during the grazed years, but declined in the ungrazed treatment in 1996, a wet year. This indicates that both drought and grazing stresses provided the opportunity for an increase in forb species. A slight increase in number of different shrubby species occurred from initial readings in the light and ungrazed treatments, although no differences among treatments were detected. During the grazed period, the average number of total species recorded increased for all treatments. In the year after grazing ceased, only the medium grazed treatment showed an increase in number of total plant species compared to the initial reading (Table 7).

Plant Community-Types

There was greater evidence of a change in the frequencies of community-types in the dry meadow portion of the pastures than in the streamside areas. The frequency of the tufted hairgrass type (P<0.01) and the Kentucky bluegrass type (P<0.01) increased inversely to grazing pressure at the expense of the thick-stemmed aster type (P<0.01), the

primary forb type on the study area. The greatest change occurred in the ungrazed pastures. A group of late seral graminoid community-types (beaked sedge, water sedge, bluejoint reed grass, and Baltic rush), that inhabited the more moist locations in the dry meadow area, decreased in all treatments (P<0.01).

Plant Cover and Litter

On the dry meadows graminoid cover decreased during the period of study with no difference among treatments (Table 8). Forb cover increased in all treatments during the grazed years, but 1 year after grazing stopped the medium grazing treatment was the only treatment different than the initial measurement. There were no changes in shrub cover. Total plant cover decreased on the dry meadows during the grazed years, but in 1996 only the no grazed treatment had less total cover than initial readings (Table 8). Generally, less litter was recorded during the study than in the initial readings, although little difference occurred among treatments.

Discussion

Streamside

Grazing along streambanks probably does as much or more damage to stream-riparian habitats through bank

alteration as through changes in vegetation biomass (Winward 1986). Overuse by cattle can easily destabilize and break down streambanks as vegetation is weakened and the physical forces of hoof impacts shear off bank segments (Marlow and Pogacnik 1985, Trimble and Mendel 1995). As grazing and trampling damage are reduced, the residual vegetation aids in trapping of sediments that serve as base material to rebuild streambanks (Clary et al. 1996). The channel narrowing and the reduced width/depth ratio of all 3 treatments in this study suggest the grazing stress applied during treatment was within the sites' capabilities for annual recovery and that the original degree of degradation did not preclude an improving trend under these conditions. Because the degree of change in these variables was associated with grazing intensity, this study illustrates that streambank and aquatic habitat impacts can be controlled through grazing management. When streambanks rebuild and channels narrow, the decreased width/depth ratio improves the stream's hydraulic and sediment transport efficiency (Morisawa 1968, Olson-Rutz and Marlow 1992, Leopold 1994) and provides potential increases in fish hiding cover (Meehan et al. 1977, Kozel et al. 1989, Bjorn and Reiser 1991, Overton et al. 1995).

All treatments decreased in substrate

Table 7. Changes in numbers of dry meadow plant species, Stanley Creek.¹

Grazing treatment	Plant growth form							
	Graminoid		Forb		Shrub		Total plant	
	1990&1994	1996	1990&1994	1996	1990&1994	1996	1990&1994	1996
	Change in no. 0.25-m ⁻²							
Medium grazing	0.98 Bb ²	0.91 Bb	0.84 Ab	0.44 Bb	0.01 Aa	0.02 Aa	1.83 Bb	1.37 Bb
Light grazing	0.58 Ab	0.34 Ab	0.54 Ab	-0.16 Aa	0.03 Ab	0.04 Ab	1.15 Ab	0.22 Aa
No grazing	0.46 Ab	0.37 Ab	0.52 Ab	-0.23 Ab	0.03 Ab	0.05 Ab	1.01 Ab	0.19 Aa

¹1990 and 1994 measurements were taken during grazed, droughty years; 1996 measurements were taken in ungrazed, wet conditions 1 year following cessation of treatments.

²Treatment means sharing an upper case letter within a characteristic and year are not different at P≤0.05. Lower case letters indicate: a=not different from initial reading, or b=significantly different from initial reading.

Table 8. Changes in dry meadow ground cover, Stanley Creek.¹

Grazing treatment	Ground cover characteristics									
	Litter		Graminoid		Forb		Shrub		Total plant	
	1990&1994	1996	1990&1994	1996	1990&1994	1996	1990&1994	1996	1990&1994	1996
	Change in % cover									
Medium grazing	-3.15 Ab ²	-3.60 Ab	-14.38 Ab	-11.43 Ab	5.00 Ab	11.09 Cb	0.01 Aa	0.01 Aa	-9.37 Ab	-0.33 Aa
Light grazing	1.63 Bb	-1.22 Ab	-11.71 Ab	-5.27 Ab	3.04 Ab	1.83 Ba	0.02 Aa	0.03 Aa	-8.65 Ab	-3.41 Aa
No grazing	0.80 Aa	-1.62 Ab	-16.00 Ab	-8.67 Ab	3.75 Ab	-2.04 Aa	0.02 Aa	0.04 Aa	-12.23 Ab	-10.67 Ab

¹1990 and 1994 measurements were taken during grazed, droughty years; 1996 measurements were taken in ungrazed, wet conditions 1 year following cessation of treatments.

²Treatment means sharing an upper case letter within a characteristic and year are not different at P≤0.05. Lower case letters indicate: a=not different from initial reading, or b=significantly different from initial reading.

embeddedness by the end of the study, but the decrease in proportion of the surface composed of fine sediments was variable. This response may have been affected by downstream movement of old dredge mining sediments. Channel bottom conditions are greatly affected by sediments contributed by upstream sources and may not respond rapidly to on-site management (Rinne 1988). The channel substrate status is important to spawning and incubation of stream fishes, production of aquatic invertebrates for salmonid food, and cover for young fish (Bjornn and Reiser 1991).

Willow height and cover increased in all treatments of this study. The maintenance of an adequate herbaceous forage supply (Winward 1994, Pelster 1998) and control of season of grazing undoubtedly reduced impacts on the willow community as compared to historic grazing procedures (Kovalchik and Elmore 1992, Winward 1994). Some impact on willows is typical even under managed grazing (Myers and Swanson 1995), thus the positive growth response of willows in this study exceeded expectations. The benefits of streamside vegetation canopies, particularly of various species of willow are: provision of hiding cover, modulation of stream temperatures, and contribution of leaf detritus and terrestrial insects that expand food sources for fish (Meehan et al. 1977, Murphy and Meehan 1991, Kovalchik and Elmore 1992, Li et al. 1994).

Plant species richness in the grazed pastures increased in all categories during the treatment years. The continued grazing stress in the grazed pastures, together with the below normal precipitation that was present for the bulk of the study, apparently opened the stand and allowed new plant establishment. Changes in species richness in the ungrazed treatment were noticeably less, as was expected (Hayes 1978, Green

and Kauffman 1995). In 1996, one year after cessation of grazing and a year of above average precipitation, forb species numbers dropped to less than initial counts for the lightly grazed and no grazed treatments as grazing and moisture stresses were reduced. The increase in frequencies of strongly-rooted, late seral graminoid community-types in streamside locations under light or no grazing was expected (Green and Kauffman 1995). The extent and strength of the roots and rhizomes of these plants provide essential stability to the banks (Kleinfelder et al. 1992, Dunaway et al. 1994), thus allowing undercuts to form as habitat segments for salmonids (Platts 1991). The lack of differences among treatments in height of graminoids, after 1 year of rest from grazing, suggests that any loss of vigor from the current grazing treatments was largely recovered after 1 year. A similar response was suggested from studies of simulated grazing (Clary 1995).

Although substantial changes occurred in a number of characteristics that benefit the stream environment and aquatic habitat, changes of herbaceous plant characteristics along the stream edge at Stanley Creek were limited. Overall, stream channel characteristics of the Stanley Creek riparian area seemed to respond more rapidly than the vegetation characteristics—a sequence differing from studies in some other locations (Kondolf 1993, Knapp and Matthews 1996).

Dry Meadow

During this study we were applying differential grazing treatments and the regional climate was applying drought stress for most of the years of grazing. These combined stresses opened the stands sufficiently to provide an opportunity for additional species to thrive. Stress conditions on dry meadows, par-

ticularly grazing stress, typically provide disturbance conditions favorable for increases in species richness and diversity (Dobson 1973, Hayes 1978, Green and Kauffman 1995). After protection from grazing, dry meadows characteristically experience a reduction in the forb component while retaining the exotic Kentucky bluegrass component (Kauffman et al. 1983, Green and Kauffman 1995). Reduction in graminoid cover during the study was probably a result of drought because the ungrazed treatment decreased as well. There were mixed directions of successional changes. The increase in tufted hairgrass and a decrease in forb dominance under reduced grazing pressure suggest improved meadow conditions. A decrease in wet-site rhizomatous graminoids during drought suggests a depletion of meadow conditions (Reid and Pickford 1946, Hansen et al. 1995).

Management Implications

No single management approach is best for all situations, nor perhaps is even required for a given situation (Clary and Webster 1989, Ehrhart and Hansen 1997). There are, however, management approaches that work well in many circumstances. For instance, several authors have emphasized the potential benefits of late summer grazing (Kauffman et al. 1983, Marlow and Pogacnik 1985). Alternatively, spring grazing has shown promise in many areas of the western United States (Hayes 1978, Platts and Nelson 1985, Siekert et al. 1985, Goodman et al. 1989, Kovalchik and Elmore 1992, Pelster 1998). The combination of succulent upland forage, cool temperatures, and wet soils near water sources acts to encourage a more dispersed spring grazing pattern (Krueger 1983, Marlow and

Pogacnik 1986, Kovalchik 1987, Myers 1989, Clary and Booth 1993).

Grazing strategies employed in this study were designed to stay within the annual tolerance of the site for plant or streambank/channel impacts each year. Even though many riparian forage plants have season-long access to adequate soil moisture, their ability to withstand grazing has limits (Allen and Marlow 1994, Lamman 1994, Clary 1995, Hall and Bryant 1995, Dovel 1996). Willows are notably vulnerable to cattle use in late summer (Kovalchik and Elmore 1992, Lamman 1994, Winward 1994, Myers and Swanson 1995), particularly as the forage supply is reduced (Pelster 1998). Heavy trampling on streambanks is typically very damaging (Trimble and Mendel 1995), especially when the banks are moist (Marlow and Pogacnik 1985). The strategy in the Stanley Creek study was to limit grazing to the early season when less grazing use occurred near the water's edge. The Stanley Creek streambank substrate composition was amenable to this grazing approach; its relatively permeable streamside soils were not likely as susceptible to spring trampling damage as other more fine textured soils (Chaney et al. 1993) (Personal communication, D. Dallas and C. Marlow). Cattle congregated on the dry meadows during those weeks the forage there was still green and succulent, rather than concentrating on the wetter streamside areas (Clary and Booth 1993). Grazing was terminated each year before herbaceous vegetation on the dry meadows had matured.

Riparian grazing recommendations for the recovery of depleted meadow riparian systems, presented after initiation of this study, suggested that 10–15 cm of forage stubble height should remain on streamside areas at the end of the growing season, or at the end of the grazing season after fall frost, to limit potential impacts to the herbaceous plant community, the woody plant community, and streambank stability. Spring or early summer grazing was recommended where feasible (Clary and Webster 1989, 1990). The grazing strategy on the Stanley pastures closely paralleled these recommendations even though the grazing rates were originally based on use of the dry meadow sites. Compared to historic management patterns, the total forage utilization in this study was less, and

mid to late season grazing was eliminated. This approach appears to have been successful. Most riparian area changes in grazed pastures were in a similar direction, but in different magnitudes, to those in the ungrazed treatment here and in other ungrazed mountain meadows (Knapp and Matthews 1996). At the end of the study the conditions on Stanley Creek were continuing to improve, but it was not known how much additional change could have been expected under either carefully grazed or ungrazed conditions. Stanley Creek appeared to be approaching relatively stable conditions when compared to undisturbed meadow systems (Overton et al. 1995), .

Although changes were slow in this cold mountain valley, these early season grazing regimes allowed improvements in stream channel conditions and streamside vegetation characteristics. Most measurements improved to some degree under all 3 treatments; this suggests that early season grazing practices that leave 10 to 14 cm of residual forage stubble height provide an avenue for riparian habitat improvement while maintaining substantial livestock use of the meadow area. Potential changes in other riparian meadow situations will vary depending on past grazing management, streambank substrates, weather, and other factors.

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