Time of grazing effects on stream channel stability instream sediment loads
by Thomas Martin Pogacnik

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Science
Montana State University

Abstract:
A study was conducted during the 1981 and 1982 summer grazing seasons to determine the effects of time of livestock grazing on stream channel stability and suspended sediment concentrations for Cottonwood Creek, a small watershed located on the Red Bluff Research Ranch in southwest Montana. Eight pastures were grazed in succession for 14 days each from June 14 through October 4, with a ninth pasture remaining ungrazed as a control. Stream channel stability, soil moisture, stream flow, and suspended sediment concentrations were monitored during each grazing period. Stream channel alterations were found to be significantly greater during the early grazing periods (June 14 - August 9), with Iate-season channel alterations (August 9 -October 14) being not different from the ungrazed control ($P < 0.01$). Periods of peak channel alterations were associated with high vegetation utilization rates and were correlated to high soil moisture ($r^2 = 0.84$). Alterations associated with the winter monitoring periods were 10 to 800 percent greater than alterations directly attributable to livestock grazing and may be an indirect repercussion of summer livestock activity. No direct relationship between peak concentrations of suspended sediment and cattle activity was discernible. Peak sediment concentrations occurred during periods of high rainfall and appear to be a function of erosion from streambanks altered during the previous season's grazing. Sediment concentrations were generally higher downstream of areas exhibiting the greatest streambank instability.

TIME OF GRAZING EFFECTS ON STREAM CHANNEL

STABILITY INSTREAM SEDIMENT LOADS

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ABSTRACT

A study was conducted during the 1981 and 1982 summer grazing seasons to determine the effects of time of livestock grazing on stream channel stability and suspended sediment concentrations for Cottonwood Creek, a small watershed located on the Red Bluff Research Ranch in southwest Montana. Eight pastures were grazed in succession for 14 days each from June 14 through October 4, with a ninth pasture remaining ungrazed as a control. Stream channel stability, soil moisture, stream flow, and suspended sediment concentrations were monitored during each grazing period. Stream channel alterations were found to be significantly greater during the early grazing periods (June 14 - August 9), with late-season channel alterations (August 9 - October 14) being not different from the ungrazed control ($P < 0.01$). Periods of peak channel alterations were associated with high vegetation utilization rates and were correlated to high soil moisture ($r^2 = 0.84$). Alterations associated with the winter monitoring periods were 10 to 800 percent greater than alterations directly attributable to livestock grazing and may be an indirect repercussion of summer livestock activity. No direct relationship between peak concentrations of suspended sediment and cattle activity was discernible. Peak sediment concentrations occurred during periods of high rainfall and appear to be a function of erosion from streambanks altered during the previous season's grazing. Sediment concentrations were generally higher downstream of areas exhibiting the greatest streambank instability.

INTRODUCTION

Riparian areas are productive, yet very fragile ecosystems which serve as a focal point of management for the entire watershed. Although the riparian zone may occupy only about two percent of a watershed's area (Buckhouse nda), it is in these communities that user interest is disproportionately high. Managers of virtually every natural resource discipline focus their attention on the utilization of riparian areas, which often results in many user groups competing for a limited resource. The multitude of interests, management objectives, and values expressed by the various groups makes a conflict over riparian areas inevitable.

One such conflict concerns the effects grazing livestock exert on riparian ecosystems. The management goals established by wildlife and fisheries biologists to maintain the integrity of riparian habitat for terrestrial and aquatic organisms are occasionally in conflict with the management goals of livestock producers, who are marketing herbage through a ruminant animal and look to riparian areas as a highly productive source of forage, water, shade, and protection throughout the grazing season.

In recent years, numerous studies have equated livestock grazing with declining riparian ecosystem stability. Although many other activities can result in as much or more degradation of riparian habitat (Busby 1979, Claire and Storch in press), it is livestock grazing, because of its high visibility, which has been implicated as the principle force contributing to the destabilization of riparian areas (Busby 1979).

Damage traceable to livestock grazing occurs when improper management practices allow livestock to concentrate in riparian areas for extended periods of time (Armour 1977). The resulting impacts generally occur as destabilized streambanks, altered stream channels, increased suspended sediment loading, and excessive vegetation removal (Behnke and Raleigh 1978; Platts 1981a). The impacts livestock exert on riparian areas may be obvious immediately, as denuded vegetation and collapsed streambanks, or the damage may occur as subtle annual alterations which can take many years to detect (Platts 1981a).

Natural resource managers are being pressured to reduce the impacts livestock inflict on riparian systems, yet a lack of research pertaining to alternative grazing practices in riparian areas limits the management options available. Many studies have suggested that the only management alternative, which is compatible with maintaining the integrity of riparian habitat, is to exclude or restrict livestock use in these areas (Ames 1977, Behnke 1979, Davis 1982, and Platts 1978). However, the restriction or elimination of livestock access to riparian areas may be undesirable for the livestock producer as these areas may constitute the primary forage base of a pasture and produce the only desirable forage during late summer grazing periods.

A number of studies examining the impact livestock exert on riparian communities have been conducted in recent years. Much of this research has centered on attempting to establish to what degree livestock grazing impacts riparian areas and evaluating the effectiveness of various grazing methods to reduce livestock impacts in these areas. Much of the research to date has been based on subjective data, which may include only one year's observations with little consideration given to the measurement of quantifiable parameters or to statistical design. Many times these studies have failed to consider stocking rates, duration of grazing, or season of use in analysis of data. This results in a lack of pertinent information on which management decisions could be made. It is in regard to this fact that the need for more accurate and precise research becomes evident.

In response to the need for research concerned with minimizing livestock grazing impacts on riparian communities, a five-year study is being conducted by the Montana Agricultural Experiment Station in conjunction with Montana State University to determine the effects of time of grazing on a series of riparian ecosystem characteristics. A portion of this study is to discern that period or periods during the grazing season (June 15 - October 4) when livestock-induced streambank and channel instability and suspended sediment loading are minimized.

The principle objectives of this study were: 1) to determine what time during the grazing season streambanks were most susceptible to cattle grazing impacts, and 2) to determine if fluctuations in suspended sediment levels occured during periods when cattle were present.

LITERATURE REVIEW

The combined influences of geology, climate, soil structure, geomorphology, vegetation, and water runoff often result in unstable riparian systems, even in a state unaltered by human activity (Meehan and Platts 1978). When excessive stress is exerted on these marginally stable systems through improperly controlled land management practices, severe damage usually results (Meehan and Platts 1978).

It has been suggested that one of the most destructive forces influencing riparian ecosystems is long-term overgrazing by livestock (Behnke 1977, Davis 1982, Leopold 1975). Townsend and Smith (1977) and Cope (1979) have reported that livestock grazing degrades riparian habitat and subsequently reduces the productivity of these areas. Mismanagement of livestock can result in animals being concentrated in riparian areas, thus inflicting some degree of damage on each of the four major components of a riparian ecosystem: 1) streamside vegetation, 2) stream channel morphology, 3) streambank stability, and 4) water quality (Behnke and Raleigh 1978, Claire and Storch in press, Marcuson 1977, Platts 1979, Platts 1981a).

Streambank vegetation maintains the integrity of riparian areas by stabilizing streambanks (Meehan, Swanson and Sedell 1977, Winegar 1977), reducing erosion (White and Brynildson 1967), reducing water temperatures by shading streams (Armour 1977, Bowers et al. 1979, Platts 1978), and as a source of organic detritus and terrestrial insects which serve in the food chain of riparian systems (Cummins 1974, Meehan, Swanson and Sedell 1977).

There exists an abundance of literature regarding the effects livestock exert on riparian vegetation (Ames 1977, Boldt, Uresk and Severson 1978, Bryant et al. 1972, Buckhouse nda, Claire and Storch in press, Crouch 1979, Davis 1977, Evens and Krebs 1977, Hayes 1978, Knoph and Cannon 1982, Meyers 1981, Pond 1961, Roath 1980, Roath and Krueger 1982, Smith nda, Tuinstra 1967, Vogler 1978, Winegar 1977). These studies have reported that livestock grazing results in undesirable changes in plant succession, community productivity, species composition, reproduction, and diversity associated with riparian areas.

The effects of livestock grazing on riparian vegetation can generally be termed as negative (Buckhouse nda). As early as 1946, livestock were reported to concentrate in riparian communities and utilize the vegetation more intensively than in adjacent habitat types (Reid and Pickford 1946). The impacts of excessive herbage removal in riparian areas can be categorized by vegetation structure: utilization of herbaceous vegetation and utilization of woody vegetation (Buckhouse nda).

The primary effect of excessive livestock grazing on herbaceous vegetation is the replacement of native bunchgrasses by invader grasses and forbs (Dobson 1973, Evenden and Kauffman 1980, Hayes 1978, Volland 1978). Grazing has been reported to increase the number of undesirable species found in riparian areas (Everden and Kauffman 1980) by opening up the vegetation and creating niches in which ruderal species may become established (Dobson 1973, Hayes 1978). Information regarding productivity of streamside vegetation, as influenced by grazing is conflicting (Buckhouse nda). Numerous studies have reported decreases in productivity due to livestock grazing (Duff 1979, Gunderson 1968, McClean, Nicholson and Ryswyk 1973, Marcuson 1977, Pond 1961). However, Roath (1980) and Volland (1978) found livestock grazing had no significant affect on biomass production and Kauffman et al. (in press) observed greater production in grazed communities over similar ungrazed areas.

The effects of herbivory on shrub and tree production and reproduction is a critical impact to riparian ecosystems (Buckhouse nda). Marcuson (1977) found shrub production to be 13 times greater in an ungrazed area than in a severely grazed area. Carothers (1977) and Glinski (1977) report that excessive grazing pressure prevents the establishment of seedlings or suckers resulting in communities which are even-aged and non-reproducing. Vogler (1978) found light browsing may stimulate sprouting of riparian woody species, yet, persistent livestock use can result in the elimination of woody species (Crouch 1979).

Season of use appears to have an affect on the ability of riparian vegetation to withstand grazing pressure. Claire and Storch (in press) and Roath (1980) in Oregon have shown late-season grazing has little impact on either herbaceous or woody riparian vegetation, while Myers (1981) concluded that livestock use of riparian habitat in the spring is more conducive to shrub survival than during the "hot period" of late summer.

Perhaps the greatest impact of excessive livestock grazing in riparian communities is the subsequent destabilization of streambanks following vegetation removal. The first sign of riparian damage, as a result of livestock activity, will occur as reductions in vegetative cover and a subsequent increase in streambank and stream channel instability (Platts 1981a, Skolvin 1967). Studies by Berry (1978) Hayes (1978) and Winegar (1977) all indicate that accelerated streambank undercutting occurs after excessive vegetation removal by livestock. Platts (1981b) reported less stable streambanks when utilization rates were 65 percent or greater, while utilization rates of 25 percent or less resulted in little or no streambank damage. Similar results were presented by Hayes (1978), who reported increased streambank instability after vegetation utilization rates exceeded 60 percent. Cooper (1979) states that streambank damage may be independent of animal numbers though and that it does not take full utilization of streambank vegetation to seriously damage sensitive banks.

The impact of livestock grazing on stream channel morphology and streambank stability varies depending upon the nature of the stream being studied (Buckhouse nda). It has been suggested that streambank susceptibility to livestock impact may be determined by soil structure and bank rock content (Behnke and Raleigh 1978, Cooper 1979, Gunderson 1968, Marcuson 1977, Platts 1979). Cooper (1979) states that banks containing a higher percentage of rock significantly impede ungulate damage. Streambanks with low percentages of bank rock as well as soils with sandy textures are reported to be highly susceptible to trampling damage (USDI 1978).

Numerous studies have reported the effects of livestock trampling on soil compaction and soil disturbance (Alderfer and Robinson 1979, Bryant et al. 1972, Orr 1960, Rauzi and Hanson 1966, Roath 1980). Roath (1980) states that the greatest impact livestock exert on riparian areas is trampling damage and he notes that the amount of impact appears to be dependent upon soil moisture. Cooper (1979) speculated that moisture frozen in streambanks may supply the soil with sufficient support to withstand heavy weight.

Livestock grazing has been shown to alter stream channel shape, resulting in channels which are typically wider and shallower than comparable areas not being grazed (Armour 1977, Duff 1979, Gunderson 1968, Kauffman et al. in press, Marcuson 1977, White and Brynildson 1967). A stream channel receiving heavy grazing pressure from sheep was reported by Platts (1981b) to be four times as wide as an area receiving light grazing. Kauffman et al. (in press) found a riparian system grazed under a stocking rate of 2.5 ha/AUM lost over three times as much streambank as an ungrazed control area.

However, these findings conflict with those reported by Buckhouse et al. (1981), Hayes (1978), and Roath (1980). Hayes (1978) found fewer changes in streambank shape within pastures being grazed by cattle than in pastures which receive no grazing. Both Buckhouse Skolvin and Knight (1981) and Roath (1980) report insignificant streambank alterations following livestock grazing in Oregon. They surmize that the naturally occurring impacts of water flow (Roath

1980) and ice damage (Buckhouse et al. 1981) resulted in more channel alterations than were contributed by cattle. Buckhouse (1980) states it is accepted that livestock do impact streambanks, but it is important to quantify how much of the damage is in excess of naturally occurring changes.

Trampled streambanks have been reported to increase overland water and sediment flow, resulting in higher suspended sediment levels in streams (Armour 1977, Johnson et al. 1978). Rosgen (1975) reports a good correlation between streambank stability, water flow and suspended sediment levels. Rosgen's relationship is based on the assumption that a given water discharge can transport a set amount of sediment in suspension and the availability of sediment is dependent upon streambank stability. As bank damage increases, sediment levels also increase (Cooper 1979).

Increased levels of suspended sediment in the water column have been identified as the most damaging impact livestock have on stream productivity (Armour 1977, Duff 1979). Berry (1978) and Cordone and Kelley (1961) found that suspended sediment decreases a stream's total organism productivity. Numerous studies have indicated that overgrazing by livestock may result in increased suspended sediment levels and increased levels of sediment in the streambed, resulting in reduced fish biomass production and lowered salmonoid numbers within the fish population (Armour 1977, Behnke and Raleigh 1978, Bowers et al. 1979, Claire and Storch in press, Cordone and Kelley 1961, Duff 1979, Gunderson 1968, Marcuson 1977).

There is general agreement among aquatic biologists that the introduction of particulate matter into a body of water can result in adverse ecological consequences (Cairns 1968). There is, however, a lack of agreement as to the amount of suspended sediment which can be assimilated before threshold values for aquatic organisms are reached (Cairns 1968, and Hoak 1957). McKee and Wolf (1963) state that water containing suspended sediment levels of 80 mg/l is not harmful to aquatic organisms. Peters (1962) reported that levels of 200 mg/l were found to inflict 75% mortality for incubating embryo rainbow trout (Salmo gairdneri). Herbert and Merkins (1961) reported suspended sediment concentrations of 30 ppm (parts per million) having no adverse effect on aquatic organisms yet levels of 270 ppm resulted in a 50 percent death rate among the salmonoids being monitored. In contrast, a study by Benoit, Cairns and Reimer (in press) reported young salmon could tolerate over 120 hours in as much sediment as could be kept in suspension by vigorous aeration. Reported lethal levels of suspended sediment for salmonoids range from 75 ppm to 270,000 ppm (Wallen 1951).

Although aquatic organisms can survive in water within a wide range of suspended sediment levels (Cairns 1968), it is the loss of spawning areas and food which may be most detrimental to their survival (Cairns 1968). Cairns (1968) noted that invertebrate organism production is substantially lower in sand and silt than in rubble and gravel. When inorganic sediments cover rubble and gravel, fish food and spawning areas are destroyed.

Livestock have been implicated as the principle source of increased sediment levels in streams (Cooper 1979, Busby 1979, Platts 1978, Winegar 1977). Yet, studies by Gary, Johnson and Ponce (1983) and Johnson et al. (1978) have indicated little correlation between livestock activity in riparian areas and the large concentrations of suspended sediment recorded in the stream they were monitoring. Both studies concluded that, although livestock activity did result in a slight increase in suspended sediment levels, the amounts were insignificant relative to naturally occurring concentrations. Peak sediment concentrations were recorded during periods of high water flow in both the grazed and ungrazed reaches of the stream (Johnson et al. 1978), and they felt it was apparent that these high concentrations originated upstream of the study site with the cattle contributing insignificant amounts of additional sediment.

Recognizing and understanding the impacts livestock exert on streamsides is a prerequisite to formulating riparian management plans (Claire and Storch in press). Often, what is found to be good range management is not good riparian management (Platts 1979). Methods for improving riparian zone management to reduce livestock damage include: exclusion of livestock, alternative grazing methods, changes in the class of livestock, and managing riparian areas as special-use pastures (Buckhouse nda).

Several studies, reported by Buckhouse et al. (1981) evaluated various grazing methods for their compatability with the objectives of both livestock and wildlife managers of riparian areas. Some grazing methods have shown potential for preserving riparian wildlife habitat, with rest-rotation achieving the most success (Davis 1982, Claire and Storch in press, Hayes 1978, Kimball and Savage 1977, Swan 1979). Drawbacks of rest-rotation and other grazing methods includes increased trailing along fence lines, concentration of livestock in riparian areas, increased trampling damage, and streambank instability (Ames 1977, and Meehan and Platts 1978). No widely-used grazing method has been observed to be compatible with the objectives of all riparian ecosystems user groups (Ames 1977, and Meehan and Platts 1978).

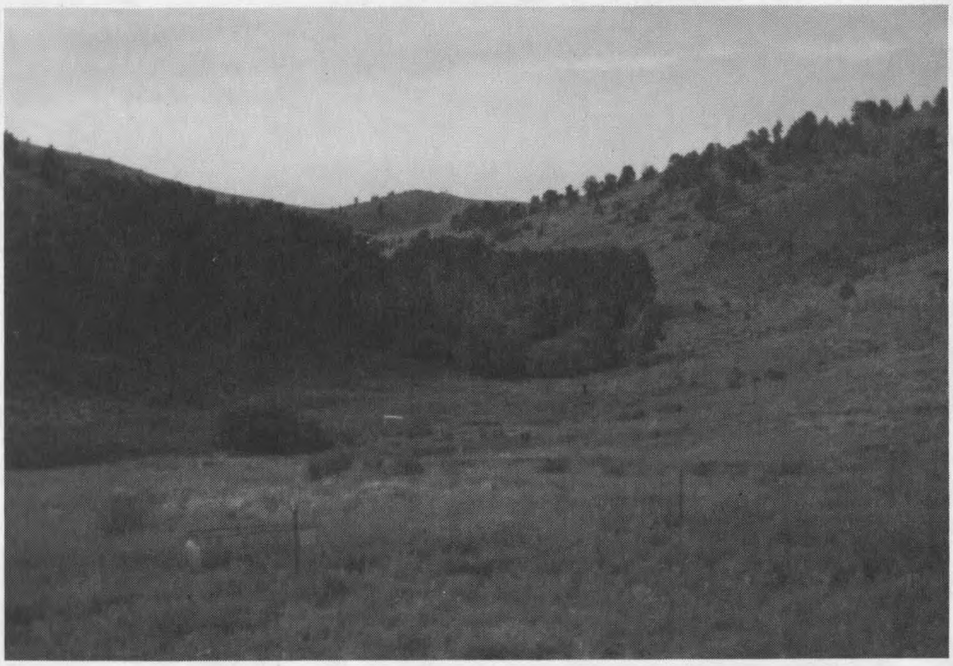
Total exclusion of livestock from riparian areas, as recommended by Ames (1977), Dahlen (1978), Davis (1982) and Platts (1978), has met with marginal benefits (Volland 1978). Although some success in restoring damaged riparian areas has been achieved by excluding livestock (Behnke 1979, Davis 1977), Volland (1978) reports that a riparian area excluded from livestock grazing for eleven years was found to produce less vegetative biomass than an area being grazed. Also, politics, funding, personnel constraints, and conflicting resource demands make livestock exclusion an unacceptable alternative for resource managers (Davis 1982).

Fencing riparian areas separately into special management pastures may be a successful multiple-use system of riparian management (Kauffman et al., in press). Studies by Johnson (1965), Kauffman (1982), Pond (1961), and Roath (1980) all reported reduced livestock damage to riparian areas when grazed late in the season. Cooper (1979) suggests that late fall grazing may have been conducive to reducing streambank damage on riparian areas in Wyoming. Further study is necessary relating to the effects of time of grazing on riparian ecosystems in establishing proper riparian grazing practices (Platts 1981b).

SITE DESCRIPTION

This study was initiated in 1981 on the north fork of Cottonwood Creek, a tributary of the Madison River in southwest Montana. Cottonwood Creek is located in the foothills of the Madison Mountain Range and drains a small watershed of approximately 1360 hectares (Figure 1). The Cottonwood watershed is situated 16 kilometers

Figure 1. View of the Cottonwood Creek Drainage Taken From the Center of the Study Site Looking South.



southeast of Norris, Montana on the Montana Agricultural Experiment Station's Red Bluff Research Ranch (Figure 2).

Cottonwood Creek

Cottonwood Creek is approximately 4 km in length and flows northeast where it joins the Madison River in Beartrap Canyon.

Figure 2. Montana Agricultural Experiment Station's Red Bluff Research Ranch in Southwestern Montana showing Location of Study Site.