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Interactions of Riparian Zones and Grazing as Related to Water Quality

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Water quality may be one of the major issues affecting agriculture in the coming decade. In the past, more emphasis was placed on point-source pollution, i.e., factories, water treatment plants, feedlots, etc. These sources are referred to as point-source because the pollution originates from a point that is relatively easy to specify. However, in recent years there is increasing emphasis on nonpoint-source pollution, where the originating point of the pollution is difficult to specify. Land use practices such as farming, road building, forestry, and grazing are some of the commonly listed contributors to nonpoint-source pollution. Fertilizer and pesticide contamination of both surface water and groundwater has probably received as much attention as any form of nonpoint-source pollution. Agriculture is often implicated as the biggest single contributor of nonpoint-source pollution. The Federal Clean Water Act is due for re-authorization and stronger emphasis on nonpoint-source pollution is very likely. In this paper we will discuss the primary types of nonpoint-source pollution, the influence of livestock management and riparian vegetation on water quality, and present data from a study conducted in Plumas County, California.

WATER QUALITY FACTORS

There are many types of water quality factors, but we will limit the discussion to those that are influenced by grazing.

Nutrient Enrichment

Streams require nutrients to function properly, but it is possible to receive too much of a good thing. If pastures are fertilized, then either nitrogen or phosphorous can be a problem. If grazing alone occurs, then nitrogen is usually the primary nutrient of concern. As we will point out later, the condition of a stream's riparian zone can have a major impact on potential nutrient enrichment.

Suspended Sediment

Again, the problem with sediment can be too much of a good thing. Input of sediment from the uplands is natural, in fact, it helps form the deep, productive soils that characterize the riparian zones that surround many of our streams. Erosion is a natural process and should not be viewed as universally bad. However, excessive sediment

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production can disrupt the natural food chain in a stream, and negatively impact salmonid fish populations. Salmonid refers to fish of the family Salmonidae, for most practical purposes, salmon, trout, and chars (Meehan 1991).

Temperature

The water quality concern is generally with temperatures that exceed the level necessary for maintaining salmonid populations. High temperature problems generally occur mid-to late-summer when air temperature is high and streamflows relatively low. Bjornn and Reiser (1991) have summarized the preferred temperatures and lethal temperatures for a number of salmonid species. In general, salmon prefer temperatures between 54 and 57° F (12-14° C), and trout can thrive in water slightly warmer. Lethal temperatures range from 73 to 83°F (about 23 to 30°C) depending on species. High water temperatures also reduce the solubility of oxygen. Under some conditions excessive low winter temperatures can result from removal of insulating vegetation (Platts 1991); anchor ice formation increases fish mortality.

Dissolved Oxygen

Streams with good water quality are relatively high in dissolved oxygen. This factor interacts with all three of the previously listed water quality factors. Oxygen is more soluble at lower water temperatures, thus dissolved oxygen decreases as temperature increases. Sedimentation can increase water temperature by reducing stream depth (Satterlund and Adams 1992); thus indirectly influencing dissolved oxygen. High nutrient levels can stimulate algal blooms that use a good deal of available oxygen for growth. Large inputs of organic material to a stream increases the amount of oxygen required in the decomposition process, which reduces the supply of dissolved oxygen (Satterlund and Adams 1992).

Bacterial Contamination

The primary form of bacterial contamination, especially with regard to livestock grazing, is fecal coliform. The concern over bacterial contamination relates mainly to potential disease transmission to humans (Buckhouse and Gifford 1976). Although fecal coliform is not a disease causing organism, it is considered an indicator of contamination by warm-blooded animals (U.S. Environmental Protection Agency 1976).

GENERAL PRINCIPLES

With increasing emphasis on riparian zones, and now on water quality as well, we think it would be wise for everyone involved in the range livestock industry to gain a basic understanding of watershed and riparian zone function. In this article we intend to focus on rangeland streams (creeks) in the western U.S.. There are many sources of information, but for a start we recommend obtaining the two publications put out by EPA and authored by Cheney, Elmore, and Platts (1990, 1993). The contacts for obtaining copies of the publications appear at the back of this article. The intent of the publications is to help livestock producers take the lead in solving potential water quality problems.

On western U.S. rangelands, riparian areas constitute only a small portion of the landscape. Elmore and Beschta (1987) indicate that the value is less than 0.5% for eastern Oregon rangelands, yet surface water from the entire watershed is concentrated into this small percentage of the land area. Water may reach the stream via surface runoff (overland flow) or through subsurface flow. The concentration of energy in the stream channel makes it imperative to maintain good cover of riparian plants. These species are well adapted to holding the stream/riparian complex together. Ironically, riparian management 30 to 40 years ago focused on removing woody vegetation to increase stream flows, and now we are planting willows (Svejcar *et al.* 1992).

Another past practice that negatively impacted riparian zones and water quality was the straightening of streams and rivers, or channelization. Many streams and rivers were straightened to increase the water velocity and thereby reduce flooding potential. Unfortunately, this activity also reduced the potential of these systems to maintain good water quality (Karr and Schlosser 1978, Faafeng and Roseth 1993). The streams are intentionally made shorter (by taking out meanders) which reduces the degree of water contact with channel and limits the amount of sediment deposition, thereby reducing the self-purification potential of a stream.

One problem we all encounter when trying to generalize about riparian zones is that they come in every shape and form, and no two are exactly alike. The minute we blurt out a generalization, someone thinks up an exception. The dynamic and variable nature of streams and riparian zones also makes research difficult, especially with respect to water quality. Streams vary tremendously in the various water quality factors even without human influences. Keep in mind that streamflow and runoff characteristics are a function of the entire watershed. Geology, soils, topography, vegetation, climate, and land use all interact to shape the nature of each stream. Branson *et al.* (1981) suggest that streamflow in western rivers originates mainly in the forested mountains, whereas sediment loads come from the lower elevation rangelands. This has implications for the structure of riparian zones. The higher elevation streams receive relatively low inputs of sediment because of a high degree of vegetation cover, and thus do not form wide riparian zones and have relatively limited soil development. Many of these streams are lined with boulders and are relatively stable. A lower elevation stream may receive a good deal of sediment over time and if the gradient isn't too steep, the sediment will eventually build deep, productive soils. The bad news is that because of the deep soils these areas may be prone to "downcutting", which results in an "incised channel". In Figure 1, we attempt to demonstrate the results of downcutting. In Figure 1A, the riparian vegetation provides stability for the streambanks, the streamchannel is not isolated from the floodplain during peak flows, and the riparian zone serves as a filter to sediment, and other pollutants that might otherwise enter the stream. Water temperature remains at an acceptable level because of shading, a low width/depth ratio, and subsurface flows of cool water from the floodplain. Vegetation is often dominated by willows, alders, sedges, and/or rushes. The situation in 1B is entirely different. During the process of downcutting the channel becomes much larger and thus has the capacity to carry more water. The increased capacity reduces the number of "overbank events", which means the stream no

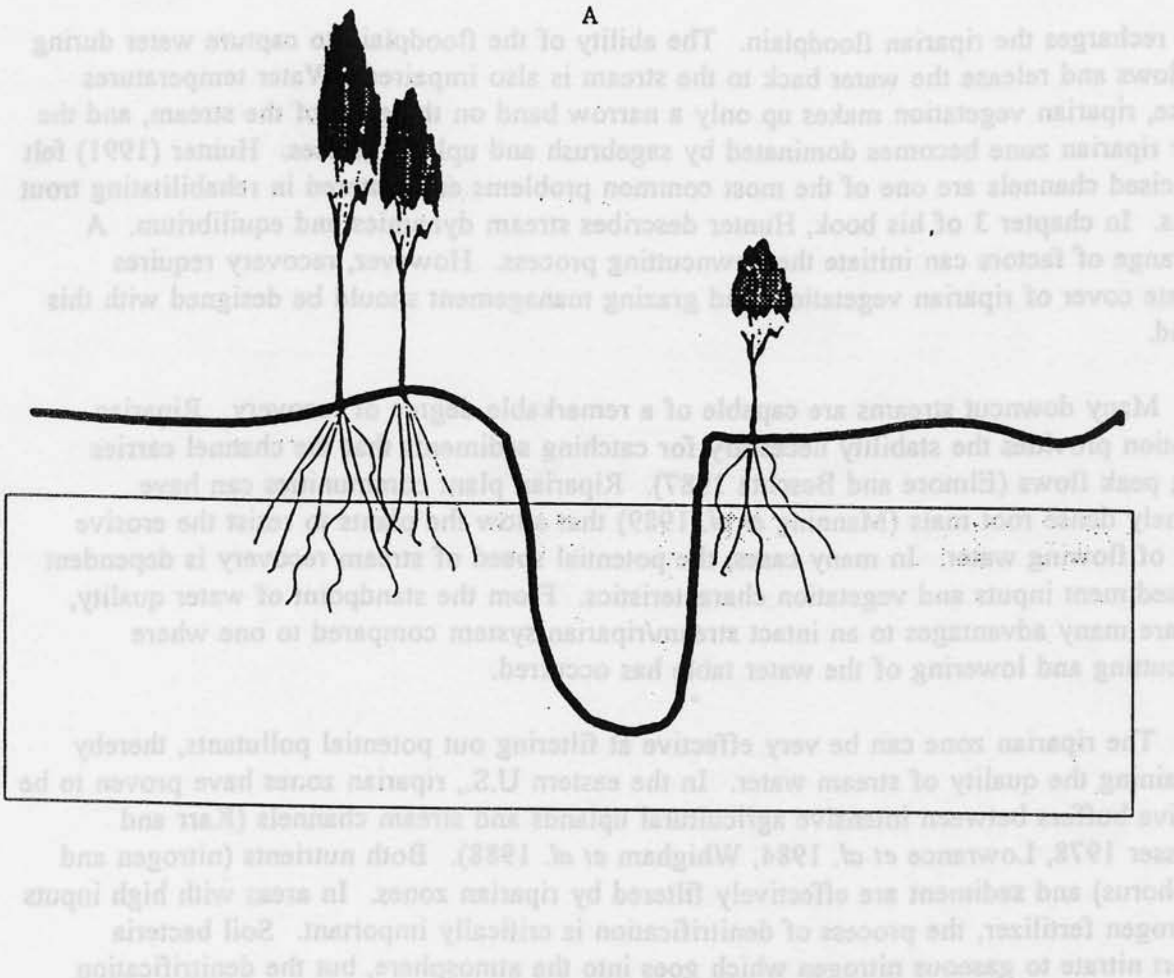

FIGURE 1. Idealized crossection of an intact stream (A), and a downcut stream (B). The shaded section is the water table.

longer recharges the riparian floodplain. The ability of the floodplain to capture water during peak flows and release the water back to the stream is also impaired. Water temperatures increase, riparian vegetation makes up only a narrow band on the edge of the stream, and the former riparian zone becomes dominated by sagebrush and upland grasses. Hunter (1991) felt that incised channels are one of the most common problems encountered in rehabilitating trout streams. In chapter 3 of his book, Hunter describes stream dynamics and equilibrium. A wide range of factors can initiate the downcutting process. However, recovery requires adequate cover of riparian vegetation, and grazing management should be designed with this in mind.

Many downcut streams are capable of a remarkable degree of recovery. Riparian vegetation provides the stability necessary for catching sediments that the channel carries during peak flows (Elmore and Beschta 1987). Riparian plant communities can have extremely dense root mats (Manning *et al.* 1989) that allow the plants to resist the erosive forces of flowing water. In many cases, the potential speed of stream recovery is dependent upon sediment inputs and vegetation characteristics. From the standpoint of water quality, there are many advantages to an intact stream/riparian system compared to one where downcutting and lowering of the water table has occurred.

The riparian zone can be very effective at filtering out potential pollutants, thereby maintaining the quality of stream water. In the eastern U.S., riparian zones have proven to be effective buffers between intensive agricultural uplands and stream channels (Karr and Schlosser 1978, Lowrance *et al.* 1984, Whigham *et al.* 1988). Both nutrients (nitrogen and phosphorus) and sediment are effectively filtered by riparian zones. In areas with high inputs of nitrogen fertilizer, the process of denitrification is critically important. Soil bacteria convert nitrate to gaseous nitrogen which goes into the atmosphere, but the denitrification process only occurs under saturated (anaerobic or without oxygen) conditions. So, if a stream has downcut and the water table declines, the denitrification potential of the site will also decline.

GRAZING AND WATER QUALITY

The assumption is often made that grazing impacts on water quality are limited to areas used by domestic livestock. However, impacts resulting from large ungulates are similar regardless of whether the animals are wild or domestic. Generally the differences between the two groups is a result of the timing, intensity, and duration of the grazing. We will address two rather different ways in which grazing can influence water quality: 1) directly, through deposition of urine and fecal material, and 2) indirectly, through alteration of upland and riparian habitats.

Direct Effects

Of the water quality factors listed in the previous section, nutrients and bacterial contamination are most likely to be influenced directly by the presence of livestock. Specifically, nitrogen from urine and/or feces, and fecal coliform from feces are the items of concern.

A number of studies have demonstrated that livestock grazing can influence fecal coliform in streams (Stephenson and Street 1978, Doran and Linn 1979, Tiedemann *et al.* 1987). The fecal coliform input to a stream may occur through direct defecation into the water, or transport of fecal coliform in surface runoff. Under some conditions, stream fecal coliform levels may remain elevated for months after livestock are removed from a watershed (Stephenson and Street 1978). The number of fecal coliform declines rapidly with distance from the feces. Buckhouse and Gifford (1976) found that only the fecal patch and surrounding meter radius were subject to fecal bacteria pollution. These authors suggest that unless feces are deposited in or adjacent to a streambed there is little danger of significant bacterial contamination. However, the potential for contamination will probably depend on the timing of grazing and runoff events in a particular watershed. In a Wyoming study Skinner *et al.* (1974) found a peak in fecal coliform counts in July and August. In Grant County, Oregon, Tiedemann *et al.* (1987) measured a nearly linear increase in fecal coliform from winter to summer in non-grazed and moderately grazed watersheds. In heavily grazed watersheds the values declined from winter to spring, and then increased into the summer. The authors suggest that higher winter fecal coliform levels in heavily-compared to moderately- or non-grazed treatments is the result of a carryover effect, and is related to the presence of fecal material in or near the stream channel.

The relationship between grazing strategy and fecal coliform has not been investigated in much detail. This type of research is difficult for many of the reasons mentioned previously Skinner *et al.* (1984) compared deferred-rotation and continuous grazing systems, and found fecal coliform concentrations tended to be higher under deferred-rotation. Tiedemann *et al.* (1987) studied 13 watersheds that included the following treatments: 1) no grazing, 2) moderate grazing, 3) moderate grazing with fencing and water developments to improve distribution, and 4) intensive grazing with fencing and water developments, but also cultural practices such as seeding, fertilizing and forest thinning to improve forage production. The actual stocking rates over the four years of this study were 0, 20.2, 17.7, and 6.9 acres per animal unit month, respectively. The results indicate that fecal coliform was higher with intensive grazing, intermediate with the two moderate grazing treatments, and lowest with no grazing. However, only a few samples from the intensive grazing treatment ever exceeded the 200 colonies per 100 milliliter of streamwater count for fecal coliform that is generally used as a threshold water quality level. The authors of this study concluded that "levels of fecal coliform in streamflow appear to be more closely related to watershed characteristics that determine where livestock are likely to concentrate than to stocking rates". Thus, the take-home message is to know where the cattle spend their time and do everything possible to keep them out of the stream.

The potential direct effect of grazing on nitrogen levels in streamwater appear to be minimal, but are directly proportional to livestock concentration. The primary nitrogen enrichment problems tend to be associated with swine, dairy, and feedlot operations, where many animals are concentrated in a small area. These operations really are more point-source in nature, and are dealt with differently than extensive grazinglands. In an Ohio study, Owens *et al.* (1983) found that surface runoff of a wooded watershed contained higher levels of nitrate-nitrogen than did surface runoff from an adjacent grazed pasture. And in Nebraska, Schepers and Francis (1982), compared runoff water during grazing and non-grazing periods, and found that total nitrogen in the runoff was actually less during the grazing period.

The one practice common to the Intermountain region that could produce direct nitrogen enrichment would be winter feeding. Dixon *et al.* (1983) studied the effects of winter feeding on water quality in southwestern Idaho. They concluded that loss of nitrogen and other chemical constituents through irrigation return flow from land used for wintering cattle was relatively low. In this study the cattle were wintered from early January to mid-March or early-April at a stocking rate of 4 head per acre, and cattle were fenced out of the stream. The authors calculated an annual loss of 0.12 to 4.0 kg/ha of nitrogen over the course of the study, compared to 100 to 1600 kg/ha in a typical beef cattle feedlot. Even on intensively managed flood-irrigation pastures, livestock did not have much effect on nutrient levels in return flows (Miller *et al.* 1984).

Indirect Effects of Grazing

With the possible exception of fecal coliform, the influence of grazing on water quality parameters is more likely to be indirect. By that we mean the livestock may alter the vegetation or stream structure, which in turn influences water quality. Cheney *et al.* (1990 and 1993) have done a good job of illustrating with pictures the influence of improper grazing management on riparian zones.

The factor influenced by habitat changes in many areas of the western U.S. is stream temperature. There are several potential ways that habitat changes can influence stream temperature: 1) reducing streamside vegetation, especially woody vegetation, decreases the shading and can greatly increase stream temperature (Karr and Schlosser 1978); 2) breaking down of stream banks can result in a wider, shallower stream; and 3) downcutting can effectively reduce water storage in the riparian zone/floodplain, which lowers summer flows (Elmore and Beschta 1987) and thus increases temperatures. Thus, the key to either maintaining or achieving cool streamflow lies in the vegetation and physical structure of the stream/riparian zone complex.

The condition of upland vegetation can influence one of the water quality factors-sediment yield. In fact, some of the earliest reports of watershed conditions on western U.S. rangeland dealt with the relationship between overgrazing and sedimentation. Reynolds (1911) described the excessive erosion and frequency of floods that resulted from the heavy grazing that occurred in the late 1800's and early 1900's. The author presented pictures of uplands with no vegetative cover and deep gullys, and sediment choked streams below. It was conditions such as these that provided much of the impetus for the Taylor Grazing Act of 1934. During the early days of range management the emphasis was on upland vegetation and the improvement in plant cover greatly reduced the degree of erosion. If upland grazing is heavy it can increase sediment transport to the stream (Branson *et al.* 1981), but moderate grazing generally has a minimal effect on sediment losses (Johnson *et al.* 1978, Blackburn *et al.* 1990). The key is to maintain a good cover of vegetation. We suspect that under most moderately grazed situations grazing will not have much effect on sediment transport from uplands to the stream. Sediment movement from upland habitats varies over time and location, and is generally controlled by the combination of soil, landform, vegetation, and climatic events.

The more likely effect of grazing on sedimentation is again through alteration of the riparian zone. We pointed out earlier in this discussion that riparian zones can act as filters and accumulate upland sediments that might otherwise end up in the stream. But under many circumstances a more likely source of sediments is the streambank and streamchannel. Neff (1982) found that the water quality of surface runoff from southeastern Montana rangeland was good to excellent. He concluded that downstream sediment yield resulted from bank and channel erosion. So again, the best defense against water quality problems with sediment is to keep our riparian zones in good condition.

Many of our small wildland streams in the western U.S. have very low levels of both nitrogen and phosphorus (Quigley *et al.* 1989). In the thirteen watersheds studied by these researchers, average nitrate-nitrogen and orthophosphate levels were always less than .02 and .06 parts per million respectively, regardless of grazing level. The information we will present from a study in the Sierra Nevada also indicates nitrate and phosphate levels in a montane stream are very low. Nutrient levels will vary, and may be more of a problem on lower elevation streams. But, in general, unless fertilized pastures or hay ground are involved we would not expect grazing to increase nitrogen or phosphorus levels to the point that water quality is compromised.

There is not much information on the influence of grazing on dissolved oxygen. But we can make some inferences from the effects grazing can have on riparian vegetation and channel structure. The factors that influence temperature (reduced woody vegetation, increased width/depth ratio, and altered streamflows) will also influence dissolved oxygen. Keep in mind the inverse relationship between temperature and dissolved oxygen, as water temperature goes up the capacity to hold oxygen goes down (Karr and Schlosser 1978).

Thus, it appears that maintaining riparian zones in good condition will help a great deal in producing high quality water, and providing habitat for the ever increasing list of endangered fish species. In their review of salmonid/logging interactions, Hicks *et al.* (1991) drew similar conclusions (see page 518 for an excellent discussion of this topic). They further suggest that research should be conducted by teams of individuals that represent the various resources. Such efforts are also needed for dealing with grazing/riparian/water quality issues.

Grizzly Creek Study

We conducted a 4-year (1990-1993) study to evaluate the effects of grazing on soil solution chemistry. The study was conducted on Grizzly Creek in Plumas County, California. The study site is about 60 miles northwest of Reno, Nevada. Four 1.5 acre paddocks (2 grazed at moderate levels and 2 ungrazed) were used for the study. Each paddock extended 300 ft. from the forest edge, across a section of meadow, and included a section of Grizzly Creek. At the forest edge, mid-meadow, and streambank locations we buried sampling lysimeters. At the streambank location the lysimeters were buried at 4 and 24 inches, and they were buried at 4, 24, and 48 inches for the other 2 locations. The lysimeters allowed us to extract soil solution, and we used a Dionex ion chromatograph to analyze the solution for a range of elements. Samples were collected 2 or 3 times a month during April, May, and June of the four years. Saturated soils are required in order to obtain samples, and during the drought years 1990-1992, most of the lysimeters were dry by the end of June. We also analyzed stream water for comparative purposes.

The data presentation will be limited to nitrate. Levels of ammonium and phosphate were so low that they approached the lower detection limit of the available laboratory procedures. Table 1 contains a summary of yearly nitrate levels.

Table 1. Nitrate levels (in parts per million) for grazed and nongrazed treatments during 1990-1993.

YEAR	GRAZED	NONGRAZED	STREAM
1990	2.163	0.564	0.028
1991	0.581	0.474	0.030
1992	0.688	0.351	0.003
1993	0.094	0.188	0.002

During the drought years the grazed treatment had slightly higher nitrate levels, but in 1993 the pattern reversed. Also note the decline in nitrate levels during the above-average precipitation year of 1993. But regardless of year, stream nitrate levels were always extremely low. For comparative purposes, EPA recommends a maximum of 10 ppm in drinking water.

There was a gradient of nitrate levels from the forest edge to the stream. Table 2 illustrates the gradient, with highest nitrate levels at the forest edge and lowest levels in the stream.

Table 2. Nitrate levels (in parts per million) at different locations in the grazed and nongrazed treatments, averaged over year.

LOCATION	GRAZED	NONGRAZED
Forest Edge	0.765	0.742
Mid-Meadow	0.401	0.296
Streambank	0.113	0.093

These results suggest that the montane meadow may well be functioning as a "filter" or sink for nitrogen. The nitrogen may either be denitrified and lost to the atmosphere, or bound up in plant tissue or other organic matter. But the very low levels indicate that nitrogen inputs to the stream are unlikely.

CONCLUSION

Managing for water quality on rangelands illustrates the concept of "ecosystem management". This is one instance where a number of factors are clearly tied together. Riparian vegetation and the structure of the stream are critical in dealing with potential water quality problems. A healthy riparian zone will normally produce cool, clear water that is low in nutrient levels and high in dissolved oxygen; it will also produce the habitat necessary for a number of endangered fish species and several soon-to-be endangered bird species. But the point to remember is that these riparian zones are also key areas for forage production, and good management can increase livestock production in the long run. The carrying capacity must not be viewed as the number of animals a piece of land will support over the entire growing season. Rather, grazing must be tailored to meet the specific needs of the area in question. There are a number of references that compare different grazing systems for compatibility with riparian vegetation. We recommend looking at the publications by Platts (1991), Kovalchik and Elmore (1992) and two by Cheney *et al.* (1990 and 1993). County extension agents and local USDA - Soil Conservation Service personnel are good contacts for help in finding more information or with the design of management options. Agriculture can lead the way in dealing with water quality and endangered species issues, or we can wait and see what happens. The former option seems much more appealing.

MISCELLANEOUS

Addresses for obtaining copies of the EPA publications, "Livestock Grazing on Western Riparian Areas", and "Managing Change: Livestock Grazing on Western Riparian Areas".

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