



# **Livestock Management in Grazed Watersheds**

*A Review of Practices that  
Protect Water Quality*

Technical Coordinator  
Melvin R. George

UCD Animal Agriculture Research Center • UC Agricultural Issues Center

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*November 1996*

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## *Preface*

Conflict over land management arises not only from different world views but because each of us have observed different cases, and we tend to cite the case that supports our position. In truth, there are many locations across the Western landscape where livestock have had an adverse impact on riparian areas and associated streams. Many of these sites have changed irreversibly—their current potential is different than it once was, and they cannot be returned to their past condition. Equally evident are the many cases of healthy ecosystems with good grazing management.

Thus, there are many streams and riparian areas that can support grazing with proper management; but there certainly are situations where even the lowest level of grazing will adversely affect the stream, its riparian zone and even its watershed. We can only strive (1) to understand the stability and productive potential of rangeland ecosystems and their associated riparian areas and streams, and (2) to apply that knowledge in developing effective grazing strategies that meet management goals.

In 1993, the U.S. Environmental Protection Agency funded a research project to evaluate the effectiveness of livestock and range management practices for reducing livestock impacts in grazed watersheds. The authors of this report are conducting that project, in California, Oregon and Nevada. EPA's purpose was to determine if there are effective management strategies or practices that lie between the extremes of continuous grazing and grazing exclusion. While EPA is interested in evaluating such practices in the field, the project investigators felt that the research and case study literature also should be reviewed.

This report reviews the literature that compares management practices—both replicated and unreplicated comparisons. Many of the practices that are used to manage livestock have been learned by trial and error, or evaluated only by common sense; others have been the subject of extensive research or case studies. All have been found to work somewhere, and most also have failed to meet management objectives in specific situations.

Dr. Bill Krueger's opening chapter describes the considerations in developing an effective grazing management strategy. Then Dr. Sherman Swanson discusses some of the factors that determine a stream's need for management and its response to management. Dr. Melvin George and Dr. John Buckhouse review research and case study experiences with various grazing management practices. Dr. Royce Larsen discusses the risk of pathogen contamination of water bodies in grazed watersheds, and practices that are commonly applied to reduce the risk of contamination. In closing, Krueger discusses coordinated resource management as a process to define and accomplish ecosystem management objectives.



## ***Executive Summary***

### **Developing an Effective Grazing Strategy for Riparian Vegetation (Krueger)**

Livestock or big game can co-exist with or they can damage riparian systems. These responses are highly site-specific; no template for a grazing strategy can guarantee success. Over the long run in an ecosystem, interacting factors rather than simple relationships will control change. Thus, evaluations of riparian zone potential should take into account (1) interacting factors, (2) the desired vegetation complex, and (3) how ungulates can fit into the system.

Potentially successful grazing programs must consider the nuances of specific watersheds, in specific settings, during specific weather patterns, with specific livestock or big game herds, and involving specific people. They should be based on clearly thought-out objectives and potential of the site. Strategies should involve:

**Animal behavior.** Understanding the behavioral tendencies of large ungulates can help us learn to direct their actions. For example, early in the grazing season cattle disperse more easily and there may be less need for specific management practices to avoid excessive grazing in the riparian zone. In reseeded areas, different grass varieties can be attractive to free-ranging animals or not, depending on the season and maturity of the plant. Effects of climate, drought in particular, may change behavior and call for adjustments in dates of grazing. Cows and calves behave differently than yearlings; animals familiar with the area behave differently than newcomers.

Riparian vegetation also can be enhanced by maintaining the feed supply, and by making the uplands more attractive to livestock. Because palatability has a substantial influence on grazing behavior, making use of the relative palatability of different plant species throughout the season is an important management strategy.

**Plant responses.** Timing of grazing in relation to the growing point of the plant is a crucial consideration. If grasses are grazed while the growing point remains close to the ground, there is little impact on seasonality of growth; but if the point becomes elevated and is then removed, the plant must activate new buds and begin its annual growth cycle later in the season. Forbs and shrubs react similarly, and because of their exposed buds are more vulnerable to loss of vigor. For them, the purpose of grazing management is primarily to defer maturity.

Because of its diversity and extreme yearly variation, riparian vegetation is difficult to manage precisely. However, strategies can be designed to favor or reduce woody vegetation, depending on objectives. Intensity of use is far less important than season of use, within reasonable limits of intensity.

**Hydrology.** Water and hydrologic forces associated with it are the guiding forces for vegetation production and, to some degree, animal behavior in riparian zones. These forces have a major influence on seasonality of vegetation development as well as quantity and quality of riparian forages. Wet, anaerobic soils also support specially adapted vegetation which may serve to remove nitrogen and other pollutants.

**Practicality.** The essence is to focus on what will work. Any management strategy has to be accomplished within the financial and skill limitations of ranchers or wildlife managers. A grazing strategy that takes excessive time is just as impractical as one that takes excessive money. Consideration of risk is a major factor. In many cases, grazing requirements on public land force specific grazing practices on private land. Changes may be needed in both areas.

### **Reading a Stream's Need for Management (Swanson)**

Managing livestock grazing in accordance with riparian values often produces conflict. To create mutually beneficial solutions, riparian and range managers need to understand at least some of the complex interactions that affect streams and riparian habitats. It is necessary to (1) monitor past and current grazing management, (2) assess riparian systems to read the stream's need for management and (3) use this knowledge to understand stream potentials, set management objectives and select, implement and monitor management plans.

Differences among streams can be important. Some streams or some parts of streams depend more than others on vegetation and react faster to changes in livestock grazing management. The size, type and amount of riparian vegetation changes the flow rate of both water and sediment. Vegetation also helps form fish habitat. Where riparian attention focuses on water quality and fish habitat, managers emphasize the vegetation or woody debris needed to form and maintain channel features.

Channel shape affects stream velocity and other characteristics such as base and peak flow, erosion, deposition of sediment and water quality. Different streambed types depend differently on riparian vegetation for channel form and function. Furthermore, streamside areas form the core of the watershed's groundwater recharge area. This has focused attention throughout the West on the value of properly functioning watersheds.

Vegetation is the most useful tool for maintaining or restoring watersheds, streams and riparian areas. But which streams depend on stable banks, or on vegetation to stabilize banks? Which plants best form what kinds of stream banks? How does grazing affect different riparian plants? How do livestock management and time of grazing affect use patterns, forage preferences, plant effects, or the severity of bank trampling? Collectively, managers have learned much about these questions, but few of the many useful ideas have been tested in controlled research.

**Streams and land form.** Many scientists have studied watersheds, but few have focused on vegetation's influence on stream shape. However, this knowledge is the foundation for understanding the role of vegetation in land or resource management. Commonly, vegetation is the most manageable of the land-forming factors. Most watershed and stream damage is caused, at least in part, by changing or



removing vegetation. This and other human disturbances such as roads, dams and gravel mining, often have replaced the role of natural catastrophes such as earthquakes and landslides by changing the base level of streams. This steepens the stream and increases erosion, sedimentation and channel changes.

Such a change represents the crossing of a geomorphic threshold. Afterward, a stream or watershed will be out of balance; it will look much different. Many streams have the potential for such changes—for example, a stream that has cut down into its bed so that its flood plain is rarely flooded. Such flood plains no longer absorb floodwater or stream energy. They also lose historic riparian vegetation. Preventing such downcutting should become or remain the top priority for most riparian managers.

Where downcutting has occurred, managers must work with the current potential by considering entrenchment, flood stress, erosion, deposition and riparian vegetation. (Entrenched streams rapidly increase depth, velocity and shear stress as flow increases; entrenchment hinders the ability of a stream to spread out during a flood.) Meanwhile, vegetation slows water by increasing roughness (friction) in a flood channel. Changing vegetation or the debris from vegetation often is the best way to efficiently manage stream hydraulics.

Many streams are in dynamic equilibrium, balancing sediment supply and erodibility with available energy. However, many of these streams cycle over time. Their net erosion and net deposition phases start by crossing a geomorphic threshold. This cycle was occurring well before Europeans came to North America, but management actions and/or climate events recently have pushed many streams through a geomorphic threshold into the net erosion phase.

**Riparian vegetation.** Willows or other woody riparian plants are useful on steep and entrenched streams where high shear stress requires a tough vegetative fabric. Many range managers have focused on methods for increasing willow growth. Meanwhile, grasses, sedges, rushes and other grasslike plants that depend on, or at least tolerate, saturated soils provide the binding necessary for many meadow streams.

However, as meadow streams become trampled and wider, the sites suitable for willows often increase. After downcutting, increased water velocity increases the role of strong, deep woody roots. With decreased stability from water-loving grasslike plants comes increased dependence on roughness elements such as woody roots and logs.

Managers of land with downcut streams probably should focus on stopping headcuts, and catching sediment downstream. Managers of streams that might downcut should focus on vegetation before these reaches become too altered to heal.

**Livestock and management.** Some streams resist most livestock influence, while others unravel quickly at relatively light livestock use. To estimate what management can accomplish, use classification, inventories, comparisons among similar streams managed differently, and on-the-ground experience, including photographic evidence.

Because many streams and plant communities are constantly changing, it is necessary to compare to potential future conditions—not the present or the past. For example, preventing downcutting by not crossing a geomorphic threshold may pay tremendous dividends even though the future appears much like the present.

Vegetation management has become the core of riparian, as well as upland,

watershed management, but managers also must consider (1) direct livestock effects to soils from compaction, surface disturbance and trailing and to stream morphology from trampling and (2) watershed-wide effects of riparian disturbances.

There are many unanswered questions, but it is often not possible to delay management decisions. Monitoring and learning from past experience will provide some guidance to better management in the future.

Complex biophysical systems require cooperation from researchers in many fields; the tendency to use narrowly-focused studies in setting broad standards seems inappropriate. Only interdisciplinary research will identify and answer questions most relevant to riparian and watershed ecosystem management.

### **Management Practices to Change Livestock Behavior in Grazed Watersheds (George)**

Livestock and wildlife are attracted to riparian areas because of the availability of water, shade, higher quality forage, easier terrain, and favorable microclimate. Most of the management practices used to attract livestock away from riparian zones and other heavily used areas have been learned by trial and error. Consequently, success of these techniques is inconsistent, often unexplained and may not be transferable to other sites.

Grazing management strategies used in riparian zone protection, rehabilitation and maintenance include (1) exclusion of livestock, (2) alternative grazing strategies, (3) changes in kind and class of animals, (4) managing riparian zones as special use pastures and (5) several livestock distribution practices.

**Attraction.** If existing grazing practices have only small or moderate adverse impacts on riparian/stream values, small to moderate reductions in livestock use may be adequate—thus avoiding the costs associated with intensive grazing systems. Practices designed to attract cattle away from the riparian area are used to do this.

Providing shade, drinking water, salt or supplemental feed away from the stream can reduce the time spent by livestock in riparian areas. Reseeding with palatable grasses or thinning timber stands also may reduce pressure on streamside zones.

Stock water development is a major tool for improving distribution of livestock. Behavior of cattle in watering and using the riparian area has been intensively studied.

Individual animals may be "riparian huggers" or "ridge climbers." Males are more destructive than females; yearlings may be more willing to forage widely; older cattle may lead the way to favored grazing areas. Breaking herd behavior may require culling of individuals.

Cattle avoid sites where access is difficult, especially if suitable forage is available elsewhere. Thus, sensitive streambank sites can be protected by using barriers such as rock fields or boulders, shrub thickets (especially willow), dense timber stands and fallen trees.

**More intensive practices.** If attracting cattle away from heavy use areas is insufficient, herding or fence construction must be considered. Herding is labor intensive, but improved handling methods may reduce stress and costs. Fencing

may be used to segregate riparian pastures, facilitate grazing systems, and for exclusion. Management considerations are pasture size, proportion of upland versus riparian forage, and location of streams and other water sources.

Numerous researchers have shown that riparian habitats in fenced enclosures or otherwise protected from intensive grazing have dramatically improved, compared to similar unfenced areas. Although the evidence appears overwhelming, these studies should be accepted with caution because the two treatments often were not truly comparable. Other researchers have pointed out the advantages of creating a riparian pasture instead of enclosure fencing.

Electronic (fenceless) control of livestock in riparian and other critical areas shows some promise for the future.

**Standards and guides.** To reduce impacts of grazing in riparian and associated areas, standards and guides for stubble height and for trampling and chiseling have been used by public land managers. While the recommended stubble height (at least 4" to 6") has wide application in the intermountain region, it often exceeds the productivity of meadow sites in the Sierra Nevada. Standards and guides for trampling and chiseling have been developed and applied by the U.S. Forest Service. While both research and common sense indicate that livestock do impact riparian areas, there is little published research linking various levels of trampling and chiseling to actual loss of riparian ecosystem health or impaired water quality.

**Management choices.** In selecting practices to re-distribute grazing pressure in a watershed, these questions must be considered:

- What is the topography of the allotment or pasture?
- Does the riparian area contain the only flat or gently sloping land?
- Is water available away from the riparian area?
- Can water be developed far enough from the riparian area to reduce trailing in between?
- If we reduce livestock use of the riparian area, will management objectives be met—or are there other barriers?
- Can livestock distribution practices provide sufficient "cow habitat" in the form of water, forage, shade, gentle slopes and other amenities to attract cattle away from the riparian zone?
- Are there animals in the herd that are "riparian huggers" or that lead the herd back to sensitive areas?
- Are there times when riparian grazing is not harmful, or is beneficial?
- Are there public policy rules and regulations that prevent timely response to management opportunities and hazards?
- Are the practices economically feasible?

Managing grazed watersheds is a tricky business because we must take biological uncertainty into account. This unpredictability suggests the need to learn from experience because data are sparse and theory is limited—in other words, the use of "adaptive management."

### **Controlling Season, Intensity and Frequency of Grazing (Buckhouse)**

Since the early decades of this century, various improved grazing systems have evolved, all designed to control intensity and/or timing of grazing. These im-

proved systems can have dramatic effects on range use and productivity. Some can maintain or improve riparian systems, in contrast to year-round or season-long grazing which typically result in destruction or degradation of riparian communities under normal grazing intensity due to concentration of livestock in these areas.

While season-long grazing is commonly the source of riparian problems, exclusion of livestock—by stream corridor fencing, for example—is often impractical. Thus, it is necessary to assess the effectiveness of practices that control season, intensity and frequency of grazing. These include seasonal grazing, riparian pastures and various grazing systems that incorporate rest.

**Seasonal grazing.** The objective is to avoid periods when vegetation and the stream bank are most vulnerable to damage. Differences in stream bank and adjacent upland vegetation, size of grazing areas, kind and age of livestock, stocking rates, palatability of forage and management objectives must be considered.

In spring, cattle often avoid riparian zones because of cold temperatures, wet soil and immature forage. As a result, permitting livestock to use riparian areas early in the season when adjacent upland forage is lush often results in less use of streamside forage and a decrease in damage to streamside vegetation. Since this precludes late-summer use, browsing of willows is light and response of riparian vegetation is good. However, meadow plants are most susceptible to damage early in the season.

In late season (after mid-August) grazing, despite increased pressure on willows and other streamside shrubs, various trials have shown potential benefits. These include less mechanical damage on drier soils and improved infiltration. Where winters are cold but snowfall is light, winter grazing may be appropriate with few detrimental effects on the riparian zone.

**Rest-rotation grazing.** This system—which rotates seasons of use and one-year rest periods among three, four or more pastures—has been widely used in the Intermountain West with mixed success. Although opinions vary as to which variations best protect riparian communities, research reports and case studies suggest that rest-rotation grazing often provides such protection. The problem of not allowing rest-rotation systems to go through several cycles before being analyzed confounds the interpretation and application of some research results. In reality, any grazing strategy that incorporates control over proper stocking rates, rest, season of use, and frequency of use would probably provide a high degree of protection to the range resource, including riparian areas.

**Riparian systems.** This concept, in which riparian areas are managed independently, has potential advantages of better control over animal distribution, grazing intensity and timing, as well as increased vegetative production. Benefits have been identified from separate, fenced riparian pastures that are grazed late in the season when riparian vegetation has finished growing and has stored adequate energy for regrowth.

Compared to season-long grazing, appropriate use of grazing systems can improve plant community vigor. Rotation or deferred-rotation grazing promotes herbaceous growth, and in some instances woody vegetation. Late-season grazing, before the fall rains, also generally promotes herbaceous vegetation, but may not be appropriate for promotion of streamwide woody plants. Dormant-season and early-growing season grazing may promote both shrubs and herbaceous vegetation, but there are potential problems such as lowered nutritional value.



## Survival and Transport of Fecal Pathogens in Grazed Watersheds (Larsen)

When cattle concentrate near streams, they can adversely impact water quality. Many factors may influence concentration of indicator bacteria in rangeland streams, including fecal output by livestock and cattle, proximity of fecal distribution to stream channels, survival of indicator bacteria in rangeland watersheds, and the attenuating effects of vegetation on pathogen concentrations in surface runoff. Wildlife also can contribute to pathogen concentrations in streams.

Tests for total coliform (TC), fecal coliform (FC) and fecal streptococci (FS) are the primary indicators of potential presence of pathogens in water. These tests were originally designed to detect human contamination of drinking water supplies, and may not be directly applicable to wildland streams with possible ruminant fecal contamination. Also, it has been recognized that fecal contamination originating from ruminants carries a reduced risk of disease transmission to human beings as compared to the same coliform concentrations that originate from other human beings.

**Fecal transport in grazed watersheds.** Comparisons of indicator bacteria concentrations in streams from grazed and ungrazed pastures, or before and after grazing, have had mixed results. Some comparisons have found significant differences that can be attributed to grazing livestock, while others have not. Thus, there seems to be much variation in pathogen indicators and nutrients in wildland streams, making interpretation difficult. Although buffer strips and vegetative filters have been studied, the relationship of source distance to transport from free grazing areas is not well understood. However, some general trends can be identified. Peak fecal coliform concentrations are related to runoff events. As grazing intensity increases, bacterial indicators increase and nutrients remain about the same in wildland streams with free-grazing livestock.

**Fecal output and distribution.** Free ranging cattle will defecate an average of 12 times per day. Non-uniform distribution in a pasture can result in 0.4%–2% of the area being covered by fecal deposits; less on open range. However, feces concentrations can be much higher in certain areas—water troughs, gates, fence lines, bedding areas.

**Survival of indicator bacteria.** Indicator bacteria in fecal material may remain viable for at least one growing season, depending on the type of organism, moisture, sunlight and other factors. There is potential for bacterial contamination long after cattle have been removed from a site, but it is greatly reduced with age. There is some question as to whether pathogens, especially protozoal parasites such as *Cryptosporidium* and *Giardia*, will have survival patterns similar to those of indicator organisms.

**Direct fecal deposition into a water body.** Because fecal coverage in uplands is usually very low and overland runoff is infrequent in most of the West, the primary mode of fecal contamination of rangeland streams may be direct fecal deposit. There seems to be much variation in indicator organisms in stream bottom sediments as well as in the overlying waters. However, there could be high concentrations of coliforms in stream bottom sediments, especially if livestock are nearby. Coliforms in bottom sediments clearly survive longer than in the stream itself and daily inputs can accumulate over time. Peak flows, cattle trampling, etc., can resuspend these contaminants.

**Management considerations.** Potential pathogen pollution problems associated with livestock grazing are primarily from cattle concentrating in or very near streams. Rangeland improvement practices that attract livestock away from riparian zones—for example, water troughs located away from the stream—have a positive effect on water quality. Buffer strips may ultimately prove effective in preventing fecal contamination from reaching streams via overland flow. However, buffer strip standards developed in high rainfall zones may not be appropriate for arid and semi-arid rangelands.

### **Grazing and Ecosystem Management (Krueger)**

Grazing management of livestock and of big game are important components of ecosystem management. In designing an ecosystem management strategy, the first step is to determine a vision of success. What will the landscape look like? How will water quality, yield, nutrient cycling and other aspects of sustainability be affected? How will people benefit? Will management produce healthy businesses, quality recreation, aesthetic pleasure, desirable fish and wildlife populations, etc.?

Coordinated Resource Management (CRM) has been proved effective in setting, implementing and monitoring for livestock and wildlife habitat objectives. The process is readily adaptable to many land management practices. The Land Issues Forum in central Oregon has developed a coordinated resource management planning protocol which meets all of the legal mandates of public and private agencies, as well as resource needs of commodity and amenity users.

The keys to successful management are (1) develop the vision, (2) design management according to the vision and (3) emphasize communication and mutual understanding. Involvement of the people is key, since people will support what they create themselves.

## ***Developing an Effective Grazing Strategy for Riparian Vegetation***

*Bill Krueger<sup>1</sup>*

A review of over a thousand riparian-focused publications yielded 90 that were related to management of ungulates with emphasis on riparian vegetation. This literature, specifically relating large ungulates to riparian vegetation, is largely based on documented case histories or observation and comment. Some have data, and about a third are largely observational. Less than 5% are experimentally based, i.e. replicated and statistically valid avoiding pseudo replication. The experimentally-based papers, though well replicated and statistically valid, usually lack pre-treatment data and cover short time frames—less than four years. They are mostly specific and deal with fine detail. They do not always come to the same conclusions. For example, Schultz and Leininger (1990) reported density of willows was not affected by grass competition, while Billig (1992) found that grass significantly impacted density of willows.

The case history literature is heavily oriented to the relations of cattle to riparian vegetation. The results are highly varied and difficult to synthesize for generalizations. This difficulty in interpretation results from the following problems: (1) The specific grazing influence is often described as grazed versus ungrazed or is described so vaguely it is difficult to get a clear idea of the grazing practices being reported. (2) Frequently the report is based on an enclosure set up for a different purpose than evaluating the impact of grazing on riparian vegetation. There is a tendency in the literature to report on enclosures that were installed to protect a stream reach from abusive grazing practices. These yield benefits to riparian systems but only explain the obvious, that riparian zones are resilient and usually recover rapidly when an abusive practice ends. (3) Finally, the historical land use practices are almost never explained. Historical use can have a great bearing on status and potential of riparian zones. Even though riparian zones are resilient and recover rapidly, there can be long-term impacts from engineering practices, vegetation control, and other practices. Understanding the history is as important to understanding current conditions as is understanding current ungulate grazing practices.

Even with the conflicting results associated with this varied literature base, a few broad generalizations are reasonable. It is clear that livestock or big game can and do co-exist within sustainable riparian systems. Likewise, ungulates can and do change riparian vegetation structure in undesirable ways. Vegetation responses are highly site specific. Consequently, every grazing strategy will not work somewhere. There is no formula or template that can be used to guarantee success. Ecosystems

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are highly variable in time and space. In addition, most driving forces that change ecosystems seem to result from interactions of factors. A grazing strategy needs to be based on the expectation that interactions will direct change. Obvious and simple relationships can be relatively unimportant in directing long-term changes. A careful evaluation of the riparian zone potential, in the context of natural variability, can be a foundation for developing a practical grazing prescription that will work. This evaluation should include: (1) The forces (interacting factors) that will direct change; (2) what the desired vegetation complex should be; and (3) how ungulates can fit into the system.

### **Developing a Grazing Strategy**

Based on the understanding that riparian zones and their associated uplands are varied and that inherent site specificity is a key in riparian zone response, it is reasonable to conclude that any static grazing system will have limited utility. Rather, a grazing prescription based on site potential and clear objectives is necessary. By understanding the nuances of specific watersheds, in specific settings, during specific weather patterns, with specific livestock or big game herds, and involving specific people, a program with a high degree of potential for success can be developed. The nature of this program will be a form of adaptive management that is frequently described as an effective concept to achieve ecosystem management on public lands.

A grazing strategy should consciously incorporate:

- Animal behavior
- Forage palatability
- Plant responses
- Plant community change
- Hydrology
- Practicality

Each of these factors will be discussed in the context of vegetation management and grazing. Beyond the specifics of vegetation responses, an effective grazing strategy should also be placed in the context of an ecosystem and the totality of ecosystem response. This will include the relations of one animal to another, stream hydrology and geomorphology, water quality, landscape interactions (scale in time and space), and others. An ecosystem management strategy should include ecosystem structure, function, and social needs. An ungulate grazing strategy needs to include all of these aspects, as well. This chapter is, by design, focused on vegetation response and is incomplete as a guide to develop an ecosystem focused grazing plan.

### **Animal Behavior**

In dealing with animal behavior, we need to recognize that it is difficult to force an animal to perform contrary to natural preferences and instincts. A knowledge of the behavioral tendencies of large ungulates can help us learn to direct their actions. We can design grazing programs that attract animals to specific areas at specific times to encourage grazing patterns that yield a desirable response of the vegetation. For example, we know that there are distinct seasonal differences in the way livestock will graze riparian zones. Early in the grazing season cattle disperse



more easily than later in the season. Consequently, early turnout will reduce the need to protect some riparian zones from cattle, since the cattle will not be attracted to the riparian zone. Conversely, if the pasture needs to be grazed during the season when the riparian zone is attractive, then specific management practices may be necessary to avoid excessive cattle use in the riparian zone. A simple matter such as turn-on date can bring about major positive or negative responses of the vegetation.

Many riparian areas of concern are in forested areas. As these areas are logged they are often seeded to control erosion. A wide variety of grass species is used, and all of them have some ability to control erosion. At the same time, most plant species differ in their palatability or attractiveness to cattle. For example, intermediate wheatgrass is palatable early in the season, but in the pine zone it becomes unpalatable by early summer, often as early as mid-June. The orchardgrasses are also used for erosion seedings, and their palatability remains high through much of the summer. Seeding with a particular plant species can attract or repel free-ranging animals depending on the season and maturity of the plant. This creates opportunities to use practices like erosion control seedings to manipulate animal behavior. A similar scenario could be drawn for using fertilizer to make areas more attractive and concentrate cattle or big game use, perhaps reducing use of other areas.

Every year is different, and the results of weather patterns are manifested in the vegetation. A drought can cause the growing season to be earlier and shorter. This, in turn, means animals will change their grazing patterns to reflect the drought. Riparian zones may be most attractive much earlier in the grazing season, and the dates of grazing may need adjustment. Beyond the indirect effect of drought on grazing behavior, there may well be other considerations of the effect of the drought on functioning of the riparian zone. Will these changes affect the ability of the riparian zone to support cattle or big game grazing? Some degree of flexibility in specific practices is necessary to accommodate yearly weather differences.

The kind and background of animals is a consideration in anticipating behavior. Cows with calves are usually less mobile than yearlings and consequently set up different grazing patterns in a pasture. The experience of the cattle has a major influence on how they graze a given area. Cows set up home ranges much like big game and can be expected to stay in particular areas. Inexperienced cattle will have much less predictable behavior in a pasture when compared to cattle that traditionally use an area. The level of stress also contributes to animal behavior. It is often said that if you have good grass you do not need good fences. Keeping animals on sufficient quantity and quality of feed minimizes management difficulties.

Finally, we need to remember that in large forested or diverse pastures, animals naturally use only a small part of the pasture. Focusing management practices to encourage use of a larger area reduces the impacts of grazing in areas of preference. A major enhancement of riparian zone vegetation may be achieved by making the uplands more attractive to the grazing animal.

### **Forage Palatability**

Forage palatability has a substantial influence on grazing behavior, as just reviewed. Palatability is a dynamic plant characteristic that changes throughout the annual plant growth cycle. Consequently, a knowledge of the relative palatability of

plant species of concern is needed to develop management strategies that yield the desired result. There are generalizations that fit many situations, e.g., in riparian areas cattle do not browse woody plants if they have a sufficient supply of palatable grass. There are exceptions to most generalizations and refinements that necessitate knowledge of the specific situation being managed. Once specific grazing results are defined, it is usually possible to utilize knowledge of palatability to achieve the desired result from grazing.

### **Plant Responses**

The most easily managed aspect of grazing is achieving the desired plant response after the animal behavior and palatability aspects are understood. The most important consideration is to time the grazing in relation to the growing point of the plant. The growing point is the area of active meristematic tissue that differentiates each plant part. When a plant is grazed without removing the growing point, growth continues, and there is little impact on seasonality of growth; the plant keeps growing and matures at about the same time as an ungrazed plant. In grasses the growing point is close to the ground before the individual stems start to elongate to eventually support the seed head (Figure 1). If the growing point of a grass stem is elevated during elongation of the stem and is removed, the plant must activate a new bud and begin growth over for the year. This can defer growth for two or three weeks which results in a different growth form with different palatability. For forbs and shrubs the growing point is usually elevated, and so they respond to grazing or browsing more like grasses that have elevated the growing point (Figure 2).

Timing of grazing with respect to elevation of the growing point provides an effective tool to manage the annual growth cycle of grasses. Management of plant responses of grazed forbs and shrubs is primarily done to defer maturity, since a grazed or browsed forb or shrub will respond by activating a new bud and beginning the annual cycle later in the season. This will result in a leveling of nutrient supply over the season for animals that can utilize regrowth of the vegetation, since the regrowth from activated buds will be younger and more nutritious than that from ungrazed forages.

In riparian zones the soil moisture is more abundant than on uplands so regrowth is usually limited only by temperature or other environmental factors. The opportunity to graze in a variety of seasons and intensities is multifaceted, and opportunities to fine tune results of grazing are limited only by degree of control of grazing animals.

Because forbs and shrubs usually have their growing point available to be grazed, it is much easier to reduce the vigor of these plants with grazing than for grasses. When the relation of grazing to the position of the growing point of the plants is considered, the ability to manage plant responses is enhanced.

### **Changes in Plant Communities**

Riparian plant communities can change rapidly during the growing season. The rich soils and good moisture supply result in abundant and varied growth of different plant species. This, coupled with strong year effects due to residual biomass and annual weather patterns, creates an exceptionally diverse assemblage of

vegetation. Because of this complexity and highly varied year differences, it will be difficult to direct or even understand plant community changes on a fine scale. However, it is realistic to graze livestock in ways that favor woody vegetation or that reduce woody vegetation, depending on objectives. Management strategies can be designed to favor plants with inaccessible growing points over those with exposed growing points. The key is to develop a grazing strategy with emphasis on season of use to influence plant communities in desirable ways.

Intensity of use or stocking intensity is far less important than season of use, within reasonable limits of intensity. However, even a relatively light intensity of use can have profound effects on growth of shrubs if the growing point is removed, so that the objectives for shrub growth cannot be met. This can be corrected by changing season of use for livestock. Big game animals create a very difficult problem when they retard the shrub component of riparian plant communities even with relatively low stocking densities.

### **Hydrology**

Water and the hydrological forces associated with water are the driving forces for vegetation production and to some degree animal behavior in riparian zones. Water can affect vegetation directly by promoting and extending growth. When the soil profile fills with water, the oxygen is displaced. These anaerobic soils support specially adapted vegetation and perform chemical processes much like a water treatment plant. This function of water purification is often touted as a critical function of riparian systems, but there is little quantification of its ecological importance. To some degree the anaerobic nature of soils is a function of water supply, and to some degree it is probably a function of management. Grazing semi-wet meadows can dry the system by reducing mulch layers and promoting growth of grasses over sedges and rushes. When this occurs, the ability of the soil to remove nitrogen and other pollutants is lessened. This is worth consideration in developing riparian grazing strategies, although the total ecosystem impact of this kind of change needs clarification.

Hydrology has a major influence on seasonality of vegetation development as well as quantity and quality of riparian forages. This is expressed in large year effects that may require significant changes in grazing strategies to achieve ecosystem objectives. As channels move and hydrological forces change, the relation to management will likewise change. Meadows that become marshy require less attention than drier wet meadows since cows avoid very wet areas when possible.

### **Practicality**

Poverty is the worst enemy of conservation. Poor people usually severely damage the resources before they go broke. Consequently, in the final analysis any management strategy has to be accomplished within the financial and skill limitations of ranchers, who ultimately have to make the grazing programs work, or wildlife managers as they work with big game herds. Ranchers must show a profit, or they cannot conduct a grazing program. Wildlife managers are limited in their ability to control big game numbers and seasons of use of any particular area.

In grazing livestock, from a business sense, the rancher is essentially trading time for money. A grazing strategy that takes excessive time is just as impractical as one that takes excessive money to properly implement. A major factor is a consideration of risk. The lower the risk, the more likely it is that a rancher will be able to successfully implement a program.

The essence of practicality is to focus on what will work. That is, fence only where fencing is needed to accomplish an objective; ride to move cows when they will go where you want them to go; and graze pastures when the cows will influence vegetation change according to clear objectives. Consider the relationship of public and private land. In many cases the requirements of grazing public land force specific grazing practices on private land. It does not make much sense to force damage to a private riparian zone in order to protect a public riparian zone. There may well need to be changes in both areas. Grazing to enhance Kentucky bluegrass will optimize livestock yield (Korpela, 1992). Yet, biodiversity goals may require a different complex of vegetation. Can we develop a grazing strategy for the typical blend of public and private land that works for everyone's needs? Or, will we rigidly manage public lands for a species mix that will force reasonable private landowners to manage for Kentucky bluegrass pastures in private riparian zones?

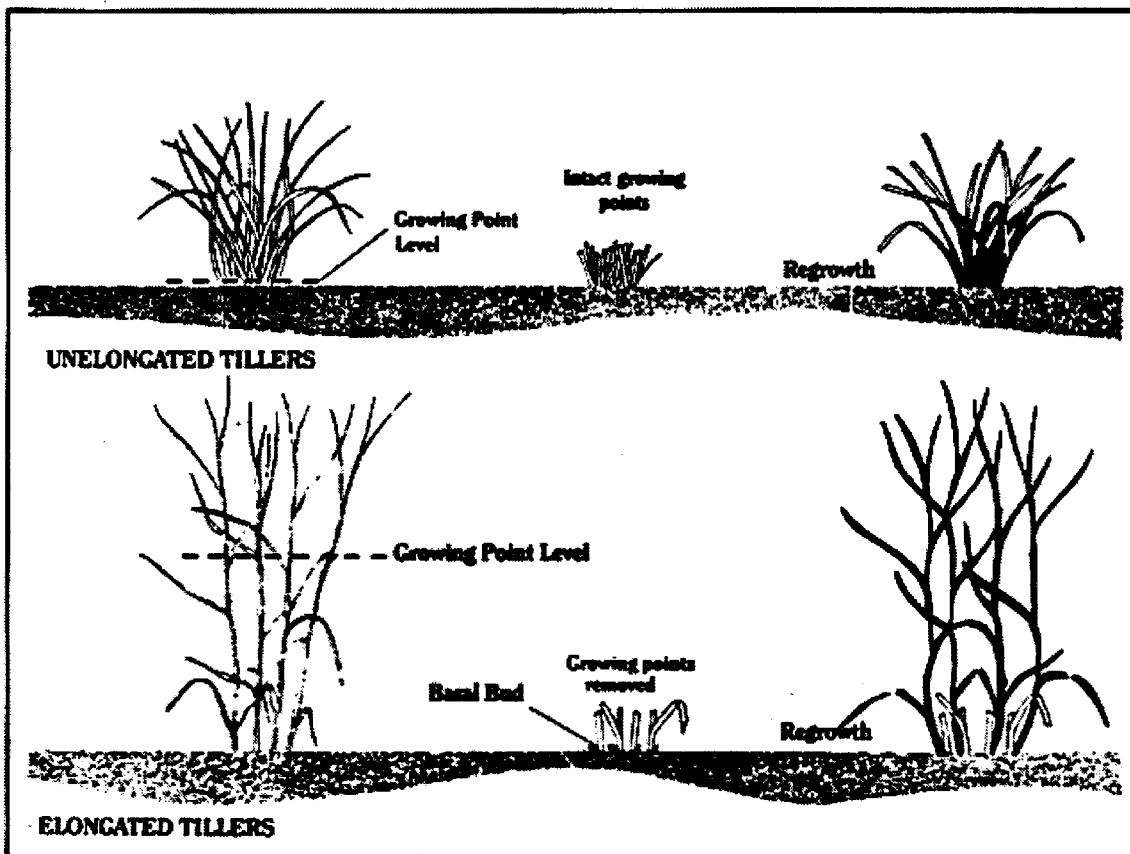


Figure 1. Regrowth of grass from intact growing points compared to regrowth from basal buds. (From: Waller et al. 1985, p. 12).

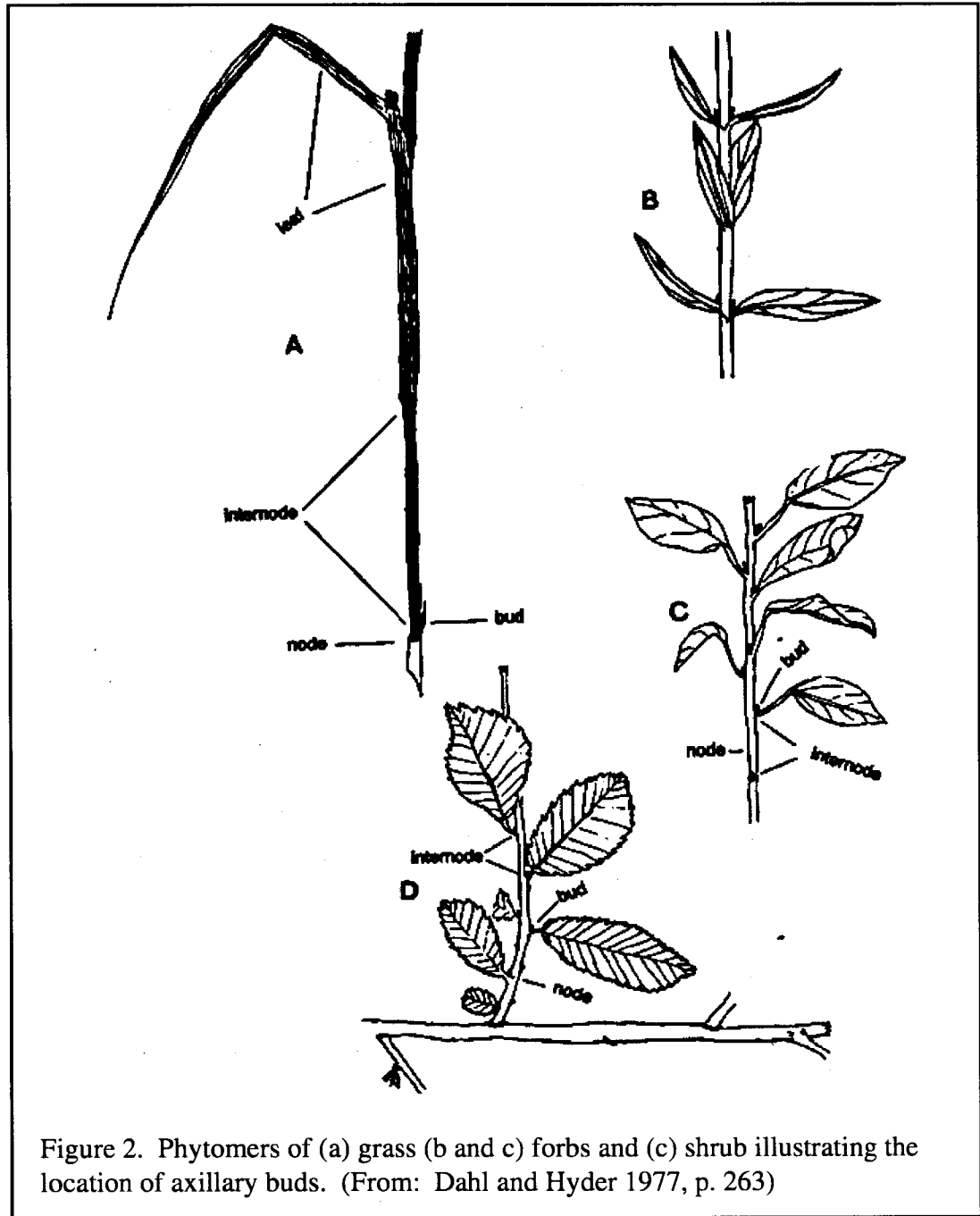


Figure 2. Phytomers of (a) grass (b and c) forbs and (c) shrub illustrating the location of axillary buds. (From: Dahl and Hyder 1977, p. 263)



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## ***Reading a Stream's Need for Management***

*Sherman Swanson<sup>2</sup>*

To evaluate the effectiveness of livestock grazing and range management practices, one quickly focuses on key areas. Key areas are important because management has changed them. Furthermore, future management will likely influence their characteristics and impact values important to people. Range managers now recognize that riparian areas very often fit this description. They have learned that these riparian systems provide special habitats for fish and wildlife and play a critical role in watershed function. As a critically important part of the watershed they help capture, store, and safely release water for a long list of uses (Skovlin, 1984; Braun, 1987; Kauffman and Krueger, 1984; Swanson, 1988; Platts, 1991; Chaney et al., 1990; and Bedell et al., 1991). Riparian functions have become the focus of watershed management and many rangeland grazing management decisions.

Livestock grazing management for riparian values often produces conflict. People do not like paying high costs for someone else's simple solutions. Yet, the effect of livestock on stream functions was long ignored because stream management is complex. In the face of complexity and conflict, some would choose to avoid the issue by continuing past management even where it has led to obvious problems. Others suggest avoidance of stream disturbance by stopping rangeland grazing or by fencing all streams and riparian systems. They would ask others to pay any financial cost to fix an environmental problem. Neither approach seems practical nor realistic for a very large number of the streams currently or historically grazed.

To create mutually beneficial solutions, rangeland, riparian, and livestock managers need to understand at least some of the complex interactions that affect streams and riparian habitats. Therefore, most grazing managers must monitor past or current grazing management to learn its effects (MacDonald et al., 1991; Bedell and Buckhouse, 1994; and Bauer, 1993). They must also assess riparian areas to learn where and how the system could respond to different livestock management or vegetation. They must read a stream's need for management. Using this knowledge

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to understand potentials; to set management objectives; and to select, implement, and monitor management plans remains the heart of enlightened riparian grazing management.

For themselves and their grandchildren's grandchildren, people want many things from land and streams (clean water, diverse and productive plant and animal communities, and sustainable economies). People who earn their living from the land learn to read it. They soon realize that wet places deserve special attention, especially in drier climates. Differences among streams that at first seem interesting, later become important. One learns that different places may shelter certain birds; provide good fishing; grow certain trees, shrubs, or other plants; attract cows; break down from trampling; or generate controversy. One also learns that different streams or places along streams keep steadily flowing, dry up in a dry year, flood, wash out, build stream banks, or form pools. Underchanges in livestock grazing management causes people to invest their time, energy, and good care on the most useful practices in the places where it will do more good.

Riparian areas provide habitat for many more wildlife species than surrounding lands, especially where the contrast between wet riparian areas and the aridity of nearby deserts is greatest (Lowe, 1989; Johnson and Haight, 1985; and Johnson and Lowe, 1985). Terrestrial species either use both the riparian and upland habitats, or they depend on the riparian vegetation. Thus, much of the riparian attention, especially in the desert Southwest, has focused on the value of riparian habitats to wildlife. To maintain or restore such habitats, managers focus on plant succession or important species or groups such as aspen or willows, and they focus on the water needed to support important plant communities (Johnson et al., 1989).

The shape of the stream and the size, type, and amount of riparian vegetation change the flow rate of both water and sediment. Vegetation can make a channel rougher so that friction slows stream velocity and reduces downstream floodpeaks. Plant roots knit soil or stream banks into a fabric with variable and at times amazing strength (Smith, 1976). The shape of a channel and floodplain is determined by what happens at the boundary with the water (Beschta and Platts, 1986). Vegetation helps form many stream features (such as pools) needed for fish habitat (Hickin, 1984; Platts, 1991). Therefore, much of the riparian attention, especially in the Pacific Northwest where salmon migrate to and from the ocean, focuses on water quality and fish habitat. To maintain or restore water quality and fish habitat, managers focus on the vegetation or woody debris needed to form and maintain channel features.

Channel shape affects average stream velocity and the speed of water next to the bank or bottom. It therefore affects base flow and peak flow, erosion, sediment deposition, size of channel materials, water quality, water table elevation, and water available to riparian vegetation (Leopold et al., 1964; Richards, 1982; Knighton, 1984; and Gordon et al., 1992). Different bed-form channel types (for example, step-pool, plane-bed, and pool-riffle) (Montgomery and Buffington, 1993) and stream types (Rosgen, 1994) depend differently on riparian vegetation for channel form and function.

Furthermore, stream-side areas often form the core of the watershed's ground-water recharge area (Dunne and Leopold, 1978). This has focused much riparian attention throughout the West on the value of properly functioning watersheds (Bedell



et al., 1991; DeBano and Schmidt, 1989; and Washington Forest Practices Board, 1994). To maintain or restore watersheds, streams, or riparian areas, vegetation is the most useful tool for land managers (Elmore and Beschta, 1989).

If vegetation management provides most of the tools for riparian management, learning to use plants to improve streams becomes important. Several questions arise: Which streams depend on stable banks for slowing water or for creating pools needed by fish? Which streams depend on vegetation for bank stability or bank building, and how much? Which plants best form or knit what kind of stream banks? How does grazing affect different plants? How do livestock management and the timing of grazing affect use patterns, forage preferences, plant effects, or the severity of bank trampling?

Collectively, managers have learned much about each of these questions. However, few of the many useful ideas have been tested in controlled research. Furthermore, most research leaves open many questions about applications in a varied landscape. This chapter describes a few of the ideas that seem to be important for riparian grazing management.

### **Streams and Land Form**

Some people study land forms created by water flowing over different rock types and the influence of climate. Many authors (Leopold et al., 1964; Richards, 1982; Knighton, 1984; Gordon et al., 1992; and Ritter et al., 1995) have described the physical factors and relationships that determine how, and how well, watersheds capture, store, and release water. They also describe the structure and form of stream and river channels.

Not many earth scientists have chosen to focus on vegetation's influence on stream shape. For notable exceptions see Hickin (1984) and Schumm (1977). However, it is this foundation that enables one to develop an understanding of the role of vegetation in land or resource management. Perhaps this is because of the long time period needed for most land-shaping processes (Schumm and Lichty, 1965). Over geologic history and without human disturbance, vegetation effects may become so interwoven with climatic effects that climate study seems sufficient. However, people who study the specific mechanisms of land shaping processes cannot ignore vegetation and its management. Vegetation is the most commonly manageable of the land-forming factors. Vegetation change or removal caused at least part of most watershed disturbances and stream damage.

Other recent human disturbances, for example, roads, bridges, diversion structures, dams, gravel mining, and urbanized watersheds, often replace the role of natural catastrophes such as earthquakes and landslides by changing base level for streams (DeBano and Schmidt 1989). Lowering stream elevation steepens the stream and usually increases upstream erosion. Lowered base level often incises low-gradient streams, forming a gully that may cut headward for a long distance. Where a stream incises at the mouths of tributaries, they also cut headward. The combined increase in sediment from upstream may overload downstream reaches, causing a number of channel changes. Excess sediment fills pools, at least during low flows, and may form bars. As the channel capacity decreases, stress on banks increases, especially on those across from bars. Bars may accelerate bank erosion, further increasing

downstream sediment. If the channel becomes over wide because of bank erosion or channel filling, it may become braided with many unstable channels (Rosgen, 1994). This is the "complex response" (Schumm, 1973) of a stream system with differences through space and time caused by the upstream or downstream influence of previous effects. Often streams straighten, steepen, and accelerate to erode and cut downward. This alters the form and roughness of meander bends, pools, riffles, or log steps.

Schumm (1973) discusses intrinsic and extrinsic causes for crossing geomorphic thresholds. After crossing such a threshold, a stream or watershed will be out of balance. In the future it will look much different. Understanding this should become part of the working knowledge for riparian managers. Many streams have a future potential substantially different (at least for the short-term) from past potentials. Perhaps the most obvious examples involve streams that have cut down into their beds so they cannot flood a floodplain nearly so often. Such floodplains no longer absorb floodwater or stream energy. They also lose historic riparian vegetation (Kovalchik, 1987). Preventing such downcutting should become or remain the top priority for most riparian managers (Van Havern and Jackson, 1986; Swanson, 1989a; Prichard et al., 1993). Streams disturbed enough to possibly straighten and downcut, should be labeled "functional at risk" to show that proper management is a high priority (Prichard et al., 1993).

Where downcutting has occurred, managers must work with the current potential by considering entrenchment, flood stress, erosion, deposition, and riparian vegetation. Entrenchment reduces the ability of a stream to flood a floodplain or otherwise spread out instead of deepening during a flood. It dramatically influences stream channel changes during floods. Erosion and sediment deposition, the fundamental processes altering channel form, depend on water and sediment flow as well as channel form. Entrenched streams rapidly increase depth, velocity, and shear stress as flow increases (Rosgen, 1994). Channel erosion depends on whether actual shear stress is greater than the shear stress needed to detach and move channel materials. Deposition occurs when the upward movement (from turbulence) of entrained particles becomes less than their settling velocity. Stream slope and channel roughness influence flow velocity and therefore shear stress.

Vegetation slows water by increasing friction or roughness in a stream or flood channel (Li and Shen, 1973; Rosgen, 1994; Cowan, 1956; Ree, 1949; Ree and Palmer, 1949; Petryk and Bosmajian, 1975; Parsons, 1965; Dawson, 1978; and Gurnell and Midgley, 1994). Often, changing vegetation or the debris from vegetation is the best opportunity to efficiently manage stream hydraulics. However the shear stress added by entrenchment and steepening may decrease the opportunity for vegetation to establish or cause floods to remove established vegetation (Swanson, 1989a). Incision results in loss of floodplain access and vegetation contact, therefore decreasing the roughness effect of riparian vegetation. Before downcutting, streams may be quite stable or may slowly gain deposited sediments. Following stream disturbance, accumulated stored sediment often provides an easily erodible sediment supply (Schumm and Hadley, 1957). For nonclay soil, the finer the soil, the greater its erodibility (Hjulstrom, 1939).

Following downcutting, erosion of gully walls or terrace edges creates room for either a wider channel with shallower flows or a wider floodplain. Generally,

widening the bottom of an entrenched stream decreases shear stress on the stream bed. However, in a stream without a floodplain, sediment deposited during low flows often erodes quickly during high flows. If vegetation grows on and stabilizes deposited sediment, it may change the gully bottom into a "grassed waterway" (Ree, 1949) that catches more sediment with each flow (e.g., Camp Creek [Elmore and Beschta, 1987]). When vegetation grows only where the water is not the deepest, the gully bottom may change into a two-stage channel with a vegetated flood channel or floodplain and an unvegetated stream channel (Schumm and Kahn, 1972; Graf, 1978; and Swanson, 1989b).

The two-stage channel uses the relatively greater velocity in the narrower and deeper active channel to route more fine sediment down stream. Bigger channel materials tend to become left behind (Rosgen, 1994). The floodplain of the two-stage channel absorbs some flood energy and sediment as a shallow layer of water spreads over the widened and vegetated (roughened) surface (Elmore and Beschta, 1987). As a gully widens and the active channel narrows and deepens, the vegetated floodplain grows, and the less shear stress will increase from base to flood flow.

Streams differ in their sediment supply and their ability to transport sediment. A flow of magnitude that moves bed materials may come several times each year or only a few times per century (Grant et al., 1990). Streams also differ in sediment supply. Some streams use their abundant energy (for example, because they are entrenched and steep) to route most sediment quickly through the system. The narrow or "V-notch" valley bottom of some streams identifies them as generally eroding over the long-term. Some of these are erosion-resistant (sediment-limited, often rocky), and some are highly erodible and produce abundant sediment. They have enough power to transport all the sediments that flow to them. Other streams typically deposit sediments because of their limited energy (Schumm, 1977). The more sediment that reaches them, the faster the sediment builds up. Even though fine soil often forms upper stream banks and surface floodplain deposits, most suspended sediment gets transported by most streams. Except to the degree that vegetation slows velocity and causes fine-grained sediment deposition for bank building, it is coarse grained bedload sediment that forms stream channels. Many streams have come into a dynamic equilibrium, balancing sediment supply and erodibility with available energy. For them and other streams that either erode or deposit through time, the quantity of sediment moving through them and only temporarily staying in or near them, greatly exceeds net loss or gain. When the supply of finer bedload sediments increases, the stream may continue to transport them after normal sediment transport and pool formation has ceased. These fine bedload sediments then lodge in pools (the  $V^*$  of Lisle and Hilton, 1992). Pool water velocity is higher during channel forming flows but then decreases rapidly as flow decreases to become lower than nonpools (Keller, 1971).

However, many dynamic-equilibrium streams cycle (Schumm and Hadley, 1957). Their net erosion and net deposition phases start by crossing a geomorphic threshold. This cycle was occurring well before Europeans came to North America. Old gully outlines show in the walls of modern gullies. However, management actions and/or climate events recently pushed many streams through a geomorphic threshold into the net erosion phase. Evidence for this comes in part from the relative narrowness of many gullies and from the high erosion rates experienced by

high erosion prone gully banks (Zonge, 1993). Although the continuing debate over the cause of stream downcutting or arroyo formation points to either climate change or land management, there may be no reason to exclude a combined effect (Bull, 1991). Differences among streams in their vulnerability to crossing a geomorphic threshold creates part of the confusion regarding stream responses to land management.

### **Riparian Vegetation**

Although riparian areas have been defined in many ways by different agencies and organizations, most definitions focus on the association between a stream or other water body and riparian vegetation that depends on or at least tolerates saturated soil. The extent and type of riparian vegetation varies mostly because of differences in surface and ground water availability. However, topography, elevation, climate, soil texture, salinity and fertility, also cause differences in the amount and timing of saturation. Many of these characteristics depend on the nature and condition of the watershed, especially its delivery of water and sediment. While almost all riparian vegetation is valued for the multiple functions it provides (Prichard et al., 1993), values differ widely. Furthermore, it is not possible to define riparian areas so as to include all those acres worthy of any special management and exclude all others (Swanson, 1988).

Many riparian advocates push for increased willow (*Salix* sp.) cover or canopy volume (Myers, 1987). Many range managers have focused on methods for increasing willow growth (Kovalchik and Elmore, 1992). However, not all stream systems or riparian community types produce willow (Winward and Padgett, 1989; Manning and Padgett, 1992; Hanson et al., 1991; and Kovalchik 1987). The unique characteristics of willows may help or hinder in particular settings. In addition, Burton et al. (1992) discuss differences among willows in terms of root depth, noting that taller willows often root deeper than shorter species. Rosgen (1993) notes that deep-rooted willows provide especially needed stability to high stream banks.

Willows, or other woody riparian plants, may provide the greatest function on steep and entrenched streams where high shear stress requires a tough vegetative fabric. Their woody and fibrous roots may work especially well for binding together coarse gravel, cobbles, or boulders. Logs or masses of woody roots provide the steps or the flow deflectors that help form many pools in the moderate-gradient streams studied by Myers and Swanson (1994); and in the similar streams studied by Heede (1985).

Grasses, sedges, rushes, and other grass-like plants provide the soil binding necessary for many meadow streams (Zimmerman et al., 1967). Some plant communities produce incredible root masses. Nebraska sedge (*Carex nebraskensis* Halizize) communities studied by Manning et al. (1989) and Kleinfelder et al. (1992) had surface-soil root-length densities averaging greater than two meters of roots per cubic centimeter. That is more than a mile of roots in a four-inch cube, and some samples exceeded that by four times. Kleinfelder et al. (1992), confirmed that root-length density made sod stronger. Swanson and Kamyab (1996) and Dunaway et al. (1994) found that simulated stream flow caused less soil erosion with more root mass, length or volume. However, variable soil characteristics also significantly

influenced erosion results.

Streams may depend on different vegetation before and after downcutting. Ironically, many streams that currently suffer from a lack of willows, or for which willow production is a key management objective, may not have provided habitat for willows until human-caused disturbance created suitable niches. Many willows depend on soil aeration and do well in sandy or gravelly substrate. Meadow streams with a high water table provide little of this habitat. Their wide floodplain and narrow channel creates little difference in shear stress between floods and base flows. Hence they transported sediment rather than forming temporary bars. Furthermore, grasslike plants, especially those living in wetter meadows (Manning et al., 1989) and anaerobic soils (Di et al., 1991), protect these streams very adequately (Kamyab, 1991). Meanders tend to swing across and sweep down a valley, forming a rather level floodplain behind them. However, the high sinuosity and low width/depth ratio of some such streams suggests great stability and only rarely will these meanders become cut off unless they are unduly disturbed.

However, as these streams become trampled and wider, they develop sites for gravel deposition. If they widen and downcut, the sites suitable for willows often increase. After downcutting, the increased water velocity increases the role for strong deep woody roots. With decreased stability from healthy water-loving grasslike plants comes increased dependence on roughness elements such as woody roots and logs to form pools suitable for fish cover and to absorb energy. There may be a lot of coincidence between the stream's needs for vegetation and the site requirements of riparian plants. Presumably erosion and deposition near streams have helped create the soil and water characteristics of riparian sites. Over longtime spans, these site characteristics guided riparian species evolution. As riparian vegetation helps to form the stream and control water flow, the saturated soil environment also guides species evolution. The above example is but one of many in which riparian vegetation and the hydrologic setting are mutually interdependent through short and long time spans.

However, there are limits to this concept. Some phases of a gully evolution cycle clearly do not sustain vegetation suitable for erosion resistance. Stream banks that become high drained gully walls change vegetation from well-rooted water loving plants to species with few roots that are adapted to dry soil, especially in a desert. Such high banks erode in a variety of ways, at rates far greater than could be considered stable. This was confirmed even during a drought by Zonge (1993) using the moveable frame technique described by Zonge and Swanson (1994). Much of this gully-bank erosion appears independent of present management. Managers of land with downcut "nonfunctional" (Prichard et al., 1993) streams should probably focus on stopping the headcut and catching sediment downstream, rather than worry about on-site wall erosion of narrow gullies. Managers of streams that could downcut should focus on vegetation and healing before these reaches become too altered to heal.

### **Livestock and Management**

Vegetation and stream bank disturbances dramatically affect some streams, changing many aspects of water flow, channel shape, and fish habitat (Myers and

Swanson, 1991). Other streams depend far less on vegetation (Myers and Swanson, 1992). Some stream reaches resist most livestock influences, whereas others unravel quickly at relatively light livestock use. Unfortunately, the desire of some riparian grazing managers for simple standards concerning utilization or trampling will be hampered by a lack of data about most of this range of variation. For example, Abt et al. (1993) found evidence that shorter stubble height may help induce sediment deposition for bank building, but that longer stubble height may help protect banks from erosion. Their study was conducted in a flume with Kentucky bluegrass, *Poa pratensis*, and results may vary by stream setting and by vegetation species or type. The tendency for focused studies to set broad standards (Clary and Webster, 1989) seems inappropriate.

To estimate what management can accomplish, use stream and other riparian classifications (Swanson et al., 1988), inventories (Leonard et al., 1992), comparisons among similar streams managed differently, and on-the-ground experience in a similar area. Photographic evidence of change in response to management is efficient and extremely useful (Elmore and Beschta, 1987; U.S. GAO, 1988; Masters, 1994; and Sipple, 1995). What can be accomplished also depends on what people accept and strive for. There is much about riparian management that people now accept. We have knowledge built on research and monitoring that recorded good and bad effects from many different kinds of management actions. We also have a lot to learn.

Riparian work provides more satisfaction than most other rangeland work because streams and riparian vegetation respond quickly. This makes improvements obvious. However, the most rapid response comes early for many stream systems. As responses become slower with continued management or with management of streams that are slower to respond, measurement of success or failure will become more difficult. Focusing objectives on stream reaches where measurements could change most dramatically decreases the need for costly high-precision monitoring.

Good management objectives must be achievable, measurable, and worthy of the management expense necessary to achieve them and monitor their attainment. The above discussion of streams, land form, and riparian vegetation provides some ideas. It does not provide standard riparian management objectives.

Managers should always invest each dollar where it creates the best response. To figure out economic viability, one must compare among future conditions caused by differing management actions. This is because many streams or plant communities are changing. For systems that are changing, comparing the present with the future or the past will mislead evaluations of the effect of management. For example, preventing degradation by not crossing a geomorphic threshold (downcutting) may pay tremendous dividends even though the future appears much like the present. Whereas, attempting to fix a downcut stream costs a great deal (except on very small streams) and generates limited benefits if the stream is not yet ready to heal (Swanson, 1989a or b).

Vegetation management remains the core of upland watershed management and has become the core of riparian watershed management. However, grazing land managers must also consider direct livestock effects to soils from compaction, surface disturbance (Gifford and Hawkins, 1978), and trailing. Livestock directly affect stream morphology by trampling stream banks (Trimble and Mendel, 1995; Marlow et al., 1983). For many streams, bank trampling and channel widening con-

stitute the most important effect of livestock (Platts, 1991). In addition, grazing land managers must consider effects over the entire watershed even if the disturbances, and the effect of disturbances, become concentrated in or near the riparian zone. Once streams downcut, upstream reaches may be too steep to be stable.

To set riparian objectives, ask what impacts could be reduced and what changes could happen, or happen faster, with more or different vegetation. Ask how the vegetation will change the stream and how the stream or new watertable will change the vegetation. Start by spending time in the field identifying those parts of the watershed(s) where current management causes important solvable problems. Also identify where future management could fix problems from past management.

Our understanding of stream and riparian systems and how they respond to land management leaves many unanswered questions. However, it is often not possible to delay management decisions while waiting for answers. Managers practice an art based on partial science. Progress in management requires learning from past management. Monitoring how well applied management meets objectives, or at least causes an upward trend, in areas where change is expected provides some of the understanding needed for better management in the future.

Progress in science similarly depends on asking the right questions. Complex biophysical systems require cooperation from researchers in many fields. Although we will never manage land based solely on research results, we must focus research on important land management questions. Only interdisciplinary knowledge, skills, and abilities will likely succeed in identifying and answering some of the questions relevant to riparian and watershed ecosystem management.



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## ***Management Practices To Change Livestock Behavior In Grazed Watersheds***

*Melvin George<sup>3</sup>*

The practices that are used to attract livestock away from heavy use areas or to exclude them from these areas are as old as "salt away from water" and "take half, leave half." Most of the practices that we use to attract livestock away from riparian zones and other heavily used areas have been learned by common sense, trial and error, and experience; not by experiments adhering to scientific method.

Consequently, the success and predictability of livestock distribution management practices are inconsistent, often unexplained, and may not be transferable to other watersheds, ecosystems, or landscapes. Before we can predict the outcome of livestock management practices in grazed watersheds, we must come to understand how livestock interact with watersheds, ecosystems, and landscapes.

Why do livestock congregate in the wet soil areas next to streams, lakes, estuaries, and wetlands known as riparian areas? What management practices are required to alter this behavior? Do these practices work? These are the questions that will be addressed in this section.

### **Why do Cattle Congregate in Riparian Areas?**

Livestock and wildlife are attracted to riparian areas because of the availability of water, shade, higher quality forage, suitable terrain, and favorable microclimate. In California's foothill and valley areas it is commonly believed that cattle seek refuge from heel flies by standing in water (Wagnon 1963). Cattle prefer areas in which palatable plants make up large proportions of vegetative composition (Cook, 1966; Miller and Krueger, 1976). Reid and Pickford (1946) postulated that preference for riparian zones was due to high herbage production, dominated by grasses and grass-like plants, and that riparian communities maintain green palatable herbage for longer period than adjacent upland communities. Gillen et al. (1985), in a study of the use of riparian meadows in the Blue Mountains of eastern Oregon, found that cattle continued to use riparian meadows even as herbage levels decreased to the physical limits of grazing.

During the summer, cattle spend a disproportionate amount of time in ripar-

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ian zones as compared to upland areas (Roath and Krueger 1982). Bryant (1982) postulated that conditions of temperature and relative humidity in the late season produced less comfortable environments in canyon bottom riparian zones and more comfortable environments on the up-slopes; but found that when temperatures are high, cattle will seek the cooler microclimate of the riparian area.

As slope increases, frequency of livestock use decreases (Bryant, 1982; Mueggler, 1965). Cattle normally graze heavily on valley bottoms and more level land near water before moving to rougher terrain (Cook, 1966). Percent slope and distance of slope from water accounts for 81 percent of the variation in use of the slope (Mueggler 1965). Bryant found that alternative sources for water separated from riparian zones by steep slopes were not utilized (1982). Roath and Krueger (1982), in their study of cattle grazing in the Blue Mountains of eastern Oregon theorize that slope and turn out location contributed to concentrating the cattle on the riparian zone early in the grazing season.

### **What Practices are used to Reduce Riparian Grazing?**

Grazing management strategies used for riparian zone protection, rehabilitation, and/or maintenance include exclusion of livestock, alternative grazing strategies, changes in kind and class of animals, managing riparian zones as special use pastures, and several livestock distribution practices. Deciding which practice(s) to initiate depends on the objectives set for the ranch or allotment and conditions in the watershed.

If existing grazing practices have only small or moderate adverse impacts on riparian/stream values, then a management goal of small to moderate reductions in livestock use may be adequate. Using improved livestock distribution practices such as trailing, salting, fencing, and water developments can be moderately effective in reducing time spent in riparian areas (Kauffman et al., 1983). These practices are often less costly than the fencing and water development associated with intensive grazing systems. Conversely, if your goal is complete exclusion during all or part of the grazing season to achieve watershed management goals, fencing, water development, and grazing rotations become the solutions of choice.

On public lands, reducing livestock numbers is a common means of reducing grazing impacts in riparian/stream systems. If stocking rate exceeds carrying capacity of the allotment, then reducing livestock numbers is an appropriate response. However, if there is a threshold of grazing or trampling impact that occurs at any stocking rate, reducing livestock numbers may not solve the problem. Riparian grazing impacts are often problems of distribution that cannot be solved by reducing stocking rate.

To avoid the costs associated with herding, fencing, and intensive grazing systems it is common to apply practices that are expected to attract cattle away from the riparian area. If attraction is not considered an effective practice for the situation, moving the cattle by herding and excluding cattle with fences comes into consideration.

**Attraction:** Providing shade, drinking water, salt, or supplements away from riparian zones can reduce the time livestock spend in this community. However, these practices require changes in management, and in the case of water develop-

ments can be expensive.

Storch (1978) and Claire and Storch (1977) suggested techniques that enhance upland sites for livestock. They recommended reseeding with palatable grasses and thinning timber stands to reduce pressure on stream side zones. Durbin (1977) cleared and reseeded 70 acres of juniper woodland near a stream to promote deer use and decrease pressure on riparian areas. Swanson (1985) suggested range fertilization and seeding of adjacent upland sites and noted that cattle are attracted to recently burned areas.

McDougald, Frost, and Jones (1989) reduced the proportion of range pastures that were heavily grazed by distributing hay in winter into areas that normally received light utilization. The heavily used areas tended to be near water or on slopes less than ten percent.

Stockwater development is a major tool for improving livestock distribution (Skovlin, 1965; Cook, 1967). Frequency of drinking will depend on temperature, condition of feed, and distribution of water (Arnold and Dudzinski, 1978). Beef cattle grazing U.S. rangelands in the summer drink between one and four times a day (Dwyer, 1961; Sneva, 1970; Wagnon, 1963; McInnis, 1985). Gillen et al. (1985) found that cattle preferred the quality of free-flowing water to that held in an impoundment. Clawson (1993) reported that use of a mountain stream and bottom area (spring) decreased after a water trough was installed adjacent to these areas. Use of the stream dropped from 4.7 to 0.9 min. per cow per day, and use of the spring dropped from 8.3 to 3.9 min. per cow per day after the trough was installed. This case study found that cattle watered at the trough 73.5 percent of the time, the bottom area 23.5 percent of the time, and stream 3 percent of the time. The cattle exhibited a daily pattern of use in riparian zone, with 97 percent of the use falling between 12:00 noon and 6:00 p.m.

Wagnon (1963) reports that beef cows in California's foothills rarely drink at night and start drinking about 6:00 am with most drinking in the afternoon. During the summer, Sneva (1970) found that yearling cattle, on sage-brush range in eastern Oregon, had varied drinking times; 30 percent occurred between 6:00 am and 12:00 noon, 53 percent from noon to 4:00 p.m., and the remaining times between 4:00 p.m. and 8:00 p.m.

Wagnon (1963) reports that in late winter and early spring beef cows mostly utilized wet-weather water sources as they grazed. As these sources dried up the cows began using developed watering sites. Based on 35 twenty-four hour observation periods from February 1947 to October 1950, beef cows were observed to water 0 to 4 times in 24 hours with an average of 1.5 times. The average amount of time spent drinking was 2 to 3 minutes. Cows spent 5 to 6 minutes drinking if the trough was nearly empty or muddy.

Sneva (1970), however, observed that cattle in eastern Oregon drank for an average of 17 minutes per day. McInnis (1985) observed a mean drinking time of 26.6 minutes per day in eastern Oregon. Even when not drinking, cattle may loaf around water for several hours (Dwyer, 1961; McInnis, 1985). In contrast, Wagnon (1963) observed that beef cattle did not loaf around water sources, usually drinking and then leaving within 4 minutes.

Miner et al. (1992) found that under winter feeding conditions the amount of time cattle spent drinking or loafing in the area of the stream was reduced by more

than 90 percent by the presence of a watering tank. It is believed that warmer water in the tank contributed to this reduction in use of water in the stream.

**Culling Practices:** If attraction practices are partially successful, but some individuals continue to concentrate in the riparian area, culling has been suggested to rid the herd of "riparian huggers" or "bottom dwellers." Swanson (1985) and Roath (1980) indicated that within breeds, or even herds, certain individuals are "bottom dwellers" and others "ridge climbers." Males are considerably more aggressive and destructive than females and their calves, and yearlings may be more willing to forage widely and leave the bottom lands (Swanson, 1985). Platts (1981, 1982a, 1982b) and May and Davis (1982) have demonstrated that sheep can exert considerably less impact on riparian ranges because sheep herders control the distribution of animals. Platts (1981b) noted that sheep can degrade riparian/stream ecosystems if the vegetation is grazed for long periods or if the animals are forced to remain in the riparian areas. Although not well studied, some range managers believe that use patterns are partly learned behavior within the herd. Older cattle in the herd lead new members of the herd to favored grazing areas, thus use patterns are passed on from year to year. Breaking this herd behavior may require replacing the herd with new individuals.

**Barriers:** Cattle are known to avoid sites where access is difficult, especially if suitable forage is available elsewhere. Thus, sensitive stream bank sites can be protected by discouraging cattle use. Techniques include use of barriers such as rock fields or boulders, shrub thickets (especially willow), dense timber stands, and fallen trees. The overall goal would be to protect sensitive sites and to encourage use of less sensitive areas with easier access. The presence of intact riparian vegetation downstream of heavily used sites can help absorb impacts and buffer the resulting sedimentation and related impacts.

**Livestock Herding:** If attracting cattle from heavy use areas is not practical or does not work, herding or fence construction must be considered. Herders can regulate the amount of time livestock spend in riparian zones (Claire and Storch, 1977). Storch (1978) reported that this was the most effective and practical range management technique on the Malheur National Forest in eastern Oregon, where livestock were herded on a daily basis. May and Davis (1982) suggested locating driveways and trailing areas away from riparian areas and using bridges and rock revetment to minimize impacts when riparian areas cannot be avoided. Gillen et al. (1985) pointed out that cattle occupation of riparian meadows was greatest during afternoon hours.

Herding is labor intensive and has declined as labor costs have increased over the years. However, low stress herding and handling methods such as those described by Grandin (1993) may reduce stress and costs associated with herding.

**Fencing:** Fencing can be used to separate heavy use areas from areas of light to moderate use. Fencing may be used to segregate riparian pastures, facilitate grazing systems, and for exclusion. Separation of riparian areas or bottom land from steeper or rougher uplands is commonly recommended to control livestock distribution.

Related range management considerations are pasture size, proportion of upland vs. riparian forage in a pasture, and location of streams and other water sources within pastures. Platts and Nelson (1985a) indicated that pasture designs that alter



these factors may reduce damage to the stream-riparian resources. Hughes (1979) reported that cattle utilized ridge top forage more in smaller pastures. Cattle have favored "home ranges" and will not stray far from favored watering areas because of the time required to return to watering sites (Roath, 1980; Platts and Nelson, 1985a). Upland pastures farthest removed from water may, therefore, not be fully utilized.

Exclosures can be used to regulate grazing pressure on riparian communities. Exclosures provide for total exclusion of livestock, regulation of seasonal use, or use from year to year. Numerous researchers have pointed out the advantages and disadvantages of this technique (Duff, 1977; Platts, 1982a; Platts and Wagstaff, 1984; Platts and Nelson, 1985a, 1985b). Some individuals feel exclosure fencing is the only viable method to ensure protection of the riparian-stream ecosystem (Ames, 1977). Reports by Lorz (1974), Claire and Storch (1977), Duff (1977), and Marcuson (1977) suggest threefold to fourfold increases in trout biomass in protected areas compared to heavily grazed areas. Numerous researchers have shown that riparian habitats in fenced exclosures or otherwise protected from intensive grazing have dramatically improved when compared to similar unfenced areas (Gunderson, 1968; Dahlem, 1979; Claire and Storch, 1977; Duff, 1977; Wineger, 1977; Keller et al., 1979; Kauffman et al., 1983; Stuber, 1985; Platts and Nelson, 1985b). Although the evidence appears overwhelming, many studies that demonstrate differences between fenced exclosures and grazed pastures should be accepted with caution, because the two treatments were often not truly comparable, and the experimental designs of some of the studies do not adequately address important issues in a statistically sound manner.

Platts and Rinne (1985) agreed that fencing may or may not result in an improved fishery. Fencing is only beneficial if it treats limiting factors. Fences have several negative aspects including loss of forage, the need for maintenance, and increased fire hazard (Swanson, 1985). Swanson (1985) and Platts and Nelson (1985a) pointed out the advantages of creating a riparian pasture instead of exclosure fencing; this provides the opportunity to manage the vegetation and protect the valuable riparian-stream ecosystem. Fencing is often prohibitively expensive (especially when comparing benefits of improved fishery) (Platts and Nelson, 1985a). Solar-powered "New Zealand type" electric fences can be 25-50 percent less expensive to install, although maintenance costs are higher.

Electronic (fenceless) control of livestock in riparian and other critical areas shows some promise for the future. Quigley et al. (1990) reported that cattle could be trained to avoid an area without a fence-defined boundary by using remotely-controlled audio electrical stimulation. In their final report to the U.S. Environmental Protection Agency in 1993, Tiedemann and Quigley reported on the development and testing of prototype eartags and transmitters that were tested in Texas and Nevada during the summer of 1992. They report that most of the animals with electronic eartags were observed to stay away from the exclusion zone. While these prototype eartags worked, they were too heavy to be worn by animals for an extended period. While this technology is promising, further research is needed on equipment development and testing.

**Standards and Guides:** In an attempt to reduce impacts of grazing on riparian areas and associated stream systems, standards and guides for stubble height

and for trampling and chiseling have been implemented by agencies. Standards and guides are used by public land managers to guide grazing utilization. If a standard is exceeded, the manager may request a change in management by the lessees. That change might be to move the cattle to other locations in the grazing allotment or in some cases to cease grazing for the season.

For intermountain riparian areas, Clary and Webster (1989) recommended that a minimum herbage stubble height be present on all stream side areas at the end of the growing season, or at the end of the grazing season if grazing occurs after frost in the fall. The residual stubble or regrowth should be at least 4 to 6 inches in height to provide sufficient herbaceous forage biomass to meet the requirements of plant vigor maintenance, bank protection, and sediment entrapment. This recommendation was implemented widely by the USDA Forest Service (Clary 1995).

While this stubble height recommendation has wide application in the intermountain region, it has been applied in situations where 4 to 6 inches is probably inappropriate. For example, the dry weight (approximately 1500 - 2000 lb./a) of a 4 to 6 inch stubble height often exceeds the productivity of many moist and dry meadow sites in the Sierra Nevada mountains (Ratliff et al. 1987).

A recent study in Colorado suggests that vegetation height may not be as important as believed for causing increased sediment deposition along riparian areas. Pearce (1995) found no difference in sediment filtration for three residual vegetation heights (clipped to ground surface, clipped to 4 inches and unclipped). In a Wyoming study, Rumsey (1996) did not find a difference in sediment deposition along a stream between the unclipped treatment and clipped stubble heights of 1, 3 and 6 in.

Standards and guides for trampling and chiseling have been developed and applied by USDA Forest Service in an increasing number of districts. The Inyo National Forest Land and Resource Management Plan established a maximum allowable limit of 20 percent trampling and chiseling from various management activities in standards and guidelines for fisheries and watershed. The intent of the standard is to prevent excessive trampling and chiseling from immediately adjacent to the water to bankfull in order to facilitate restoration of unstable or eroding stream banks. Trampling and chiseling standards have been criticized for being subjective...what constitutes a trample or footprint? Trampling of ground covering vegetation is counted even though ground cover has changed little and the plant or plants are able to regrow. While research and common sense indicate that livestock impact riparian areas, there is little published research that link levels of trampling and chiseling to loss of riparian ecosystem health or impaired water quality.

### **Do These Livestock Distribution Practices Work?**

The answer is yes...sometimes. Each of these practices, individually and in combinations, has successfully reduced livestock impacts on critical areas. However, each has also failed. Biological and physical uncertainty and imperfect knowledge prevent scientists and managers from predicting the effectiveness of a practice perfectly. However, common sense and experience, along with science based information, can help us reduce the uncertainty. If we wish to reduce livestock use in one portion of the watershed and redistribute that use elsewhere in the watershed, we

must weigh several factors as we consider the efficacy of alternative distribution practices:

- What is the topography of the allotment or pasture?
- Is the riparian area the only area of flat or gently sloping land?
- Is water available away from the riparian area?
- Can water be developed a sufficient distance from the riparian area to reduce trailing in between?
- If we reduce livestock use of the riparian area, will riparian objectives be met, or are there other barriers to meeting these objectives?
- Can we use livestock distribution practices to provide sufficient "cow habitat" in the form of water, forage, shade, gentle slopes, and other amenities to attract cattle away from the riparian zone?
- Are there animals in the herd that are "riparian huggers" or that lead the herd back to sensitive areas?
- Are there times when riparian grazing is not harmful or is beneficial?
- Are there public policy rules and regulations that prevent timely response to management opportunities and hazards (Westoby, 1989)?
- Are the practices economically feasible?

Managing grazed watersheds is a tricky business because we must take into account biological uncertainty. Unpredictability suggests the need to learn from experience because data are sparse and theory is limited. This suggests the need for adaptive management.

Adaptive management is based on the idea that if our understanding of nature is imperfect, our interaction with nature should be experimental. Unpredicted events should be opportunities to learn rather than failures to predict. The above questions should help managers consider appropriate practices that meet allotment or ranch objectives. Monitoring will provide feedback to managers regarding the effectiveness of the implemented practices.

Adaptive management applied at the local or watershed level insures that problems, objectives, and solutions will be described close to the ranches or allotments where responsibility for management decisions and implementation of practices lies.



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## ***Controlling Season, Intensity, and Frequency of Grazing***

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In 1943, Stoddart and Smith published their classic text, *Range Management*. Speaking to issues of conservation of rangeland and the importance of correct grazing, they wrote: "though many factors are involved, the most important are (a) correct numbers of livestock including good distribution, and (b) grazing during the proper season" (p. 243). Stoddart and Smith in that first edition devoted an entire chapter to the importance of correct livestock numbers, importance of proper season of grazing, plant succession as a guide to proper numbers, and disturbance as an indicator of improper livestock numbers (Stoddart and Smith, 1943, Chapter 10).

Thirty-two years later, in 1975, a third edition of *Range Management* was printed (Stoddart, Smith, and Box, 1975). In that edition, the authors wrote: "Of fundamental importance are (1) grazing the range with proper kind of animal, (2) balancing numbers with forage resources, (3) grazing at the correct season of year, and (4) obtaining proper distribution of livestock over the range" (p. 256).

Most of the efforts to accomplish good rangeland management dating back to the early decades of this century hinge on these principles. Season long or continuous grazing was the de facto approach to livestock grazing over much of the western rangelands at that time. Various kinds of grazing systems evolved in attempts to understand and apply these principles. Holecheck et al. (1989) in *Range Management Principles and Practices* speaks to many of these. The first specialized system developed on western rangelands was investigated by Arthur W. Sampson (1913). He named it deferred-rotation grazing. Merrill (1954) developed a three herd/four pasture system. Cook and Harris (1968), Smoliak (1960), and Holecheck et al. (1981) investigated seasonal-suitability of grazing. Valentine (1967) proposed a best pasture system in New Mexico, and Hormay developed the rest-rotation grazing system in the 1950s (Hormay and Evanko 1958). A high intensity-low frequency (HILF) system was first reported by Acocks (1966) in South Africa. Allan Savory developed a short duration (also called short duration-high intensity, rapid-rotation, time-control, and cell grazing) system in Zimbabwe in the 1960s. This was later introduced into the USA by Goodloe (1969).

All of these grazing systems have the common element of attempting to

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control intensity and/or timing of grazing. In this author's opinion, we have made great strides toward improving upland rangeland conditions over the past several decades. It is interesting to reflect on early adjudications which followed the establishment of the Forest Reserves Act in 1891 and Taylor Grazing Act in 1934. At that time, reduction in numbers of livestock grazed, in order to meet calculated carrying capacities, was the main tool used. In the 1950s, 1960s, 1970s and after, recognition was given to intensity and timing of herbivory.

### Grazing Systems

Grazing systems facilitate control over time, intensity, and frequency of grazing and can have dramatic effects on range use and productivity (Heady, 1975; Platts, 1978). Some systems can maintain or improve riparian systems (Claire and Storch, 1977). Platts (1978 and 1990) listed the relative effectiveness of several grazing systems on the condition of stream-riparian habitats (Table 1). He indicated that no grazing, rest-rotation, or short duration high-intensity systems provide the most protection. Kovalchik and Elmore (1991) reported the compatibility of 11 grazing practices or systems with willow dominated plant associations (Table 2). They reported that spring grazing, winter grazing, exclusion, and riparian pastures were highly compatible with willows, while practices that resulted in excessive growing season grazing were incompatible. Other systems, such as year-round grazing or seasonal rotation, typically result in destruction or degradation of riparian communities under normal grazing intensity due to concentration of livestock in these areas (Gunderson, 1968; Marcuson, 1983; Gillen et al., 1985). Under season-long continuous grazing, livestock generally concentrate in riparian areas. This grazing strategy does not treat upland and riparian areas separately. Under this strategy there is little chance for riparian areas to be grazed at proper seasons, intensities, and frequencies. While season-long grazing is often the source of riparian grazing problems, exclusion of livestock from streams is often impractical.

**Stream Corridor Fencing:** Exclusion of grazing using stream corridor fencing is a common practice that often results in improvement of riparian values. Platts and Rinne (1985) in an extensive literature review showed that riparian habitats benefitted greatly after being fenced to eliminate heavy livestock grazing. However, in many areas it is not economically feasible to fence every stream corridor (Platts and Wagstaff, 1984) nor is its wide usage acceptable to most ranchers.

**Riparian Pasture:** Platts and Nelson (1985) and Swanson and Torell (1990) believe that the riparian pasture concept has merit because the riparian and stream areas will be managed independently to achieve desired habitat responses. Advantages of the riparian pasture include better control over animal distribution, grazing intensity, and timing as well as increased vegetation production. Installation of riparian pastures may be expensive.

**Seasonal Grazing:** The overall objective of managing season of use is to avoid periods when the vegetation and streambank are most sensitive to damage. Results of studies concerning season of use conducted on different streams or reaches must be applied carefully because of differences in streambank and adjacent upland vegetation types, size of grazing areas, kind and age of livestock, stocking rates, palatability of forage, and management objectives. While a great deal of the litera-



Table 1. Evaluation and rating of grazing strategies for stream-riparian related fisheries values based on observations of Platts 1990—Nevada Department of Wildlife W11600, also Billings Symposium in 1989.

Strategy	Level to which riparian vegetation is commonly used	Control of animal distribution (allotment)	Streambank stability	Brushy species condition	Seasonal plant regrowth	Stream-riparian rehabilitative potential	Rating
Continuous season-long (cattle)	Heavy	Poor	Poor	Poor	Poor	Poor	1*
Holding (sheep or cattle)	Heavy	Excellent	Poor	Poor	Fair	Poor	1
Short duration-high intensity (cattle)	Heavy	Excellent	Poor	Poor	Poor	Poor	1
Three herd-four pasture (cattle)	Heavy to moderate	Good	Poor	Poor	Poor	Poor	2
Holistic (cattle or sheep)	Heavy to light	Good	Poor to good	Poor	Good	Poor to excellent	2-9
Deferred (cattle)	Moderate to heavy	Fair	Poor	Poor	Fair	Fair	3
Seasonal suitability (cattle)	Heavy	Good	Poor	Poor	Fair	Fair	3
Deferred rotation (cattle)	Heavy to moderate	Good	Fair	Fair	Fair	Fair	4
Stuttered deferred rotation (cattle)	Heavy to moderate	Good	Fair	Fair	Fair	Fair	4
Winter (sheep or cattle)	Moderate to heavy	Fair	Good	Fair	Fair to Good	Good	5
Rest-rotation (cattle)	Heavy to moderate	Good	Fair to good	Fair	Fair to Good	Fair	5
Double rest-rotation (cattle)	Moderate	Good	Good	Fair	Good	Good	6
Seasonal riparian preference (cattle or sheep)	Moderate to light	Good	Good	Good	Fair	Fair	6
Riparian pasture (cattle or sheep)	As prescribed	Good	Good	Good	Good	Good	8
Corridor fencing (cattle or sheep)	None	Excellent	Good to excellent	Excellent	Good to excellent	Excellent	9
Rest-rotation with seasonal preference (sheep)	Light	Good	Good to excellent	Good to excellent	Good	Excellent	9
Rest or closure (cattle or sheep)	None	Excellent	Excellent	Excellent	Excellent	Excellent	10

\*Rating scale based on 1 (poorly compatible) to 10 (highly compatible) with fishery needs.

Table 2. Grazing system compatibility with willow dominated plant association (Kovalchik and Elmore 1991).

Grazing Practice	Compatibility with Willows
Corridor Fencing	Highly
Riparian Pasture	Highly
Spring (Early-Season) Grazing	Highly
Winter Grazing	Highly
Two-Pasture Rotation	Moderately
Three-Pasture Rest Rotation	Moderately
Three-Pasture Deferred-Rotation	Moderately
Spring-Fall Pastures	Incompatible
Deferred Grazing	Incompatible
Late-Season Grazing	Incompatible
Season-Long Grazing	Incompatible

ture reported here comes from the intermountain west, differences in study sites and management preclude direct application of these results to other locations. Following is a brief review of early season (spring), late season (summer) and dormant season (winter) grazing experiences that may be useful to range managers as they develop management strategies at new locations:

**Spring (early growing season) grazing:** Early growing season (spring) grazing encourages use of the uplands where forage maturity and climate are more favorable compared to the riparian zone (Platts 1984). In the spring cattle often avoid riparian zones because of cold temperatures, wet soil, and immature forage (Krueger, 1983). As a result, spring-grazed riparian zones have less than half the cattle occupancy compared to fall use (Krueger, 1983). As spring grazing precludes late-summer use, willow browsing is light and seedling survival high. Response of riparian vegetation is good, even on sites in poor condition. Vigorous willow and sedge regrowth provide excellent streambank protection, and soil and water relationships remain favorable to continued willow and sedge production.

Siekert et al. (1985) concluded that spring grazing on ephemeral streams has little effect on channel morphology, but that channel cross-section area increases with summer and fall use. Permitting livestock use of riparian areas early in the season when adjacent upland forage is lush results in a low use of streamside forage and a decrease in damage to streamside vegetation (Swanson, 1985; Gillen et al., 1985). However, Gillen also stated that meadow plants are most susceptible to damage early in the growing season.

**Late growing season grazing:** In contrast to early season grazing, Marlow et al. (1987) showed that use of riparian range late in the season after soils have dried (less than 20 percent soil moisture) decreases potential for mechanical destruction of streambanks in southwestern Montana. Swanson (1985) also observed this relationship and suggested use of riparian forage only when grasses are green to reduce pressure on streambank shrubs (willows). Kauffman and Krueger (1984) cited several positive results of late season grazing, and Bohn and Buckhouse (1985) showed late-season grazing during September had positive effects on infiltration and sedimentation, whereas grazing in October, after the onset of the rainy season, was detrimental. Gillen et al. (1985) suggested reducing the length of the grazing season to reduce impacts. Platts and Rinne (1985) conclude that the condition of the vegetation mat during late fall (wet season) directly affects bank stability.

Kauffman et al. (1983) provided a sound defense for establishing separate, fenced riparian pastures that are grazed late in the season when riparian vegetation has finished growing and produced adequate food storage for regrowth. Benefits they identified included: 1) effective utilization of upland forage without damage to riparian areas, 2) maintenance of water quality, 3) minimum disturbance to avian communities, 4) minimum soil impacts, and 5) increased calf

weight gains. Riparian shrubs were not intensely utilized, however, unless riparian herbaceous vegetation dropped below a minimum threshold. This strategy, however, did cause some stream bank erosion and decreased the density of small mammals, although carryover density was not affected. They also stated that riparian communities with perennially-saturated soils have the highest potential for compaction problems.

Storch (1978) reported that following four years of grazing exclusion along Camp Creek in eastern Oregon, late season grazing (mid-August) annually since 1968 (10 years) resulted in no apparent change in fish habitat and population. Prior to grazing exclusion, Camp Creek had been grazed continuously from June 1 to October 15. Streambank vegetative cover was low, shrub canopy cover was less than 20 percent, and soil was compacted. Streambank and vegetation conditions within the enclosure improved in four years.

**Winter (dormant season) grazing:** In locations where winters are cold but snowfall is light winter grazing may be appropriate with few detrimental stream bank effects. It is believed that winter grazing has few detrimental effects because the stream banks are frozen and vegetation is dormant. Winter grazing does not address the problem of adequate grazing areas during the growing season.

**Rest-rotation grazing:** Rest-rotation grazing is a grazing system that has been widely used in the intermountain west with mixed success. It rotates seasons of use and one year rest periods among four or more pastures. Occasionally three pasture rest rotation systems have been successfully implemented. Although opinions vary as to which grazing system(s) best protect riparian communities, research reports and case studies suggest that rest-rotation grazing often provides protection to the riparian zones. In reality any grazing strategy that incorporates proper stocking rates, rest, and control over season and frequency of use to fit the grazing resource would probably provide a high degree of protection to the range resource including riparian areas. While the system was developed in the intermountain region of northeastern California, rest-rotation has never been shown to improve forage productivity or resource protection over season-long grazing on California's annual grasslands.

In the Blue Mountains of Oregon, Claire and Storch (1977) reported achieving desired maintenance of fisheries populations with rotation grazing that rested pastures for one full year out of three. Swan (1978) reported success using a three-pasture rest-rotation system on the Humboldt National Forest, Nevada. Davis (1982) also reported success when rest-rotation was used in conjunction with willow plantings in the intermountain region. Davis (1982) reported dramatic increases in cottonwood and willow establishment using a four-pasture system where each pasture receives spring-summer rest, back to back, two years out of three. Bohn and Buckhouse (1985) reported a favorable decrease in sediment production and an increase in infiltration rates using rest-rotation in Oregon's Blue Mountains. Thomas et al. (1979) suggested using six or more pastures in rest-rotation systems instead of the usual two to five; however, they did not evaluate this technique.

According to Platts and Rinne (1985), heavily stocked rest-rotation or de-

ferred rest-rotation strategies have not been effective in stream enhancement. They also stated that removal of greater than 65 percent of desirable forage negates the benefits derived from implementing a rest-rotation system because of trampling. Platts and Rinne (1985) have shown that although rest-rotation grazing improved productivity, it does not protect riparian ecosystems because of livestock's disproportionate use of this area. Platts and Rinne (1985) concluded that three-pasture rest-rotation systems—where pastures receive early season grazing the first year, late season the second year, and rest the third year—did not maintain fall-winter vegetation in good condition during two out of three years.

Storch (1978) reported that forage retention objectives for herbaceous vegetation were not achieved within desired time limits using rest-rotation. Rest-rotation did not improve riparian vegetation, according to Hughes (1979), although it reduced soil erosion and significantly increased livestock weights. The problem of not allowing rest-rotation systems to go through a full cycle before being analyzed are referred to by Wilson (1978) and Platts (1982). This problem confounds the interpretation and application of some reported results. Positive effects of rest-rotation grazing are the maintenance or increase in ecosystem productivity (Bryant, 1985) and the provision for storage of carbohydrates and reproduction of plants. These benefits apply to both upland and riparian ranges; there is a net increase in ecosystem productivity and a decrease in erosion. According to Platts (1978), there were no positive effects on streamside riparian vegetation (composition, density, structure) or fisheries.

Modifications of rest-rotation such as the six-plus pasture system of Thomas et al. (1978), or use of special management riparian pastures in conjunction with rest-rotation (Platts and Nelson, 1985c) may increase the effectiveness of this system. From the rancher's point of view rest-rotation grazing may be impractical in some cases. It can require three roundups per year rather than two, and often a reduction in calf crop the first two years (Davis, 1986). A reduction in permit number and value and expenditures for improvements may accompany initiation of rest-rotation grazing.

## **Riparian Systems**

In the Meadow Creek Study of eastern Oregon, Bohn and Buckhouse (1985) and Buckhouse (1986) working in conjunction with Jon Skovlin and Larry Bryant found that each of several managed grazing strategies in riparian systems showed positive (albeit at different rates) trends as compared to season-long grazing. Marlow et al. (1989), Hayes (1978), Davis (1982), Platts (1982), and Elmore and Beschta (1987) published similar findings. Skovlin (1984) published a very good review of riparian grazing practices and their impacts and/or ameliorations. Buckhouse and Elmore (1993) have published a matrix which relates the natural conditions of gradient and sediment load to the managerial impacts of several grazing systems (Figure 1). Buckhouse and Elmore's 1993 article provided a logical pathway toward a managerial response. They warn, however, that it is a guide to thinking rather than a by-the-numbers blueprint.

		Natural Conditions						
		Low	Medium	Medium	Medium	Medium	High	
		Steep, Low sediment load	Steep, High sediment load	Moderate, Low sediment load	Moderate, High sediment load	Flat, Low sediment load	Flat, High sediment load	
Low	No Grazing	Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	
		Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	
Low	Dormant Season	Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	
		Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	
Low	Early Growing Season	Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	
		Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	
Med.	Late Growing Season	Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	
		Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	
Med.	3-pasture Rest Rotation	Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	
		Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	
Med.	Deferred Rotation	Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	
		Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	
Med.	Rotation	Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	
		Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	Herbs .	
High	Season Long	Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	Banks ↔	
		Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	Shrubs .	
		. increase	. decrease	↔ no change				

Figure 1. Generalized relationships among riparian vegetation response, grazing management practices, and stream system characteristics. Taken from Buckhouse and Elmore (1993).

### Bottom Line

One can promote herbaceous material and plant community vigor, at different rates of change, by appropriate use of grazing systems when compared to season-long grazing:

- Season-long grazing is detrimental to both herbaceous and woody vegetation—animals are present to graze each plant species at its susceptible stage of growth without any planned rest.
- Rotation or deferred-rotation grazing schemes seem to combine the attributes of simplicity and plant protection to promote herbaceous growth,

and in some instances woody vegetation.

- Late-growing-season grazing, before the fall rains, also generally promotes herbaceous vegetation health. In addition, it may reduce soil compaction and promote habitat for ground-nesting birds. However, it may be inappropriate for promotion of streamside woody vegetation.
- Dormant-season and early-growing season grazing may promote both shrubs and herbaceous vegetation. However, be alert to potential problems like lowered nutritional value requiring supplementation. In addition, soil compaction problems may result, depending on soil moisture and frost conditions. A big economic advantage, however, may be the opportunity to reduce winter feed costs by grazing at this time.



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# ***Survival and Transport of Fecal Pathogens in Grazed Watershed***

*Royce Larsen<sup>5</sup>*

Livestock grazing is a major land use in the western United States that can impact water quality (Moore et al. 1979). The majority of the land in the western United States is classified as rangeland. Rangelands are generally suited for grazing, wildlife habitat, recreation, aesthetics, and for providing water. Grazing livestock on public and private rangeland can be compatible with other uses of the land and contributes to the success of the ranching industry. However, if cattle are not managed properly they can have adverse impacts on water quality. Potential hazards of pathogenic organisms and nutrient contamination exist when cattle concentrate near streams. Grazing induced pathogen and nutrient pollution depends on the amount of feces deposited, fecal distribution on the landscape, overland flow, and proximity to a water body. Proper grazing management, especially livestock distribution, can help maintain water quality.

In this review we will concentrate on pathogen pollution associated with fecal deposition by livestock. We will not focus on nutrients except where nutrient levels are reported along with pathogens. Others have reviewed nutrients as a nonpoint source pollutant (Sweeten and Reddell 1978, Green and Kauffman 1989, Wolf 1992). Many of the practices used to reduce pathogen pollution in grazed watersheds are also recommended for reducing nutrient loading.

## **Bacteria and Other Pathogens**

Bacteria and other pathogens carried in animal waste can be transferred to humans via water. Documented cases of infectious diseases of animal origin in man and animals associated with water transmission have been reported (Diesch, 1970). Some bacterial diseases that can potentially be transferred to humans from infected cattle are: Salmonellosis, Leptospirosis, Anthrax, Tuberculosis, Johnes Disease, Brucellosis, Listeriosis, Tetanus, Tularemia, Erysipelas, and Colibacillosis (Diesch, 1970; Azevedo and Stout, 1974). Viruses may also be carried by animals, but seem to be a lesser threat to humans (Diesch, 1970).

Illnesses caused by protozoal parasites are of major concern because of the large number of water-borne outbreaks of gastroenteritis in humans (Atwill, 1995).

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*Cryptosporidium* oocysts and *Giardia* oocysts are found widely dispersed in the aquatic environment (LeChevallier et al., 1991). Atwill (1995) has reviewed the literature finding evidence that as many as 20% of dairy calves tested carried *Cryptosporidium*, but very little work has been done on unconfined beef operations. LeChevallier et al. (1991) found that 81% of raw water samples taken from treatment plants contained *Giardia*, and 87% contained *Cryptosporidium*. They noted that 97% of the raw water samples contained *Giardia*, *Cryptosporidium*, or both.

Total coliform (TC), fecal coliforms (FC), and fecal streptococci (FS) are the primary indicators of the potential presence of pathogens in water (Moore et al., 1979). Most bacterial water quality criteria are based on TC, FC, and/or FS concentration. In addition to TC, FC, and FS, Rychert and Stephenson (1981) have found that failure to include atypical *Escherichia coli* in water quality analysis may lead to significant error.

Fecal coliforms, total coliforms, and fecal streptococci, bacterial indicators of fecal contamination, were originally designed for public health reasons and used to test drinking water for contamination by fecal wastes from humans. Since specific disease-causing organisms are very difficult to trap and culture, the benign but ubiquitous coliform group was chosen. Coliform bacteria are easy to test, simple to culture, and indicative of fecal contamination from warm blooded animals. However, a test designed for public water systems which may have been contaminated by wastes from humans may not be directly applicable to wildland wastes which may have ruminant fecal contamination present. Bohn and Buckhouse (1985) have published a thoughtful discussion of the potential errors that may occur when interpreting coliform monitoring data from wildland streams. They concluded that a single coliform point sample may not represent the general condition of the water due to temporal and spatial variation in coliforms. While they concluded that fecal coliform and salmonella species behave very much alike in natural waters, they were concerned that other pathogens may not behave like coliforms and therefore be poorly predicted by standard coliform tests.

Gallagher and Spino (1968) found that stream surveys show little apparent correlation between TC and FC concentration and the isolation of salmonellae. Jawson et al. (1982) found that indicator bacteria were from a nonpoint source; therefore, they suggested that present FC recommendations, developed for point sources, may not apply adequately to grazed land. Schillinger and Gannon (1985) found that FC had a lower adsorption and sedimentation rate than other bacteria and may not be the best indicator of pathogens. Geldreich (1981) has concluded that "in situ" survival studies of indicator and pathogenic organisms in the water environment have done much to discredit the "universal indicator organism concept."

It has also been recognized that, at the same coliform concentration, fecal contamination (indicated by coliform concentration) originating from humans carries a greater risk of disease transmission to other humans than contamination originating from ruminant animals (Geldreich 1970). As a consequence, FC/FS ratios have been developed in an attempt to quantify species origin of the contaminates.

Van Donsel and Geldreich (1971) found salmonellae in 19% of stream bottom mud samples when the overlying water had FC concentrations between 1-200/100 ml; in 50% with FC concentrations between 201-2000/100 ml; and in 80% with FC concentrations >2000/100 ml. Jones and Matthews (1975) found small numbers

of salmonellae ( $> 1/g$ ) in 11% of fecal samples from cattle. They also found that leptospirosis was isolated from 30% of the samples, but none were pathogenic.

LeChevallier et al. (1991) found a relationship between FC concentrations and *Cryptosporidium* oocysts ( $r=0.383$ ,  $p<0.05$ ) and *Giardia* oocysts ( $r=0.702$ ,  $p<0.01$ ). Thus the presence of FC suggests the potential presence of *Cryptosporidium* and *Giardia*. There was also a significant relationship of *Cryptosporidium* and *Giardia* with TC and turbidity. Even though *Cryptosporidium* and *Giardia* were present in 97% of the water samples tested, the source was not known.

Wildlife can also contribute to TC, FC, and FS concentrations in streams. Stuart et al. (1971) have shown that elk were responsible for high bacterial pollution in a high mountain watershed in Montana. The bacteria in the elk droppings remained viable for at least one year (Goodrich et al., 1973)

### Fecal Transport in Grazed Watersheds

Results of comparisons of indicator bacteria concentrations in streams from grazed and ungrazed pastures or watersheds, or before and after grazing, are mixed. Some comparisons have found significant differences in indicator bacteria concentrations that can be attributed to grazing livestock, others have not. Doran and Linn (1979) found that runoff from a grazed pasture had coliform concentrations 5-10 times higher than from an ungrazed pasture. Crane et al. (1983) have reviewed several studies showing bacterial concentrations in runoff from pastures and grazing systems. They found little difference between runoff from pastures and control areas. They also noted that runoff from pastures often exceeds recommended standards for recreational use of water.

Stephenson and Street (1978) studied grazing impacts on a stream in a southwest Idaho rangeland. They found that in pastures with free grazing cattle and low management, maximum fecal coliform concentrations increased soon after cattle entered the pasture and remained high for several weeks to three months following removal. In some cases the peak coliform counts increased from zero to 2500/100 ml. They noted that bacterial concentrations decreased downstream in areas with steep gradients and increased roughness, suggesting that certain stream segments were self-purifying. In addition, they found that peak streamflow due to snow melt runoff had little effect on increasing coliform concentrations. However, peak FC and TC concentrations were related to runoff or irrigation return in winter feeding areas, suggesting a flushing of bacteria from the pasture.

In Colorado, Johnson et al. (1978), found that cattle did not contribute to statistically different physical and chemical parameters for a grazed and ungrazed pasture. Although bacterial counts increased in the grazed pasture, they dropped to levels similar to the ungrazed pasture in a relatively short period of time. They found that peak FC counts and nitrate nitrogen ( $\text{NO}_3\text{-N}$ ) decreased when cattle were removed. Ammonia nitrogen ( $\text{NH}_4\text{-N}$ ) and orthophosphates ( $\text{PO}_4$ ) remained about the same, while FS increased. Because indicator bacteria concentrations tend to increase as flow increases during a runoff event, and a peak flow event occurred on June 10 coinciding with the June 2-15 grazing period, the differences reported in this study may be due to flow, grazing or both.

Milne (1976) studied a cattle and sheep wintering operation along a small

creek in Montana. He concluded that nitrogen and phosphorus loading was very low and was typical of a pure mountain stream. Chlorides were found to increase as he went downstream; however, the largest increase was below a farming area not associated with livestock activity. Milne (1976) also found very little bacterial contamination associated with dispersed livestock, but a large increase in bacteria was observed where the cattle were concentrated.

Jawson et al. (1982) studied a grazed and nongrazed watershed in the Pacific Northwest. They found that TC and FS were not different between the two watersheds, with both exceeding 10,000/100 ml. They did find some correlation between indicator bacteria in runoff and how recently grazing had occurred. However, it required more than a year for FC numbers to drop below 200/100 ml following the removal of cattle.

Tiedemann et al. (1987) looked at 13 forested watersheds under the following treatments: A. no grazing, B. grazing without management for livestock distribution, C. grazing with management for livestock distribution, and D. grazing with management of livestock distribution and forage production. They found significant differences among strategies where mean concentrations were  $A < C = B < D$ . Fecal coliform concentrations were the same for winter and snowmelt runoff, and both were significantly lower for the summer period. The correlation between grazing and FC concentrations was significant, with FC concentrations six times higher with cattle present than with cattle absent (34 FC/100 ml to 6 FC/100 ml). They found that FC survived through the winter period in animal feces and that elevated levels of FC occur long after cattle are removed.

Skinner et al. (1984) found that differences in FC and FS could not be explained by differences in grazing treatments but were partially explained by the presence of beaver dams. Gary and Adams (1985) found that eight stream pools in high elevation cold water streams grazed by cattle and sheep showed very little FC pollution. They found FC counts ranged between 0 and 30 FC/100 ml of water, and FS counts ranged between 6 and 590 FS/100 ml. Coltharp and Darling (1975) looked at grazed and ungrazed watersheds in northern Utah. They found that cattle and sheep grazing significantly increased TC, FC, and FS concentrations immediately downstream from grazed areas. However, they only found slight, insignificant increases in physical (temperature, pH, turbidity) and chemical (nitrates, phosphates) parameters measured.

Buckhouse and Bohn (1983) compared levels of fecal contamination in different grazing systems in northeastern Oregon. The numerical differences between grazing systems were large but not statistically significant. Bacterial concentrations generally decreased the first year livestock were removed, though the changes were not statistically significant. They concluded that interpretation of coliform data from nonpoint sources must be handled with caution, noting that a number of sources for variation exist.

There seems to be a great deal of variation in pathogen indicators in wildland streams, making interpretation difficult. However, some general trends exist. As grazing intensity increases, bacterial indicators may increase in wildland streams with free grazing livestock. This condition may persist for long periods of time. Hussey et al. (1986) have shown that very little change occurred in TC, FC, and FS concentrations over a 10 year period. It also appears that peak fecal coliform con-

centrations are related to runoff events.

Numerous factors may influence indicator bacteria concentration in rangeland streams, including fecal output by livestock and wildlife, distribution of fecal material relative to stream channels, survival of indicator bacteria in rangeland watersheds, and the attenuating effects of vegetation on pathogen concentrations in surface runoff.

### **Fecal Output and Distribution**

Total fecal output of cattle will range from 0.5 - 0.75 percent of body weight per day, on a dry weight basis (Kronberg et al., 1986; Johnstone-Wallace and Kennedy, 1944). This fecal output will contain an average of  $3.8 \times 10^{10}$  FC and  $7.2 \times 10^8$  FS (Moore et al., 1988). Free ranging cattle will defecate an average of 12 times per day (Arnold and Dudzinski, 1978; Julander, 1955; Johnstone-Wallace and Kennedy 1944; Hafez, 1969). This is an average fecal output of 0.04 to 0.06 percent of body weight per defecation.

Hafez and Schein (1962) found that fecal deposits from cattle were indiscriminately distributed throughout a pasture. This non uniform distribution can result in approximately 0.4-2.0 percent of the area being covered by fecal deposits (Omaliko, 1981; MacLusky, 1960). The area covered by feces may be even less for an open range. Buckhouse and Gifford (1976) found 0.2% of a semi-arid range covered with bovine feces with a stocking rate of 2 ha/AUM in Southeastern Utah.

However, in certain areas (e.g., water troughs, gates, fence lines, and bedding areas) feces concentrations may be considerably higher (Hafez and Schein, 1962). For example, bovine feces concentration beneath bedding trees may reach as high as 7400 fecal deposits/ha, with approximately 4.5% of the ground covered (Larsen, 1989). Winter feeding areas for beef cattle operations may also be a source of high feces concentrations. Larsen (1989) found that a winter feeding area had 6067 fecal deposits/ha. During the spring, grazing was distributed throughout a watershed, with highest concentrations of fecal pats within a riparian area (1476 fecal deposits/ha) and the least in areas a great distance from water and on steep slopes (<76 fecal deposits/ha) (Larsen, 1989).

Free grazing of cattle on rangeland and in pastures may have a natural constraint that prevents excessive fecal coverage of an area. This natural constraint comes from the phenomenon of "dung-fouling." Each fecal deposit covers an area that is approximately 0.09 m<sup>2</sup>; cattle will avoid grazing an area six times the size of the feces, preventing excessive fecal coverage even with high stocking rates (Sweeten and Reddell, 1978).

In addition to dung fouling, it would require an unrealistic stocking density of 0.09 ha/hd (11.1 hd/ha) to achieve 4% fecal coverage in a pasture. A more realistic stocking density of 3.7 ha/hd (0.27 hd/ha) for one year would result in <1% of the area covered by feces (Sweeten and Reddell, 1978).

### **Survival of Indicator Bacteria**

Indicator bacteria in fecal material may remain viable for at least one grazing season. Buckhouse and Gifford (1976) found that viable fecal coliform persisted

Table 1. The amount of time cattle spent in the stream and the number of defecations directly into the stream in central Oregon. Time in the stream includes drinking, loafing, etc. From Larsen, 1989.

Season	Cattle Class	Time Spent in	In-stream Fecal
		Stream	Deposit
		min./cow/day	def./cow/day
Summer	cow/calf	11.2	0.41
Fall	cow/calf	3	0.19
Fall	bull	2.3	0
Winter	cow	5.6	0.2
Winter	yearling		0.14
Spring	cow/calf	3.9	0.17
	Average	5.2	0.19

for at least 18 months in the hot dry climate of Southeastern Utah. Clemm (1977) found that FC and FS can survive for more than a year in cattle feces.

Ellis and McCalla (1978) have reviewed pathogen survival in soil and found that survival depends on the organism (e.g., obligate parasite, spore forming, bacteria), moisture, sunlight, pH, temperature, organic matter, other organisms, and toxic substances. They also noted that pathogens survive from a few minutes up to several hundred days (Ellis and McCalla, 1978). Van Donsel et al. (1967) found that a 90% mortality of FC in the soil occurred within 3.3 days during the summer, and 13.4 days in the autumn. They also found a 90% mortality for FS within 2.7 days in the summer and 20.1 days in the winter.

The age of fecal deposits has an influence on the number of indicator bacteria that are released under rainfall conditions. In a simulated rainfall study, fecal deposits less than five days old released FC concentrations on the order of millions per 100 ml. Fecal deposits 30 days old released FC concentrations on the order of 40,000/100 ml (Thelin and Gifford, 1983). Indicator bacterial organisms may be released from fecal deposits for at least 100 days. Hundred-day old fecal deposits produced FC counts exceeding recreational water quality standards, but significantly lower than two-day-old fecal deposits (Kress and Gifford, 1984). Therefore, as the fecal deposits dry, their potential as a source of bacterial pollution is greatly reduced. It would require 1000, 100-day old fecal deposits to release the same amount of FC that are released from one two-day-old deposit under the same rainfall conditions (Kress and Gifford, 1984). Thus, there is potential for bacterial contamination long after the cattle have been removed from a site, but it is greatly reduced.

### Upland Runoff and Vegetative Buffer Strips

To be considered a health hazard, pathogens from fecal material must reach a water body. Bacteria from feces can reach a stream by either direct deposit or by overland transport as runoff from snow melt or rainfall carries viable bacteria into the stream.

Doyle et al. (1975) studied forested buffer strips in controlling microbial pollution on a gravelly silt loam soil spread with 90 metric tons per hectare of dairy



manure. They concluded that no significant movement of bacteria was observed beyond 3.8 m. Glenne (1984) looked at a model which simulated the generation of water pollution in three watersheds in northern Utah. He noted that a buffer strip approximately 50 meters wide is needed to reduce bacterial concentrations by 90% on a 10% slope, and 90 meters wide on a 20% slope. Bingham et al. (1980) studied buffer strips in relation to control of sediments including phosphorus and nitrogen from poultry wastes spread across clay loam fields. They concluded that the buffer strips needed to be as wide as the spread width of manure, i.e. if manure was spread 13 meters wide, at least 13 meters of a buffer strip was necessary.

Other researchers have looked at vegetative filters and their effectiveness for livestock feedlot treatment. Dickey and Vanderholm (1981) found that vegetative filters, up to 400 meters in distance, reduced nutrients and solids by as much as 80%. They also stated that bacteria levels in feedlot runoff were not significantly reduced, with concentrations as high as  $1.05 \times 10^7$  per 100 ml. Dillaha et al. (1988) reported that vegetative filter strips 9 meters wide on a silt loam soil were effective at removing total sediments, but ineffective at removing nitrogen and phosphorus. Dillaha et al. (1988) did not look at bacterial concentrations.

Dixon et al. (1982) estimated pollution transport from cattle stocking rates of zero, normal (10 head/ha), and 4x normal (40 head/ha). These cattle were semi-confined in a winter feeding pasture. Although there was snow and rainfall, the only source of runoff came from irrigation return flow. They found that as stocking rates increased pollution transport. The average annual net pollutant loss was calculated, and shown in kilograms per hectare. The average annual loss for total N was -4.78, 0.99, and 25.66 for zero, normal, and 4x normal stocking density, respectively. Net annual loss for total phosphorus rates were -0.39, 1.62, and 12.03 for zero, normal, and 4x normal stocking density, respectively. Net annual loss of potassium was -12.01, 12.11, and 184.99 for zero, normal, and 4x normal stocking density, respectively. (Negative numbers indicate pollution from the irrigation water remaining on the plots, e.g., a net gain.) TC and FC also showed large increases with values ranging from  $-7.7 \times 10^9$  to  $1.4 \times 10^{11}$  TC/ha/year and  $2.8 \times 10^{11}$  to  $2.4 \times 10^{13}$  FC/ha/year.

The relationship of source-distance to transport with free grazing cattle is not well understood in rangeland environments, and more information is needed (Springer et al., 1983). Buckhouse and Gifford (1976), utilizing a small plot infiltrometer, concluded that one month after deposition bacteria had been transported no further than one meter from the point of deposition in a sandy loam range site in Southern Utah. Larsen et al. (1994) monitored runoff from fresh bovine feces placed on grass sod buffer strips and subjected to simulated rainfall. They found that the number of bacteria was reduced by 83% during a 30-min. simulated rainfall event when the collection point was placed 0.61 m from the manure. Bacterial loads were reduced by 95% if 2.13 m of separation between the feces and the collection point was maintained.

### **Direct Fecal Deposition into a Water Body**

Fecal coverage in the uplands is usually very low (<1%), and rainfall events large enough to cause overland runoff in semi-arid environments are very infre-

quent. U.S. Weather Bureau records indicate that overland flow events occur less than 1% of the time in the most of western United States. Consequently, the primary mode of fecal contamination of rangeland streams may be direct fecal deposit in streams.

The amount of direct fecal deposits into a stream will depend on the time cattle spend in the water body. The amount of time that livestock spend in or near streams can be variable as shown by studies at the San Joaquin Experimental Range (SJER) in the foothills of the Sierra Nevada Mountains in California, and in eastern Oregon. Cattle spent 3-6 min./cow/day drinking at SJER (Wagon 1963), 17 min./cow/day (Sneva 1970), and 26 min./cow/day (McInnis, 1985) in eastern Oregon.

When cattle are present in riparian areas they can deposit fecal material directly into the stream (Johnson et al., 1978). Gary et al. (1983) observed four cattle in 1978 and nine in 1979. During eleven hour observation periods in 1978, 0.50 defecations/cow were deposited directly into the stream from grazing cattle, in 1979 there were 0.33 defecations/cow into the stream. Urinations per cow directly into the stream were 0.25 in 1978 and 0.44 in 1979. In Oregon, researchers found that time spent in the creek and direct in-stream defecations varied by season and class of animal, Table 1 (Larsen, 1989).

In small streams with low flows, the majority of the bacteria in deposited feces will rapidly settle to the stream bottom and can be re-suspended at a later time (Biskie et al., 1988). Biskie et al. (1988) found that 95% of bacteria from a slurry of manure dumped into a stream settled from the water column within 50 meters down stream.

Sediment in a stream bottom can serve as a reservoir of bacteria. Sherer et al. (1988) found that 1.8 to 760 million FC/m<sup>2</sup> and 0.8 to 5,610 million FS/m<sup>2</sup> were resuspended when the stream bottom was raked in different locations. The highest values were obtained near a concentrated feeding area. Sherer et al. (1988) also noted that when cattle had not had recent access to the stream, bacterial counts were similar to an area protected from grazing. These data further support Biskie's results that under low flow (non turbulent) conditions bacteria settle to the bottom of streams rapidly. Stephenson and Rychert (1982) found that bottom sediments contained from 2 to 760 times as much *Escherichia coli* as the overlying water. In contrast, Gary and Adams (1985) found that a cold, snow melt-fed mountain stream in the Medicine Bow National Forest did not support a large reservoir of bacteria in the stream bottom sediments. They found that disruptions of the stream bottom only increased the mean concentration of FC by 1.7 times and FS by 2.7 times. They noted that the areas with the highest concentrations were the most impacted by cattle and sheep.

There seems to be considerable variation associated with indicator organisms in stream bottom sediments as well as in the overlying waters. However, there could be a high concentration of coliforms in stream bottom sediments, especially if livestock are near.

Indicator bacteria can survive for months in an aquatic environment (Sherer et al., 1992). Sherer et al. (1992) found that FC and FS survival in the stream bottom sediments was clearly longer than in the overlying water. Fecal coliform and fecal streptococci had half-lives of 11-30 days, and 9-17 days, respectively. Sherer et al. (1992) also found that die off rates were faster for FS than for FC.

Following the removal of cattle, one to several months may be needed for

coliform counts in a stream to return to background levels (Johnson et al., 1978; Tiedemann et. al., 1987). The long survival of indicator bacteria in stream bottom sediments may partially explain this. Gerba and McLeod (1976) found *Escherichia coli* survived longer in sea water in the presence of sediment. They noted that *E. coli* had a typical mortality rate of 90% within 3-5 days in water void of sediment. In contrast, Clemm (1977) found that FC and FS survived for 3 to 5 weeks in surface water.

Indicator bacteria can be resuspended from stream bottom sediment, making sampling evaluations difficult. This may partially explain some the variation in the literature.

The extent or severity of pollution impact from grazing cattle is dependent upon the number of cattle and where they deposit their feces. Since bacteria and nutrients can persist in steam bottom sediments, daily inputs can accumulate over time. The severity of this accumulation depends on the amount of manure deposited into stream and the dilution ratio of the stream. Peak flows, cattle trampling and other disturbances can re-suspend these contaminants. Concentrating cattle in a feedlot with free access to a stream may also cause adverse impacts on water quality.

### Management Considerations

Based on this review, It appears that potential pathogen pollution problems associated with grazing livestock are primarily from cattle concentrating in or very near streams. Rangeland improvement practices which attract livestock away from riparian zones and associated streams have a positive effect on water quality. Miner et al. (1992) found that a water trough 100 meters from a stream under winter feeding conditions reduced the amount of time cattle spent in the stream by 90%. Clawson (1993) evaluated stream use following placement of a water trough next to a mountain stream in the spring time. He found that the trough significantly lowered the impact of cattle on the riparian area. Use of the stream dropped from 4.7 to 0.9 min./cow/day and use of the bottom area dropped from 8.3 to 3.9 min./cow/day (Clawson, 1993).

Clawson (1993) also evaluated water gap designs. He used water gaps 0.9 and 1.8 m wide, and found that fecal deposition into the stream was completely eliminated. Fecal concentration in the stream and riparian zone can therefore be lowered by practices which help keep cattle away from the stream.

Where cattle cannot be attracted out of water bodies, buffer strips may prove effective tools for preventing fecal contamination from reaching streams via overland flow. If the primary source of surface water contamination is from feces which land in, or very close to, the water a relatively small buffer strip may be adequate to prevent degradation of water quality from grazing animals. Additionally, riparian buffer strips may act as excellent nutrient sinks and buffer nutrient discharge from surrounding agroecosystems (Lowrance et al. 1984). However, buffer strip standards developed in high rainfall zones may not be appropriate for arid and semiarid rangelands. Further research is needed to determine the width(s) necessary to "filter" contaminants in such environments.



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## ***Grazing and Ecosystem Management***

*Bill Krueger<sup>6</sup>*

Grazing management of livestock and of big game are important components of ecosystem management. There are many other components of any ecosystem management plan. My view of an ecosystem management scenario focuses heavily on the people involved in designing the management strategy. The first step is to determine a vision of success. When ecosystem management is successful, what will the landscape look like? What will the strategy do in terms of ecosystem function, i.e., water quality, yield, nutrient cycling, and other aspects relating to sustainability? How will people benefit from management of the ecosystem? Will it produce healthy businesses, quality recreation, aesthetic pleasure, desirable fish and wildlife populations, etc.?

Once the vision is set, then specific objectives that will eventually result in attainment of the vision need to be defined. They should be clear and in the context of manageable units. Coordinated resource management (CRM) is an excellent process to define and accomplish ecosystem management objectives (Anderson and Baum 1988). CRM has been proven effective in setting, implementing, and monitoring for livestock and wildlife habitat objectives. The process is readily adaptable to a multitude of land management practices.

The key is to define the objectives, implement management, monitor results of management, and adapt. The adaptations should be based on what is learned from monitoring to refocus management practices to more precisely achieve the objectives.

The Land Issues Forum (LIFe) in central Oregon developed an excellent process to implement a coordinated resource management planning protocol (Table

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Table 1. The LIFe Coordinated Resource Management Planning Protocol

WHEN	WHO	WHAT	PRODUCT
1st month	LIFe	<p><b>SCOPING:</b> Define the area of land, what got us here (basic issues), where do we want to be a year from now, draft landscape description and desired future condition, existing resources and issues to focus on, sideboards, goals/objectives, possible methods to reach goals objectives. (Possible field trip).</p> <p><b>SOLICIT PARTICIPATION:</b> Identify people, skills, viewpoints, groups that need to be represented.</p>	<ul style="list-style-type: none"> <li>•1st draft of project scope and plan of attack.</li> <li>•Schedule for completion</li> <li>•Work group definition by expertise and source</li> <li>•Mailing list</li> <li>•Letter requesting comment and participation.</li> </ul>
2nd month	LIFe	<p><b>FINALIZE LANDSCAPE DESCRIPTION:</b> Bring new people up to speed. Review all comments received. Develop final landscape description (THIS MEETING SHOULD BE HELD AT FIELD SITE.)</p>	<ul style="list-style-type: none"> <li>•Written marching orders for work group.</li> </ul>
3rd and 4th months	Work Group	<p><b>DEVELOP DRAFT PLAN:</b> Analyze issues and develop plan and actions to reach goals and objectives. Use FOCUS groups to gain additional understanding. Identify issues that are resolved through consensus, compromise, or that are not resolved.</p>	<ul style="list-style-type: none"> <li>•Written draft of plan.</li> <li>•List of issues that were resolved through consensus and compromise.</li> <li>•List of unresolved issues.</li> <li>•List of potential projects to begin NEPA clearances.</li> </ul>
5th month	LIFe	<p><b>REVIEW DRAFT:</b> Review draft and provide comment on format, content and adequacy to accomplish goals/objectives. Provide guidance on unresolved issues.</p>	<ul style="list-style-type: none"> <li>•Written guidance on revisions needed.</li> <li>•Written guidance/direction for dealing with unresolved issues.</li> </ul>
6th month	Work Group	<p><b>FINALIZE PLAN:</b> Using guidance from LIFe group develop final proposal, actions, and alternatives.</p>	<ul style="list-style-type: none"> <li>•Written proposed plan to be submitted to agency.</li> </ul>
7th and 8th months	Agency	NEPA Documentation	<ul style="list-style-type: none"> <li>•Environmental assessment.</li> </ul>
9th and 10th months	Agency	Public review and comment. Provide feedback from and to LIFe (possible meeting).	<ul style="list-style-type: none"> <li>•Response to comments.</li> <li>•Decision.</li> </ul>
11th month and after	Agency landowners per plan	Implementation	<ul style="list-style-type: none"> <li>•Improved resource conditions, realization of landscape description.</li> </ul>

1). This process was based on several years of work attempting to integrate public and private land use to meet the vision of a wide variety of interests—from commercial to agency to environmental. The protocol will help to design and implement complicated coordinated resource management plans in a reasonable time frame. It meets all of the legal mandates of public and private agencies as well as resource needs of commodity and amenity users.

### **Conclusion**

Developing a riparian management strategy for grazing animals is a necessary component of ecosystem management. It requires clear understanding of landscape relationships and should focus on sound grazing management principles. The specific individual characteristics of riparian zones need careful attention. When this is done with full involvement of the people affected, effective grazing management programs can be developed. The keys to successful management are: (1) develop the vision, (2) design management to the vision, and (3) emphasize communication and mutual understanding. Involvement of the people is key, since people will support what they create themselves.