Idaho Forest, Wildlife and Range Policy Analysis Group

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Guidelines for Managing Cattle Grazing in Riparian Areas to Protect Water Quality: Review of Research and Best Management Practices Policy

by

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Philip S. Cook,
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and
Jay O'Laughlin

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Guidelines for Managing Cattle Grazing in Riparian Areas to Protect Water Quality: Review of Research and Best Management Practices Policy

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Role and Mission. The Idaho Legislature created the Policy Analysis Group (or "PAG") in 1989 as a way for the University of Idaho to respond quickly to requests for information and analysis about current natural resource issues. The PAG's formal mission is to provide timely, scientific and objective data and analysis, and analytical and information services, on resource and land use questions of general interest to the people of Idaho.

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EXECUTIVE SUMMARY

Riparian areas* are lands adjacent to water bodies. Consequently, these lands are more moist and more productive than contiguous floodplains or uplands. Riparian areas provide a wealth of products and values including clean water, fish and wildlife habitat, recreational opportunities, and scenic beauty. These lands are also valuable sites for timber production, cropland agriculture, and livestock grazing. Appropriate management of riparian areas is thus a vital environmental and economic issue.

Livestock grazing in riparian areas is controversial. Many riparian areas in the United States have been mismanaged and degraded by improper livestock grazing. However, the negative effects of grazing in riparian areas can be minimized or eliminated with proper management. Grazing management is the key to attaining the benefits riparian areas offer livestock while maintaining water quality standards and fully functioning riparian ecosystems.

Water quality in many of Idaho's waters translates directly into conditions that support adequate habitat for fish. Protecting water quality and providing forage for cattle are only two of the many functions of land areas adjacent to water. This report addresses only the water quality protective functions of riparian zones. This is not to say that the many other values of riparian areas are less important than water quality, but these other purposes are not required by the federal Clean Water Act.

The purpose of this report is to provide management guidelines that will help livestock producers meet the goals of the Clean Water Act while grazing cattle in riparian areas. Depending on the current condition of a particular riparian area, this could mean that the producer may have to modify the timing, frequency, and intensity of grazing in order to maintain conditions that will protect water quality. These guidelines are based on a review of research results published in the scientific literature. That review is in Chapter 1 of this report. Best management practices, or BMPs, are the Clean Water Act's approach to minimizing the adverse impacts of livestock grazing and other land-use activities on water quality. The guidelines in this report may be useful for resource stewardship in riparian areas whether or not a livestock producer is following grazing management strategies that have been officially incorporated into BMPs. Chapter 2 of this report explains the origin and purpose of BMPs, and should be informative not only for producers considering their use but also for officials responsible for designing and overseeing the implementation of BMPs.

In addition, the overall policy context of livestock grazing and water quality in Idaho is addressed in Chapter 3. Two case examples from Idaho (Sawmill Creek and Clover Creek) illustrate the relationship between scientific research and on-the-ground BMP application.

This report attempts to reply to three focus questions about riparian grazing. In short, what management strategies are indicated by research, how are BMPs administered, and how does state policy protect water quality? The full questions and short summaries of the replies are given below.

Focus Questions and Short Replies

Three focus questions were developed by the Policy Analysis Group's Advisory Committee to serve as the outline for this report. Short replies follow, with full replies in each of the three chapters of the report for which the focus questions are chapter titles.

(1) What are appropriate management strategies for cattle grazing in riparian areas?
Cattle grazing in riparian areas affects nutrients, fecal bacteria, sediments, streambanks, and vegetation in the riparian ecosystem, with associated effects on water quality. Appropriate management of grazing involves controlling the timing, frequency, and intensity of cattle use.

*Definitions of this and other technical terms are provided in the **Glossary** at the end of this document.

Riparian grazing plans should be site-specific and based upon the best research and empirical evidence available. Based upon a review of the research literature* the following guidelines are suggested as starting points for developing cattle grazing plans that will protect the functions of riparian areas that affect water quality:

1. To reduce negative impacts of grazing, determine the critical period(s) of a riparian site, and then limit grazing during the critical period(s) to no more often than once every 3 or 4 years. Critical periods and impacts are likely to be either in late spring-early summer, when streambanks are more easily broken down by trampling; or late summer-early fall, when excessive browsing may damage vegetation. Each site has its own critical period that should be individually determined. Important critical period variables are soil moisture, plant species composition, and animal behavior patterns. Sites may be grazed every year if use does not occur during the critical period(s). Extended periods of rest or deferment from grazing may be needed to enable recovery of badly degraded sites.
2. To maintain streambank stability, limit cattle access to surface water when adjacent streambanks and shorelines are overly wet and susceptible to trampling and sloughing. Streambank trampling can often be reduced by capitalizing on the natural foraging behavior of cattle. Cattle generally avoid grazing excessively wet sites or in cold-air pockets. Cattle seek out wind-swept ridges, and they graze on upland forage when it is more palatable than forage in riparian areas.
3. To increase vegetative reproduction, schedule cattle grazing to increase tiller (or sprout) density by periodically removing apical meristems (or growing points) in shoots of desirable plants. More vegetation reduces the transport of nutrients, fecal bacteria, and sediment in overland flow. If new plants need to be established ***and*** if the desirable plant species do not reproduce vegetatively, these plants should be allowed to reach seed maturity no less often than once every 3 or 4 years.
4. To graze a site more than once per growing season, moisture and temperature conditions should be conducive to plant regrowth. For such sites, allow a recovery period of at least 30 to 60 days, depending on vegetation type, before regrazing within the same growing season. Grazing more often and for shorter periods—that is, 3 weeks or less at a time—is preferable to fewer and longer grazing periods.
5. To control the timing, frequency, and intensity of cattle grazing, managers should consider creating smaller riparian pastures with similar, or homogenous, features. Adjusting timing, frequency, and intensity of grazing in individual pasture units is more important than adopting a formalized grazing system.
6. To protect streambanks, prevent cattle from congregating near surface waters. Fencing, alternative water sources, supplemental feeding, and herding work best. Inappropriate cattle grazing will usually first be evidenced by excessive physical disturbance to streambanks and shorelines.
7. To reduce impacts from cattle urine and feces, locate the edges of features where cattle congregate—such as salt grounds, water developments, and winter feeding grounds—away from surface waters to allow the filtering of runoff from heavy fecal accumulation areas through vegetation before the runoff enters surface waters. Although very little research exists, studies of manure-polluted runoff indicate that distances of at least 12.5 to 20 feet from surface waters may be appropriate depending on vegetative cover, soil type, slope, and runoff.
8. To sustain vegetation which protects water quality, herbaceous utilization levels of less than 65% are usually appropriate. Proper grazing intensity will depend on existing riparian condition, grazing system, and management objectives. Stubble heights will vary by type of vegetation. For example, in

*Citations are omitted here, and provided in Chapter 1 of the report in support of these guidelines.

grazed units or pastures, leave an end-of-the-growing season stubble height of 3 to 4 inches for sedges, tufted hairgrass, and similar species, and 2 inches for Kentucky bluegrass. Large bunchgrasses such as basin wildrye will require 4 to 6 inches. Utilization of riparian shrubs should not exceed 50 to 60% during the growing season. Maintaining at least 50% protective ground cover—plant basal area, mulch, rocks, or gravel—is appropriate.

9. To protect banks and reduce impacts from cattle urine and feces, vegetation buffer strips usually should not be necessary when cattle are grazing in riparian areas unless (1) cattle congregate near surface waters to the point that protective ground cover is less than 50%; (2) trampling damage is causing excessive streambank sloughing; or (3) large amounts of feces and urine are being deposited in or immediately adjacent to surface waters. Where buffer strips are necessary to protect water quality, there is little guidance in the literature as to an effective minimum width. However, from studies of manure-polluted runoff widths of at least 12.5 to 20 feet on each side of the stream appear to be adequate to allow filtering of nutrients and bacteria depending on slope, soil type, vegetative cover, fecal concentration, and runoff levels. Water bodies adjoined by steep terrain may need wider strips.

Again, it should be emphasized that ***riparian grazing plans should be site-specific***. These guidelines are principally useful for indicating what the water quality protective functions of riparian areas are, and some basic information that the grazing manager should consider. Given the high degree of variability across the state, neither these nor any other guidelines could serve to indicate what the specific dimensions of an appropriate grazing management plan would be.

(2) What are Best Management Practices?
Idaho's water quality law defines best management practices (BMPs) as "practices, techniques or measures developed, or identified, by the designated agency and identified in the state water quality management plan which are determined to be a cost-effective and practicable means of preventing or reducing pollutants generated from nonpoint sources to a level compatible with water quality goals" (Idaho Code § 39-3602(2)).

In other words, BMPs are officially approved ways of controlling nonpoint source water pollution, or polluted runoff. BMPs include maintenance and operational procedures as well as structural and non-structural controls. BMPs must be technically and economically feasible and socially acceptable. Idaho law requires the implementation of BMPs for mining and forest practices; however, agricultural and livestock grazing BMP implementation is nonregulatory in nature. There is a back-up regulatory program for ensuring compliance.

For private landowners, a BMP is established and implemented by working with a resource specialist from the local Soil Conservation District or the local office of the USDA Natural Resources Conservation Service, or both. A BMP is actually comprised of one or more “component practices” that have been adopted by the Idaho Soil Conservation Commission and listed in the *Idaho Agricultural Pollution Abatement Plan*. Component practice descriptions provide general guidelines and criteria that are adapted at the local level to fit a specific site. A copy of one of these component practices, *Proper Grazing Use, Riparian Areas* is provided in this report as an Appendix.

Monitoring of BMPs is important at two levels. On-land compliance monitoring of individual BMPs is necessary, and so is periodic instream monitoring of the watershed. Monitoring of individual compliance with BMPs indicates whether BMPs have been properly installed to achieve what they were designed to do on the site. Monitoring at the watershed level shows whether water quality standards are being fully supported, as the federal Clean Water Act requires. If not, then BMPs need to be modified until water quality condition is such that standards are fully supported.

(3) How is cattle grazing in riparian areas addressed in Idaho water quality policy?
Cattle grazing in riparian areas can cause

nonpoint source water pollution, and BMPs are designed to control it. Although they are fundamentally important, BMPs are only one part of the water quality policies that address nonpoint source pollution.

Water quality policy is a complex federal-state-local partnership. Numerous agencies and units at all levels of government are responsible for maintaining water quality and the management of the riparian lands that influence water quality.

Idaho has a two-pronged strategy for protection of water quality. The first provides for stream channel protection, dam safety, instream flows, and classification of rivers as natural or recreational, and is primarily managed by the Idaho Department of Water Resources. The second prong is pollution control and is chiefly administered by the Division of Environmental Quality in the Idaho Department of Health and Welfare.

As a state, Idaho must abide by the provisions of the federal Clean Water Act. In 1995, Idaho revised its state water quality law and planning process in order to comply with the Clean Water Act. The new Idaho law (Idaho Code § 39-3601 et seq.) is complex and has not yet been fully implemented in the state. The law requires the Idaho Division of Environmental Quality to identify areas in Idaho having impaired water quality, to improve water quality in those areas, and to prevent water quality in other areas from becoming impaired.

The *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993) is the state's plan to address nonpoint source pollution from agricultural activities including livestock grazing. The most recent plan focuses on BMP development, implementation, coordination, monitoring, and evaluation. It is a source of information about programs that provide technical assistance, information, and cost-sharing to livestock producers.

Many federal and state agencies have roles in the implementation and enforcement of Idaho's water quality policy. At the federal level, the U.S. Environmental Protection Agency is responsible for ensuring that the state complies with the Clean Water Act. The U.S. Forest Service and the Bureau of Land Management manage more than 60% of Idaho's land and have agreed to implement grazing policies that abide by state water quality law. The Natural Resources Conservation Service in the U.S. Department of Agriculture has broad responsibilities for agricultural and conservation programs on private lands.

At the state level, the Idaho Division of Environmental Quality has the responsibility for general environmental protection and administration of state water quality standards. These are the keys to water quality policy. The Idaho Department of Water Resources is responsible for development of the State Water Plan, water allocation, and stream flow protection. The Idaho Soil Conservation Commission is the agricultural and grazing nonpoint source pollution management agency at the state level. Soil Conservation Districts are the local management units for agricultural nonpoint source pollution activities within their boundaries. The Idaho Department of Lands is responsible for implementing the Idaho Forest Practices Act, which is designed to protect water quality in forest areas. This law requires BMPs for silvicultural activities in forested areas. The Idaho Department of Lands also is responsible for managing the 2.4 million acres of state school trust or endowment lands and the beds and banks of navigable streams and lakes. The Idaho Department of Fish and Game is responsible for collecting information about water quality violations resulting in the loss of fish and wildlife resources.

Other policies also affect cattle grazing in riparian areas. The federal Endangered Species Act affects cattle grazing because several of the 20 species currently listed under the Act in Idaho depend on riparian and aquatic habitat. The U.S. Fish and Wildlife Service, and, for salmon and steelhead, the National Marine Fisheries Service are responsible for protecting and recovering species listed under the Endangered Species Act. On federal lands in Idaho, the U.S. Forest Service and the Bureau of Land Management have adopted an interim strategy called PACFISH for protecting riparian areas adjacent to salmon and steelhead streams. PACFISH has provisions that affect livestock grazing in riparian zones. The U.S. Forest Service also has adopted a similar interim strategy called INFISH for addressing the needs of inland native fish, particularly bull trout and including cutthroat trout. Both of these interim policies establish Riparian Habitat Conservation Areas, or buffer zones, where livestock grazing and other activities must be managed so as to protect fisheries. These interim strategies remain in place on federal lands until the Interior Columbia Basin Ecosystem Management Project is completed in late 1998, which through the Upper Columbia River Basin Environmental Impact Statement (available in draft form for public comment until February 6, 1998) is supposed to replace interim guidelines with standards, or “required actions” that will affect livestock grazing on lands administered by the U.S. Forest Service and Bureau of Land Management.

INTRODUCTION

Riparian areas are lands that are adjacent to water bodies. Consequently, these lands are more moist and productive than contiguous floodplains or uplands (see **Sidebar 1**). Riparian areas provide or promote a wealth of products and values including clean water, fish and wildlife habitat, recreational opportunities, and scenic beauty. These lands are also valuable sites for timber production, cropland agriculture, and livestock grazing (see **Sidebar 2**). For all of these reasons, the proper management of riparian areas is important for the environmental and economic health of the United States.

Livestock grazing in riparian areas is a controversial issue. Many riparian areas have been degraded by improper livestock grazing. Negative effects include excessive amounts of nutrients and fecal bacteria delivered to surface waters; destabilized streambanks; increased water temperature; changes in stream structure that are detrimental to fish; decreased yield and reproduction of desirable plants; and undesirable changes in plant species composition and vegetative cover. (For informative reviews, see Kauffman and Krueger 1984, Skovlin 1984, Platts 1991, Fleischner 1994, Ohmart 1996, and Belsky et al. 1997). It is important to remember, however, that the effects of cattle grazing depend entirely upon how the grazing is managed. Well-managed cattle grazing can be compatible with healthy, functioning riparian ecosystems that simultaneously provide a diverse array of other products and values.

From a policy perspective, riparian areas are important for protecting water quality. The federal Clean Water Act requires that the "designated beneficial use" of a water body be maintained (see O'Laughlin 1996). In Idaho, such uses include agricultural water supply, domestic water supply, industrial water supply, cold water biota, warm water biota, salmonid spawning, primary contact recreation, secondary contact recreation, wildlife habitat, and aesthetics (IDEQ 1995). Water quality measurements —and criteria or standards to support designated uses—include such things as temperature, nutrient levels, and sediment loading. Some designated uses require higher levels of water quality than others. Management practices in riparian areas can be especially important for maintaining cold water organisms and spawning and rearing habitat for trout and salmon.

Appropriate grazing management is the key to attaining the benefits riparian areas offer livestock while maintaining water quality

Sidebar 1. What are Riparian Areas?

Riparian areas are lands directly adjacent to creeks, rivers, streams, ponds, or lakes where surface water influences the surrounding vegetation (Chaney et al. 1993*a*). The riparian zone is the transition between uplands where there is seldom standing water and the stream, river, or lake where free flowing or standing water should be common (Svejcar 1997*a*). Riparian areas are difficult to define and delineate because of nearly unlimited variation in hydrology, soil, and vegetation types, and because riparian areas are lands transitional between aquatic and terrestrial systems (see Gregory et al. 1991).

The following definition of riparian ecosystem from the American Fisheries Society (1980) has received widespread support (Windell et al. 1986):

> Riparian ecosystems are wetland ecosystems which have a high water table because of proximity to an aquatic ecosystem or subsurface water. Riparian ecosystems usually occur as transitional zones, or ecotones, between aquatic and terrestrial (upland) ecosystems, but they have distinct vegetation and soil characteristics. Aridity, topographic relief, and presence of depositional soils most strongly influence the extent of high water tables and associated riparian ecosystems. Riparian ecosystems are most commonly recognized by bottomland, floodplain, and streambank vegetation in the West. Riparian ecosystems are uniquely characterized by the combination of high species diversity, high species densities, and high productivity. Continuous interactions occur between riparian, aquatic, and adjacent terrestrial ecosystems through exchanges of energy, nutrients and species.

Sidebar 2. Why are Riparian Areas Important?

Abundant forage, water, and wildlife habitat attract a greater amount of use of riparian zones than their small land area would indicate. Riparian areas are of prime importance to stream function, water quality and quantity, and fisheries habitat. They are also valuable for livestock grazing, cropland agriculture, and timber production (Hansen et al. 1994).

Riparian vegetation slows flood waters, and riparian areas store water that otherwise might contribute to downstream flooding. Stored water is released more slowly, lessening its destructive effects, and extending the seasonal supply of water (see Ponce and Lindquist 1990). The stored water in riparian areas is often an important source of groundwater recharge.

Riparian areas are important for water quality (Svejcar 1997*a*). Riparian vegetation filters sediments and can absorb nutrients, chemicals and other pollutants that might otherwise be released into surface waters or aquifers (Lowrance et al. 1985).

Riparian vegetation decreases erosion and stabilizes streambanks by binding streambank soil. Vegetation further decreases erosion by providing roughness at the interface between the streambank and the water. Water velocity, and thus the energy available for transport of sediment, is decreased. Streambank building may occur during high streamflow periods as sediments are deposited. Deposits of fine fertile soils on many floodplains are due to the filtering effect of riparian vegetation. Within the active channel, vegetation debris, such as logs, create pools and reduce stream gradient.

Riparian areas provide habitat for numerous wildlife species and are critical in the life cycle of many of them (Chaney et al. 1993*a*, 1993*b*; Knopf and Samson 1994). Riparian areas are well-defined habitat zones within drier surrounding areas and provide a large diversity of breeding and forage sites (Kauffman and Krueger 1984). They create a large, significant proportion of edge as compared to upland zones, and as ecotones, contain and support many organisms associated with adjacent aquatic and terrestrial upland habitats (Connin 1991). They also serve as important travel corridors for wildlife (Hansen et al. 1994).

Riparian vegetation provides canopy that affects water temperature by providing solar insulation (Li et al. 1994). Streamside vegetation also controls the food chain of the aquatic ecosystem. If it is removed, organic detritus (or food source) needed to provide food for aquatic organisms is removed, and habitat for terrestrial insects that are a portion of the diets of many fish species is reduced (May and Davis 1982).

Riparian areas provide water, forage, and loafing sites for domestic livestock. These productive, often narrow strips of vegetation attract domestic livestock, particularly cattle, because of the shade, relatively gentle topography, drinking water, and vegetation that may remain palatable long after upland forage begins to cure.

Riparian ecosystems provide many options for humans (Svejcar 1997*b*). They furnish scenic resting areas and shade for recreationists and provide opportunities for hunters, fishermen, birdwatchers, and others.

standards and fully functioning riparian ecosystems.

Objectives

One objective of this report is to provide useful research-based guidelines for riparian area management that are consistent with the national goal of protecting water quality. It is therefore necessary to summarize what research has to say about managing cattle grazing in riparian areas. Chapter 1 contains this information. Although many types of livestock and wild ungulates graze within riparian areas, cattle are the most common livestock in Idaho, and most research studies have investigated cattle. Therefore, this report focuses on cattle.

Although many livestock managers have implemented, or will implement, grazing strategies that maintain the health of riparian ecosystems, many managers may be asked to implement more formal requirements for grazing management called “best management practices,” or BMPs. BMPs are site-specific practices that have been approved by the state to control nonpoint source water pollution, which includes the effects of livestock grazing.

A second objective of this report is to provide an overview of BMPs. What are BMPs, how are they created, and who is responsible for their development and implementation? Chapter 2 replies to these questions. The overall policy context of livestock grazing and water quality in Idaho is addressed in Chapter 3.

CHAPTER 1. WHAT ARE APPROPRIATE MANAGEMENT STRATEGIES FOR CATTLE GRAZING IN RIPARIAN AREAS?

The impact of cattle grazing on riparian ecosystems depends entirely upon how the grazing is managed. The important variables are the timing, frequency, and intensity of grazing. It is important to note that there cannot be one simple recipe for success (Elmore and Kauffman 1994, Briggs 1996). Each situation is unique and requires its own creative, locally tailored solutions. The only way to know for certain whether a management strategy is suitable for a particular site at a specific point in time is first to make an educated guess, then implement the strategy, and then monitor its effectiveness and adjust the practice as needed. This is the essence of an adaptive management strategy (see Walters 1986, Lee 1993).

Riparian grazing plans should be site-specific and based upon the best available research and empirical evidence. The review of the research literature in this chapter summarizes the existing scientific knowledge about management practices for cattle grazing in riparian ecosystems and supports the guidelines presented in the Executive Summary.

Only limited research information is available to offer much practical guidance. Although the literature is replete with studies comparing the effects of cattle grazing to the effects of no grazing (see reviews by Meehan and Platts 1978, Kauffman and Krueger 1984, Skovlin 1984, Platts 1991, Ohmart 1996), most of these studies do not provide much insight for management guidelines because they did not report sufficient details about site conditions and how grazing was managed. These are important lapses in research methods because riparian ecosystems and cattle grazing practices are extremely variable. Some of the more influential riparian site condition variables include hydrogeology, soil moisture, soil permeability, plant phenology, weather conditions, plant palatability, plant regrowth potential, and plant species composition. Important cattle grazing management variables include stocking rates, stock densities, the age and physiological condition of cattle, grazing season, and cattle behavior. All of this variability highlights the underlying principle concerning cattle grazing in riparian areas: cookbook recipes of management prescriptions are likely to fail.

Because of these reasons, a more complete description of the purpose of this chapter is to provide land managers with the best available information to help them make their educated guesses about appropriate management practices for cattle grazing in riparian areas. Research findings about controlling the timing, frequency, and intensity of grazing are presented, as are findings about grazing distribution, grazing systems, and buffer strips. These management topics are discussed with respect to grazing's effects upon nutrients, fecal bacteria, sediments, streambanks, fisheries, and vegetation within riparian ecosystems.

It should be noted that some reviewers felt that this material should be organized differently, with the effects being major headings. We used management topics as the major headings to make the analysis more useful to grazing managers.

Timing and Frequency of Grazing

The effects of cattle grazing on riparian ecosystems depend largely upon when the grazing occurs. This is because biological and physical processes such as plant nutrient uptake, plant growth, infiltration, runoff, and streambank stability are all affected by the season of year and weather conditions. For example, plants are more likely to be harmed by defoliation if grazing occurs late in the growing season when an insufficient number of growing-degree days remain for plants to regrow and replenish their organic reserves.

Frequency of grazing refers to how often a plant is grazed. If given an opportunity to regrow and replenish its organic reserves, a plant can be grazed several times during one growing season. Riparian vegetation is especially resilient to recurring defoliation because moisture is usually available to fuel plant growth. Consequently, well-managed moderate grazing can usually occur more than once per grazing season. Sheeter and Svjecar (1997), however, urged caution when making assumptions about regrowth. They measured very little regrowth when clipping occurred after mid-July. Their study site was a grass-sedge riparian community in the mountains of northeastern Oregon.

The timing of grazing can greatly influence the sustainable grazing capacity of a riparian area. Elmore (1989) described one example in central Oregon where season-long grazing was replaced with spring grazing. This change enabled the stream channel and riparian vegetation to make significant improvement while also allowing a four-fold increase in grazing capacity.

Moderate grazing can usually be sustained in successive years without rest or deferment as long as grazing does not occur during certain critical periods. Each site tends to have its own critical period, or time within a year, when it is particularly vulnerable to grazing damage. Some sites may have more than one critical period. Common examples of critical periods include late spring-early summer periods due to high streambank soil moisture, or late fall due to heavy shrub utilization. A subjective analysis of 34 grazing systems in southwestern Montana led Myers (1989) to recommend that fall-season grazing be limited to about 1 year in 4. Claire and Storch (1983) reported that a rotational grazing system with 1 full year of rest out of every 3 was sufficient to achieve desired streamside management objectives. Minimum 30 to 60-day recovery periods between defoliations are generally appropriate depending on the type of vegetation and provided that moisture and temperature conditions are conducive to plant regrowth (Myers 1989, Allen and Marlow 1994).

It is important to note that riparian areas in degraded condition cannot withstand grazing as frequently as healthy riparian areas. Extended periods of rest or deferment from grazing may be needed to achieve recovery or at least jump-start the process (see Kauffman et al. 1997). The length of this recovery period will vary from site to site.

Effects of Grazing Timing and Frequency on Nutrient Loading to Surface Water. The two nutrients of primary concern for water quality are nitrogen (N) and phosphorus (P). These two are especially significant because one or the other is the limiting nutrient in most streams, lakes, and reservoirs. It has often been assumed that P is the more common limiting nutrient, but an increasing number of studies has identified N as the limiting element, particularly in the western and midwestern U.S. (Marcus et al. 1978, Grimm and Fisher 1986, Lohman and Priscu 1992). Both N and P are essential nutrients for flora and fauna, but excessive amounts of either N or P in water bodies can over-stimulate aquatic plant growth, accelerate eutrophication of lakes, and deplete oxygen levels (Goldman and Horne 1983).

Timing of grazing in relation to precipitation and runoff events can affect nutrient transport from riparian sites to water bodies. Nutrients in cattle urine and feces, especially nutrients that are not adsorbed to sediment particles, are more likely to be transported in overland flow when soil moisture is high or when soils are frozen. Transport decreases drastically with lower initial soil moisture (Heathman et al. 1985). High soil moisture prior to rainfall can also accelerate movement of water into the soil and groundwater. This does not affect groundwater content of total P or ortho-P, but can increase N levels in groundwater (Tennyson et al. 1975).

About 20 to 50% of the forage-N consumed by cattle will be removed from the site either through retention in body tissue or lost to the atmosphere via ammonia (NH_3) volatilization from urine and feces (Dean et al. 1975, Woodmansee 1978, Schimel et al. 1986). Of the N initially excreted in urine, 60 to 80% will be volatilized (Watson and Lapins 1964, 1969). Only negligible amounts of urinary-N will be removed from the soil surface via leaching (Watson and Lapins 1969). About 80% of fecal-N will volatilize if feces remain on the soil surface, but only 5 to 15% if buried by dung (or coprophagous) beetles before the feces dry (Gillard 1967). Senft et al. (1987) found that yearling heifers retained 16% of the forage-N ingested during the growing season, but N retention was negligible when grazing occurred in the dormant season. Nutrient assimilation is also greater when grazing cattle are gaining weight. Shewmaker (1997) estimated that summer cattle grazing removed 0.02 to 0.04 lbs. P per head per day from riparian pastures in central Idaho.

Effects of Grazing Timing and Frequency on Sediment and Streambanks. Siekert et al. (1985) found no effects from cattle grazing on an ephemeral channel with low soil moisture. But if grazing occurs when soils are wet, trampling effects on runoff and streambank stability are aggravated (Tromble et al. 1974; Warren et al. 1986*a*, 1986*b*; Marlow et al. 1987). For example, Bohn and Buckhouse (1985*a*) documented that infiltration in a mountain meadow was unaffected by moderate grazing in September (2.1 ac/AUM), but grazing in October (1.9 ac/AUM) decreased infiltration compared to the ungrazed control. The authors attributed this reduction to October precipitation that increased soil moisture and made soils more vulnerable to compaction from trampling. On a site in southwestern Montana, Marlow et al. (1987) observed that soil moisture levels in late June or early July were not great enough to preclude cattle from utilizing streambanks, but the soil moisture levels were sufficient to render streambanks more susceptible to deformation by trampling. Deformed banks were then more easily eroded. These authors recommended deferring grazing until mid to late summer to allow streambank soil moisture levels to decline. Livestock in their study did not alter streambanks when soil moisture totaled between 12 to 18%.

Summer cattle grazing in Ohio caused little surface runoff or soil erosion, but feeding hay to cattle every winter in the same pasture greatly increased runoff and erosion (Owens et al. 1997). Winter feeding areas should be rotated to prevent one area from being heavily impacted.

Effects of Grazing Timing and Frequency on Fish. Cattle grazing can affect fisheries by changing streamside vegetation which may lead to changes in cover, stream channel size and shape, water temperature, nutrient and bacterial content of water, and abundance and types of food. In addition, cattle excretion and trampling in streams affects water quality and thus fish habitat. Literature examining these changes is reviewed in other sections of this chapter.

No studies were located that examined different timings and frequencies of cattle grazing and their effects on fish. Most studies document the effects of grazing intensity on fish and are reviewed in that section of this chapter.

Effects of Grazing Timing and Frequency on Vegetation. Grazing in riparian areas can be timed to remove apical dominance in grass tillers, which causes more grass shoots to grow (Volland 1978, Dahl 1995). If these new tillers are allowed to establish, the grass stand thickens. More dense stands of grass reduce soil erosion, reduce the velocity of overland flow, increase water retention time within riparian zones, and increase settlement of nutrients, fecal bacteria, and sediment (Parsons 1965, Reed et al. 1984). This reduces P loading because in surface runoff from grazed areas, most P losses are particulate P rather than soluble inorganic P (Sharpley 1981, Lee et al. 1989, Reuter et al. 1992). Losses of soluble nutrients that remain in runoff are controlled by infiltration that is influenced by vegetation. Similarly, physical entrapment and chemical adsorption in soil and vegetation are also the primary mechanisms for capturing fecal bacteria in riparian zones (Gerba et al. 1975).

In a northeastern Colorado floodplain dominated by mature plains cottonwood (*Populus sargentii*) trees, late-autumn (October-November) cattle grazing at a moderate stocking rate (1.2 ac/AUM) reduced yield by willows (*Salix* spp.), but prairie cordgrass (*Spartina pectinata*) yield was greater on grazed rather than ungrazed plots (Sedgwick and Knopf 1991). Cattle grazing in summer vs. winter was compared in north-central Colorado. After 75 to 100 years of cattle grazing, the floristic composition of willow communities did not differ (Cannon and Knopf 1984). However, willows in the summer-grazed pasture were larger and notched (i.e., lower branches were missing), more widely spaced, contained a greater proportion of dead branches, and tended to be located closer to the streambanks (Knopf and Cannon 1982).

Green and Kauffman (1995) found that moderate to heavy fall grazing (48 to 70% utilization) increased plant species richness in dry and moist montane meadows in northeastern Oregon; the increases appeared to be due to disturbance created by livestock that facilitated establishment of weedy species.

Effects of Grazing Timing and Frequency on Cattle Behavior. Cattle browsing of riparian shrubs increases with decreased palatability and availability of herbaceous vegetation (Roath and Krueger 1982*a*). As long as the herbaceous component is succulent and plentiful in the riparian zone, cattle will not utilize shrubs much, even late in the growing season (Kauffman et al. 1983). But cattle shift their diet selection to riparian shrubs if the herbaceous component has been largely consumed or has reached seasonal maturity (Myers 1989, Kovalchik and Elmore 1992). Accordingly, cattle consume more riparian browse in a dry year than they will in a wetter year (Roath and Krueger 1982*a*). If livestock do begin to browse willows, livestock tend to browse the tips of each willow leader once before returning to browse any of them a second time. Grette (1990) observed that about 4 to 5 inches of leader are commonly removed each time.

Some evidence indicates that increased browsing of willows in late summer may be related to a change in the chemical makeup of willows. Hastings (1993) observed that increased cattle browsing of planeleaf willow (*Salix planifolia*) coincided with decreased concentrations of ampelopsin in its foliage. Ampelopsin is a flavonoid, a specific plant metabolite that is believed to be unpalatable to browsing animals.

In mountain meadows shrub utilization by livestock is usually slight as long as an herbaceous stubble height of 4 inches or greater remains. A definite shift in preference typically occurs when the herbaceous vegetation is utilized beyond this level, and the shift is increasingly apparent when stubble height is reduced below 2 inches (Kauffman et al. 1983). These research results are supported by extensive field observations by Kovalchik and Elmore (1992), who reported that cattle begin consuming the current annual growth of willows when riparian herbaceous vegetation is grazed to a 4 to 6-inch stubble height (45% utilization). Browsing of willows is amplified when herbaceous stubble height reaches 2 to 4 inches (65% utilization), and livestock consume all the willow they can when less than 2 inches of herbaceous stubble height remains (85% utilization). Hall and Bryant (1995) recommended that cattle use should be closely monitored when stubble height for the most palatable herbaceous species approaches 3 inches. At stubble heights below 3 inches cattle browsing of shrubs can quickly become excessive. Cattle behavior sometimes becomes visibly more unsettled when their diets shift from herbs to browse, and astute observers can use this behavioral cue to indicate when cattle may need to be relocated.

Cattle may disperse out of a riparian zone before the herbaceous stubble height is reduced below 4 inches. In southwestern New Mexico, Goodman et al. (1989) reported that cattle selection for riparian habitat was highest in July to September, but virtually no cattle use occurred in the riparian areas during the dormant season. This resulted from a relative lack of green vegetation in the riparian zones during the dormant season compared to upland sites where evergreen shrubs provided available browse. Cattle often leave valley and canyon bottoms late in the season when cold air accumulates in the riparian zone, and when late-summer or early-fall rains improve the palatability of the forage on adjacent slopes (Bryant 1982, Roath and Krueger 1982*a*, Gillen et al. 1984, Platts and Raleigh 1984). Conversely, cold-air drainage in flat, broad valleys is not prohibitive and late in the season cattle are often drawn to a riparian area because it contains the only remaining succulent vegetation (Platts and Raleigh 1984). Understanding site-specific animal behavior is critically important for developing a riparian grazing plan.

Allowing cattle to graze an area early in the season may limit utilization of riparian plant communities if surface soil moisture is sufficiently great (Platts and Nelson 1985*a*, Clary and Booth 1993). In central Idaho, Clary and Booth (1993) reported that even as stocking rates increased from light (about 26% relative utilization and 4 to 5-inch herbaceous stubble height) to moderate (37 to 50% relative utilization and 3 to 4-inch herbaceous stubble height), cattle concentrated most of their additional use on the adjacent drier meadow where the vegetation was equally lush early in the growing season. In mountainous rangeland in northeastern Oregon, Gillen et al. (1985) found that during early season grazing (early

June to early August) cattle spent less total time in riparian meadows and occupied these meadows less frequently than when grazed all season long. Marlow and Pogacnik (1986) similarly reported that cattle on a southwestern Montana study area spent more time feeding on upland sites during late June and early July, and more time in the riparian zone from late August through September. Streeter et al. (1974) found that cattle in western Colorado preferred to graze dry meadow sites dominated by grasses rather than wet sites dominated by sedges throughout the entire study period (June 6 to November 8).

Intensity of Grazing

A growing body of research suggests that grazing intensity is the most important variable affecting response of upland range to cattle grazing (Van Poollen and Lacey 1979, Gammon 1984, Pieper and Heitschmidt 1988, Bryant et al. 1989, Dahl et al. 1992). This appears true in riparian ecosystems as well. Even when the timing and frequency of grazing are optimal, the plant-soil-water resource will deteriorate if cattle are allowed to excessively graze within riparian ecosystems.

Intensity of grazing has not been consistently measured across studies. Stocking rates, percent utilization of plants, or stubble heights have all been used to describe grazing intensity. Each measurement has its purpose, benefits, and shortcomings (see Heady 1975, Vallentine 1990). Some researchers caution against recommendations that call for a uniform level of utilization or stubble height to maintain riparian values because they feel these blanket recommendations ignore the inherent complexity of riparian ecosystems (Green and Kauffman 1995).

Effects of Grazing Intensity on Nutrient Loading to Surface Water. The effects of grazing intensity on surface water chemistry are varied, but moderate grazing intensities generally do not increase nutrient concentrations in surface runoff or stream water. Summer cattle grazing in Ohio on fertilized pasture (Chichester et al. 1979) and unfertilized pasture (Owens et al. 1983) caused very little change in surface runoff chemistry (N, P, K, Ca, Mg, Na, S, Cl, C, or salts) compared with ungrazed pastures. Stocking rates were about 0.3 ac/AUM and 0.6 ac/AUM on the fertilized and unfertilized pasture, respectively. Effects of grazing on nutrient runoff were conflicting in studies of fertilized pasture in Nebraska. Concentrations of NH_4-N, NO_3-N, soluble P, total P, Cl, total organic C, and chemical oxygen demand in runoff were increased by cattle grazing in one study (Schepers and Francis 1982). But in another study at the same location, the chemical quality of runoff from the grazed pasture was better than from the ungrazed pasture, cultivated cropland, or urban areas (Doran et al. 1981). The authors suggested that hydrological differences between the areas, the amount of vegetational cover, and wildlife activity may have contributed to differences. The stocking rate in both studies was about 0.3 ac/AUM.

Moderate grazing along a mountain meadow stream in central Colorado did not result in significant changes in suspended solids, NO_3-N, NH_4-N, or orthophosphates in streamwater (Johnson et al. 1978, Gary et al. 1983). Tiedemann et al. (1989) found no relation between intensity of grazing and levels of measured chemical constituents (NO_3-N, PO_4, Ca, Mg, K, Na, or pH) in streamflow in a study of several watersheds in eastern Oregon. On a pinyon-juniper site that had been chained, burned, and planted to crested wheatgrass (*Agropyron cristatum*), Buckhouse and Gifford (1976*a*) found that cattle grazing at 55% utilization (4.9 ac/AUM) did not affect NO_3-N, Na, Ca, P, or K in surface runoff.

Effects of Grazing Intensity on Fecal Bacteria Loading to Surface Water. The contributions of fecal bacteria from cattle grazing to surface runoff and streamwater can be significant. For example, on improved smooth bromegrass (*Bromus inermis*) pasture in south-central Nebraska, fecal coliform counts in runoff increased 5- to 10-fold over ungrazed areas (Doran and Linn 1979, Doran et al. 1981). Cattle stocking rate was about 0.3 ac/AUM. In a high elevation meadow in Colorado, moderate cattle grazing increased fecal coliform and fecal streptococci counts in streamwater 1.6 to 12.5 times and 1.8 to 3.5 times, respectively, compared to levels without cattle present (Gary et al. 1983). Tiedemann et al. (1987) found fecal coliform concentrations were nearly 6 times greater with cattle present than when they were absent. In southwest Idaho, Stephenson and Street (1978) found fecal coliform counts were directly related to the presence of cattle on summer range with moderate to heavy utilization.

Despite the magnitude of increases over background levels, fecal coliform counts in the presence of cattle grazing do not always violate water quality standards. Many states have adopted a primary contact recreation standard for fecal coliform of no more than 200 counts/100 ml. Some studies, such as Johnson et al. (1978) and Gary et al. (1983), found fecal coliform levels within the standard while other studies, such as Hanks et al. (1981), Sherer et al. (1988) and Tiedemann et al. (1988), found levels that violate the standard. The intensity of grazing affects whether coliform levels violate the standard. For example, Tiedemann et al. (1987) found that stocking rates of 19.0 and 20.3 ac/AUM did not lead to a violation of the standard while a stocking rate of 6.9 ac/AUM did. Although most coliforms themselves are benign, higher fecal coliform counts indicate an increased potential for the presence of pathogens, such as *Salmonella* (Bohn and Buckhouse 1985*b*, Tiedemann et al. 1987).

Fecal coliform can survive in feces for at least 18 weeks (Buckhouse and Gifford 1976*b*) so counts may remain elevated long after cattle are removed (Stephenson and Street 1978, Bohn and Buckhouse 1985*b*, Tiedemann et al. 1988). Fecal coliform counts in streams increase dramatically in response to storms and runoff events (Bohn and Buckhouse 1985*b*); however, few studies have examined the movement of fecal coliform from feces deposition sites on land to adjacent surface waters. Buckhouse and Gifford (1976*b*) found very few fecal coliforms appearing in runoff water more than 3.3 feet from the deposition site on dry, chained and seeded, pinyon-juniper range in southeastern Utah. They concluded that feces deposited in streambeds and gullies of dry, ephemeral watersheds with similar soils, slopes, and precipitation posed little danger of contaminating surface waters. Hanks et al. (1981) suggested that bacteria accumulate in manure, on the soil surface, and at shallow depths during dry periods and then is flushed into ephemeral channels during high intensity-short duration thunderstorms and other runoff events. Fecal coliform survival in aquatic environments is affected by turbidity, conductivity, pH, predators, antibiosis, organic matter, algal toxins, dissolved nutrients, toxic metals, and temperature (Tiedemann et al. 1988, Sherer et al. 1992).

The length of time cattle spend in the stream plays a significant role in fecal contamination. Johnson et al. (1978) observed cattle spending less than 1% of the day in the stream, but Gary et al. (1983) estimated cattle spent 5% of the day in or adjacent to the stream, and 6.7 to 10.5% of defecations were deposited directly in the stream. They concluded that the potential for cattle to contribute large amounts of manure to the stream appeared to be great (Gary et al. 1983). The amount of time cattle have access to a stream may influence bacterial concentration more than stocking rate (Tiedemann et al. 1987).

Fecal bacteria collect and proliferate in the bottom sediment of streams (Hendricks and Morrison 1967, Stephenson and Rychert 1982, Sherer et al. 1992). Animal traffic, as well as increased stream turbulence due to runoff, can resuspend sediment-load enteric bacteria (Stephenson and Rychert 1982, Sherer et al. 1988, Sherer et al. 1992). For example, concentrations of fecal bacteria in streamwater along reaches where cattle grazed increased 2.4 to 110 times background levels after disturbing the stream bottom; however, concentrations declined to background levels after only 3 minutes (Sherer et al. 1988). Stephenson and Rychert (1982) suggested that elevated bacterial counts are most commonly the result of resuspension of the stream bottom sediments and organic matter, rather than an influx to the stream.

Cattle grazing appears to have little effect on enteric bacterial concentrations in groundwater because most fecal bacteria are readily filtered by the soil. Studies with *Escherichia coli* have shown that 92 to 97% of the bacteria filter out in the top four-tenths of an inch of soil, and most of the rest filter out in the next 1.6 inches (Gerba et al. 1975). Soil's ability to filter out micro-organisms depends on its texture and pore space (Ellis and McCalla 1978). Fine-textured soils are more effective filters than coarse-textured soils (Butler et al. 1954).

Effects of Grazing Intensity on Sediment and Streambanks. Higher stocking rates generally cause increased sediment production from a site (Gifford and Hawkins 1978; Warren et al. 1986*a*, 1986*b*; Thurow et al. 1988), but some vegetation types are more susceptible than others. Overland erosion problems from cattle grazing are less in coniferous forest and mountain meadow ecosystems with adequate plant cover, but potentially greater in sagebrush steppe, juniper steppe, and salt desert shrub types (Branson et al. 1981, Buckhouse and Gaither 1982).

Overland erosion is not often a problem in riparian ecosystems if abundant vegetative cover and soil organic matter are maintained. Soil organic matter content improves soil structure and increases the cohesion of clay particles (Baver et al. 1972), enhancing infiltration and rendering the soil less erosive. In a subalpine meadow in central Utah, Meeuwig (1965) found no differences in soil organic matter content between moderately grazed plots (2 ac/AUM) and plots that had been excluded from cattle grazing for 6 years.

Infiltration and soil stability are influenced primarily by soil bulk density and the amount of protective ground cover, such as plants, mulch, rocks, or gravel. Infiltration is usually greater with increased amounts of standing vegetation (Dee et al. 1966, Pluhar et al. 1987), but infiltration is more affected by soil bulk density (Meeuwig 1965, Ueckert et al. 1978, Dadkhah and Gifford 1980). Infiltration rates also affect groundwater temperatures, which in turn can greatly modify stream temperatures and fish populations (Hynes 1983, Meisner et al. 1988). Trampling is the most important factor influencing bulk density and infiltration (Dadkhah and Gifford 1980), but trampling effects depend upon soil texture. Soils with greater fractions of silt and clay are more susceptible to compaction than sandy soils (Orr 1960). On Kentucky bluegrass (*Poa pratensis)* riparian meadows, Orr (1960) found that heavy season-long grazing increased soil bulk density in the 0 to 2-inch stratum, but no effect was found below 4 inches. The amount of standing vegetation and litter has more influence on sediment load than does soil bulk density (Meeuwig 1965, Ueckert et al. 1978, Dadkhah and Gifford 1980, Hofman and Ries 1991). Trampling has minimal effect on sediment production when ground cover is greater than 50% (Dadkhah and Gifford 1980). Dadkhah and Gifford (1980) concluded that adequate watershed protection can be obtained on sites with loam soils and less than 15% slope by maintaining 50% protective ground cover—plant basal area, mulch, rock, and gravel—with grass cover being of prime importance in determining sediment yields.

The height of vegetation also affects sediment entrapment. Short, stout herbaceous stems and leaves may entrap more sediment than taller vegetation, which tends to flatten out and offer less flow resistance (Abt et al. 1994, Clary et al. 1996*a*). For example, more sediment was deposited in Kentucky bluegrass sod clipped to a stubble height of one-half inch compared to stubble heights of 3 inches or 8 inches (Abt et al. 1994). However, when the depth of flushing flows exceeds plant height, more sediment may be retained by taller vegetation that bends over and covers the soil surface (Abt et al. 1994, Clary et al. 1996*a*). After 4 cycles of sediment loading and flushing, Clary et al. (1996*a*) found 8-inch and 12-inch stubble heights of Kentucky bluegrass continued to increase sediment retention; retention did not continue to increase under half-inch and 3-inch stubble heights. However, after 4 cycles of loading and flushing, total sediment retention by Kentucky bluegrass did not differ among half-inch, 3-inch, 8-inch, and 12-inch stubble heights (Clary et al. 1996*a*). Vegetational stiffness and cross-sectional area also appear to directly correlate to sediment-deposition enhancement and long-term entrapment (Abt et al. 1994, Clary et al. 1996*a*).

Rumsey (1996) found no difference in sediment deposition among unclipped sites and sites clipped to stubble heights of 1 inch, 3 inches, or 6 inches. Rumsey's sites were in well-vegetated streamside communities dominated by timothy (*Phleum pratense*), spike-rush (*Eleochris* spp.), and bluegrass (*Poa* spp.).

Finally, in a laboratory rainfall simulation with buffer strips of Kentucky bluegrass, Pearce et al. (1997) found that when buffer strips were 5 inches wide, zero-height stubble was more effective than 4-inch stubble at filtering sediment. When buffers were 10 inches wide there was no significant difference in effectiveness between heights, and when buffer strips were 20 inches wide 4-inch stubble was more effective. The authors suggested that vegetation height alone is not a suitable guideline for estimating sediment filtration and that width of the vegetation buffer is more important than vegetation height in filtering sediment (Pearce et al. 1997).

Sloughing and erosion of streambanks can be a significant source of sediment into a stream. Stable and overhanging streambanks are also important for providing thermal and security cover for fish. The longer cattle have access to a stream reach, the more likely accelerated channel alteration will occur from streambank deterioration (Marlow et al. 1989, Myers and Swanson 1996*a*). For example, in an analysis of 34 cattle grazing systems in southwestern Montana, Myers (1989) found that the duration of fall grazing averaged 21 days in systems judged successful and 37 days in unsuccessful ones. Systems were judged successful if they maintained riparian areas in good or excellent condition or demonstrated an upward trend in riparian areas in fair condition and had a high rate of woody vegetation response (Myers 1989). In southwestern Montana, stream channels narrowed and deepened when streambank disturbance from cattle did not exceed 30 feet per 100 feet of stream reach (Dallas 1997).

The effects of cattle grazing intensity on streambank stability depend on the soil texture and its geologic parent material (Trimble and Mendel 1995, Myers and Swanson 1995, Myers and Swanson 1996*b*). Coarse, unconsolidated soils such as those derived from decomposed granite are extremely susceptible to erosion and require vegetation with strong, deep root systems. More cohesive soils with higher clay contents are more resistant to erosion and vegetation is not as important. Vegetation and livestock do not have much impact on bedrock or boulder-lined streams.

Community types dominated by sedges may maintain bank structure and streambank stability under cattle grazing better than those characterized by other graminoids such as Kentucky bluegrass (Platts and Nelson 1989, Kleinfelder et al. 1992). In sedge/grass/willow communities in mountain meadows of central Idaho, Platts (1982) found that streambank alteration was increased over a two-year period by cattle grazing in a three-pasture rest rotation system when streamside utilization ranged from 57 to 78%. These levels of use correspond to stubble heights of less than 3 inches (Clary and Booth 1993). Buckhouse et al. (1981) compared several grazing systems—season long continuous, deferred rotation, rest rotation, August-September, and September-October—and found that regardless of grazing system, a stocking rate of 8 ac/AUM did not accelerate streambank degradation compared to ungrazed areas. Rather than livestock grazing, high runoff and occasional ice floes in winter appeared to be the most significant factors affecting bank cutting on this stream. Hayes (1978) also found that streambank instability tended to be related more to spring discharge than cattle grazing in mountain meadow streams of central Idaho.

Freezing-thawing is another natural destabilizer of streambanks. Bare ground undergoes more freeze-thaw cycles than does ground covered by mulch and the basal area of plants. Bohn (1989) reported that streambanks having just 0.4 to 0.8 inches of mulch and Kentucky bluegrass stubble had 50 to 67% fewer freeze-thaw cycles than did streambanks of bare ground. Sods with dense, deep roots resist freezing-thawing best (Decker and Ronningen 1957).

Effects of Grazing Intensity on Fish. Several studies have compared fish populations in stream reaches grazed and ungrazed by cattle. Most of these studies have compared heavily grazed sites with exclosures and concluded that heavy and very heavy grazing intensities degrade fish habitat and limit the size and vitality of fish populations. Such studies have been conducted in southern Idaho (Keller and Burnham 1982), south-central Montana (Gunderson 1968, Marcuson 1983), northeastern Utah (Duff 1983), northeastern Colorado (Stuber 1985), and southern Nevada (Taylor et al. 1989).

Knapp and Matthews (1996) concluded that cattle grazing harmed trout populations in the mountains of east-central California. When trout density and biomass were compared on a unit-area basis, 3 of 4 ungrazed reaches had higher trout density and biomass than grazed reaches; one reach showed no difference. However, when trout density and biomass were compared in relation to stream length, only one of 4 ungrazed stream reaches had greater trout density and biomass. In two of the 4 reaches there were no differences between grazed and ungrazed areas, and in one reach the trout density and biomass were greater in the grazed area.

Eleven years of exclusion from heavy streamside cattle grazing in northeastern Utah provided no increase in fish production (Platts and Nelson 1985*b*). These authors believed that low numbers of trout, the unknown impact of recreational fishing, and limiting factors created by upstream conditions and transported through the ungrazed area may be reasons that the exclosure failed to increase fish populations despite improved habitat conditions.

Rinne (1988) compared macroinvertebrate populations in a heavily grazed and ungrazed stream reach in northern New Mexico. Although differences existed in the macroinvertebrate populations, the absence of pretreatment data led him to conclude that the differences between grazed and ungrazed areas could be as easily attributed to inherent variation between the stream reaches as to exclusion of cattle grazing.

Two studies found no differences in fish populations between ungrazed areas and sites heavily grazed by cattle. Platts (1982) in central Idaho found that two years of streamside cattle grazing at 75 to 78% utilization did not decrease fish production within a mountain meadow stream that had been protected from livestock grazing in the previous 19 years. However, because this result was only based on two years of grazing, Platts (1982) concluded that it was too early to determine whether this level of grazing intensity was compatible with fish. In central Wyoming, Hubert et al. (1985) found that heavy cattle grazing did not decrease fish production in one stream, but these authors theorized that no differences were observed because the stream habitat had not been highly degraded prior to cattle exclusion, little change in habitat quality had occurred in the 4 years since exclusion of cattle grazing, or fishing pressure was greater inside the exclosure.

No studies were located that examined the effect of light or moderate grazing intensities on fish. Furthermore, only the studies by Platts (1982), Knapp and Matthews (1996), and one site in Hubert et al. (1985) appeared to be conducted on sites where the riparian habitat was not severely degraded immediately prior to exclusion from cattle grazing. Much more scientific investigation is needed into the levels of grazing intensity that are compatible with recovering fish populations and the levels of grazing intensity that are compatible with sustaining already healthy fish populations. Future research must employ more rigorous experimental design in order to eliminate the biases and ambiguities that characterize most studies of the interactions between cattle grazing intensity and fish production (Platts 1991).

Effects of Grazing Intensity on Riparian Graminoids. Exclusion from livestock grazing may initially increase above ground production of grass on sites that were excessively grazed previously, but the benefits may be short-lived. For example, in a Kentucky bluegrass meadow that had been continually grazed, above ground production increased steadily for 6 years after exclusion from cattle, but then began steadily decreasing; after 11 years of exclusion the ungrazed area had lower production and less root mass than an adjacent area that had been continuously grazed all along (Volland 1978).

Kentucky bluegrass sod tolerates heavy defoliation. Ahlgren (1938) found that the carbohydrate content of Kentucky bluegrass rhizomes was not depleted when the sod was clipped to a 1.5-inch stubble height season-long for 6 years. Similarly, Lamman (1994) reported that Kentucky bluegrass could sustain 63 to 70% utilization under season-long continuous clipping. However, Schwan et al. (1949) compared ungrazed, moderately grazed (57% utilization), and heavily grazed (71% utilization) stands of Kentucky bluegrass in a high-elevation meadow and found perennial grass production diminished as grazing intensity increased.

In a riparian meadow in north-central Wyoming, Kentucky bluegrass increased its percentage of the plant community composition under three different summer clipping treatments: clipped biweekly to 1-inch stubble, clipped biweekly to 3-inch stubble, and clipped once in late summer to a 1-inch stubble (Pond 1961). This response occurred under drought conditions. However, clipping to 1-inch stubble reduced the total density and production of native grasses and sedges, comprised mostly of tufted hairgrass (*Deschampsia caespitosa*). Clipping to a 3-inch stubble did not seriously affect the density of the native plants, but did cause a decrease in production on the meadow dominated by sedges, grasses, and forbs, primarily by affecting the sedges.

Redtop (*Agrostis stolonifera*) is also tolerant of grazing. Redtop maintained its yield in an eastern Oregon riparian meadow when clipped to a 0.4-inch stubble height. When clipped to 2 inches or 4 inches redtop produced more yield than unclipped plants (Clary 1995). On riparian sites dominated by timothy in southeastern Wyoming, Rumsey (1996) found no difference in above ground production among sites clipped to heights of 1 inch, 3 inches, or 6 inches. These stubble heights were also compared with unclipped plants and no differences were found in below-ground production. Reid and Pickford (1946) determined that tufted hairgrass in northeastern Oregon can be maintained when grazed to a 3-inch stubble height. This height corresponded to 55% utilization.

In a mountain meadow in Oregon, Dovel (1996) compared three stubble heights (2, 4, and 6 inches) within three different plant communities: bluegrass-clover (*Trifolium* spp.), bluegrass-tufted hairgrass-sedge, and sedge. In all three plant communities, forage yield was greatest when stubble height was 2 inches, and this height did not appear to reduce stand vigor after three successive years of clipping. Plants were clipped three times each summer in June, July, and August, but most of the forage yield was harvested in the June clipping. Temperature and moisture stress later in the summer limited regrowth.

Sedges are generally less tolerant of grazing than Kentucky bluegrass, redtop, or timothy, but more tolerant than tufted hairgrass. Popolizio et al. (1994) reported that percent foliar cover of sedges was not affected by grazing at 65% utilization, and individual sedge species responded differently. Allen and Marlow (1994) reported that moderate cattle utilization of beaked sedge (*Carex rostrata*) resulted in no effect on shoot productivity and an increase in shoot density above ungrazed plants, largely due to rapid growth in July following cattle grazing in June; however, Ratliff and Westfall (1987) found no difference in shoot densities for Nebraska sedge. Nebraska sedge was found to be relatively tolerant to a utilization rate of 64% by Ratliff and Westfall (1987) and 63 to 70% by Lamman (1994). This utilization level corresponds to about a 1.5- to 4.5-inch stubble height (McDougald and Platt 1976).

In subalpine meadows of interior British Columbia, McLean et al. (1963) found that clipping sedges every 60 days to a 2-inch stubble height did not depress forage yields as compared with unclipped plots or those not clipped late in the season. When clipped after the third week of August, sedges were apparently prevented from accumulating as many energy reserves before the plants entered dormancy. Clary (1995) found that clipping high-elevation sedge communities in central Idaho to a 4-inch stubble height did not reduce annual above-ground herbaceous production compared to unclipped control plots, provided that clipping occurred before late August-early September. Defoliation treatments that removed greater than 30% of the annual biomass production reduced the following year's biomass production below that of the control (Clary 1995).

Effects of Grazing Intensity on Riparian Forbs. Appropriate use levels for riparian forbs have not been widely studied. Popolizio et al. (1994) found no difference in foliar cover of forbs between treatments involving no grazing and 65% utilization. Lamman (1994) reported that forbs in a willow/sedge/Kentucky bluegrass riparian community in northern Colorado were not harmed when the overall herbaceous utilization was 63 to 70% under season-long continuous clipping. Clary (1995) noted an increase in forb composition when a high-elevation sedge community was defoliated in June to either a 0.4-inch or 2-inch stubble height, and suggested that additional changes may have appeared if the study had been longer, as 3 years is a short period for successional changes.

Effects of Grazing Intensity on Riparian Shrubs and Trees. Heavy browsing harms most shrub and tree species, and can lead to changes in the composition of the riparian vegetative community (Boggs and Weaver 1992). However, some browsing increases the above-ground production of many shrub and tree species including quaking aspen (*Populus tremuloides*) and willow (Julander 1937, Aldous 1952, Wolff 1978, Molvar et al. 1993).

Many riparian shrub species appear to be more tolerant of leaf and twig removal than do shrubs inhabiting drier sites. Many upland shrubs can tolerate utilization levels of 50 to 60%. These species include antelope bitterbrush (*Purshia tridentata*), rubber rabbitbrush (*Chrysothamnus nauseosus*), curlleaf mountain mahogany (*Cercocarpus ledifolius*), and cliffrose (*Cowania stansburiana*) (Julander 1937, Hormay 1943, Young and Payne 1948, Garrison 1953). Levels of 60-65% utilization are sustainable for serviceberry (*Amelanchier alnifolia*), Utah honeysuckle (*Lonicera utahensis*), and rose *(Rosa jonesii*) (Young and Payne 1948). Redstem ceanothus (*Ceanothus sanguineus*) and snowbrush ceanothus (*Ceanothus velutinus*) are tolerant of utilization levels less than 50% (Garrison 1953). In a montane riparian community in Colorado, Lamman (1994) reported that planeleaf willow could sustain 58 to 70% utilization. In a non-riparian but nonetheless mesic environment in Minnesota and Pennsylvania, Aldous (1952) reported that willow clipped at 50% or 100% utilization during plant dormancy produced more above-ground biomass than did unclipped controls. Under complete utilization, willow stems grew larger but there were fewer of them (Aldous 1952). Aspen tolerate 65 to 70% utilization, although greater improvement in biomass production will occur with lighter use (Julander 1937). Riparian shrubs are generally more tolerant of browsing because they benefit from greater water availability to fuel plant growth.

The effect of grazing and browsing on willow reproduction is a concern because willow seeds are short-lived and are not stored in soil seed banks (Brinkman 1974, Densmore and Zasada 1983). Some willow species readily reproduce vegetatively. First-year willow seedlings are reported to be very sensitive to browsing because of their shallow root system. Browsing of first-year shoots often results in the plants being pulled from the ground, or being killed by trampling (Kovalchik and Elmore 1992). Willow and aspen have been shown to reproduce well as long as herbaceous utilization by livestock does not exceed 70 to 75% utilization. For example, when Shaw (1992) compared no cattle grazing with heavy to very heavy continuous season-long grazing (56 to greater than 75% herbaceous utilization), light-moderate spring grazing (20 to 55% herbaceous utilization), and light-moderate fall grazing (20 to 55% herbaceous utilization), there was no difference in the density of Pacific willow (*Salix lasiandra*) seedlings. Seedling density of another species, sandbar willow (*Salix exigua*), decreased under the heavy/very heavy continuous grazing treatment. Willow seedling density increased in the control and other treatments with the greatest rate of increase in the light-moderate spring grazing treatment. This was apparently due to the increased availability of suitable microsites and reduced competition from surrounding vegetation.

Clary et al. (1996*b*) evaluated sandbar willow, Pacific willow, and narrow-leaved cottonwood (*Populus angustifolia*) under light spring grazing (21% herbaceous utilization, 6-inch stubble height), moderate fall grazing (42% herbaceous utilization, 5-inch stubble height), heavy season-long grazing (70% herbaceous utilization, 2-inch stubble height), and no grazing. For sandbar willow, they found that density was greatest in the spring grazing treatment and least under the season-long treatment. Density in the fall-grazed treatment did not differ from the ungrazed and season-long treatments. For Pacific willow, density did not differ among spring grazing, fall grazing, and no grazing. Pacific willow density was least in the season-long treatment. But when sandbar willow, Pacific willow, and narrow-leaved cottonwood were considered together, Clary et al. (1996*b*) found no difference in stem diameter or stem density among spring grazing, fall grazing, season-long grazing, and no grazing.

For aspen, Sampson (1919) stated that it reproduced well under moderate cattle grazing. Grazing was considered moderate when 50 to 70% of the palatable, non-aspen forage (presumably all herbaceous vegetation) was consumed. Clary and Medin (1990) reported that an aspen/willow plot with moderate to heavy herbaceous utilization by cattle and an ungrazed plot both had sufficient numbers of aspen saplings to sustain the stands after the present-day mature trees senesced. Browsing of riparian shrubs and trees should be monitored closely to limit removal of terminal buds from trees and to limit the amount of second year wood removed from trees and shrubs.

Grazing Distribution

To manage the timing, frequency, and intensity of grazing at appropriate levels, a resource manager must be able to control where livestock grazing occurs. This is often the most difficult management challenge in riparian ecosystems because the water, shade, succulent vegetation, and gentle topography typical of many riparian areas makes these sites very attractive to cattle, especially lactating cows with calves. Utilization in riparian areas often can be reduced by using non-lactating cows instead. Several other management practices can also be used to manipulate livestock distribution. These include water developments, fencing, salting and supplementation, predator control, prescribed burning, fertilization, insect control, seedings, trail building, herding, and selective culling (Holechek et al. 1995, Vallentine 1990). Although fencing will obviously exclude cattle from areas, few of these other practices have been evaluated for their effectiveness in influencing cattle occupation of riparian zones.

Fertilization as a Method of Controlling Livestock Grazing Distribution. Green et al. (1958) fertilized adjacent slopes on foothill rangeland in central California with sulfur (S) and reported significant decreases in the amount of time cattle spent grazing in moist swales during the dry season. Cook and Jefferies (1963) described applying nitrogen fertilizer at the rate of 60 lbs. of N per acre to slopes adjacent to stream valley bottoms in the mountains of northern Utah. This practice increased livestock utilization of slopes. Cook and Jefferies (1963) also increased cattle utilization on slopes by treating the slopes with 2,4-D ([2,4-dichlorophenoxy] acetic acid) herbicide at 2 lbs. acid equivalent per acre. The authors inferred that fertilization and herbicide application helped disperse cattle away from the riparian zones, but no data were presented documenting the effects of the practices on riparian utilization. Livestock were removed from the study area when the most palatable grasses in the bottomlands had reached about 75% utilization. Presumably, this degree of utilization was reached sooner in areas where slopes were not fertilized or treated with herbicides.

Supplemental Feeding Practices for Better Livestock Distribution. Providing supplemental feed may attract livestock away from surface waters. Ares (1953) found that cottonseed meal mixed with salt successfully distributed cattle away from water sources on desert grassland in south central New Mexico. And McDougald et al. (1989) found that cattle utilization of riparian areas was dramatically reduced by moving supplemental feeding sites away from water sources on annual rangeland in central California. Cattle will generally disperse further from supplemental feeding sites if not supplemented too frequently (Melton and Riggs 1964). If possible, protein supplements should not be provided more often than two or three times per week. Energy supplements, however, must be provided daily to prevent reductions in fiber digestion by cattle.

Cook (1967) and Skovlin (1965) used salt as an attractant and reported notable increases in cattle utilization of slopes and forested sites, respectively. Although these authors also inferred decreased cattle use of the riparian zone, neither author presented any data on corresponding utilization levels within the riparian zone. Cattle tend to consume supplemental salt when it is convenient during their normal foraging pattern, but they are not apt to appreciably alter their behavior pattern to obtain salt (Bryant 1982). Consequently, salt placement is generally incapable of overriding the attraction of water, shade, and palatable forage found in riparian zones (Vallentine 1990). Bryant (1982) and Gillen et al. (1984) reported that salting alone was largely ineffective in reducing cattle usage of riparian zones.

Additional Management Strategies for Livestock Distribution. Fencing is the most effective way to control grazing distribution, but fencing is not a panacea. A well-placed fence can be invaluable, but a fence situated in the wrong place can exacerbate existing problems and create several new problems as well. Fencing is expensive to build and maintain, may inhibit the movement of some wildlife species, can interfere with human recreation, and may detract from aesthetics. Fencing can also increase nutrient, fecal bacteria, and sediment inputs to surface waters due to cattle trailing along fences and congregating in fence corners that are located near water.

Additional watering sources that complement seeps, springs, streams, lakes, and reservoirs can usually attract livestock away from riparian zones (Smith et al. 1992). Miner et al. (1992) found that an off-stream water source eliminated 94% of the time that cattle spent standing in a stream under winter feeding conditions. The authors speculated that the warmer water in the tank was a contributing factor. After installing one off-stream watering trough, Clawson (1993) documented an 85% decline in stream use by cattle and a 53% decrease in use of an undeveloped spring. Similarly, installation of an off-stream water trough for cattle in Virginia dramatically reduced streambank erosion, nutrient loading, and fecal bacteria loading caused by cattle grazing (Sheffield et al. 1997). However, Gillen et al. (1984) reported that the presence of upland watering sources did not appreciably influence occupation of riparian meadows.

Tiedemann et al. (1987, 1988, 1989) and Higgins et al. (1989*a*, 1989*b*) studied the water quality effects of three different grazing distribution strategies: no control of cattle distribution; fencing and water developments to attain uniform cattle distribution throughout a pasture; and fencing and water developments to attain uniform distribution plus cultural practices (e.g., seeding and fertilization) to improve forage production. No differences were found in storm runoff, streamflow, or stream chemistry (NO_3-N, PO_4, Ca, Mg, K, Na, and pH) amongst streams in ungrazed areas and any of the grazing distribution strategies. Fecal coliform counts, however, were lower within ungrazed streams than in grazed streams. Grazing with fencing and water developments had lower fecal coliform counts than grazing without any effort to control distribution, and the strategy that included cultural practices had the highest fecal coliform counts. But this comparison was confounded by stocking rate. Although the no control strategy and the fencing/water development strategy were grazed at similar stocking rates, the strategy with additional cultural practices was grazed at a stocking rate about three times greater.

Herding is an effective tool for controlling riparian cattle grazing if it is done diligently. Cattle often must be repeatedly herded to alternative foraging and watering areas that are located in areas unused by livestock or unfamiliar to them. A common thread among successful riparian grazing management systems is the presence of a skillful herder who is committed to maintaining or improving the health of riparian areas (Dallas 1997). In fact, a field survey of 128 stream reaches in Montana found that the only commonalities among successful riparian grazing management programs were the serious commitment and personal involvement of the grazing manager (Ehrhart and Hansen 1997).

Cattle occupation of riparian areas can be influenced by where cattle enter a pasture (Gillen et al. 1985) because they tend to linger in the portion of a pasture first entered. This is especially true if the individual animals are unfamiliar with the pasture. Purposely having cattle enter pastures in successive years through different access points will facilitate better distribution (Roath and Krueger 1982*b*, Gillen et al. 1985). Cattle that return to a pasture in successive years also tend to distribute themselves more completely across a pasture due to their familiarity with the topography, available forage, and the location of water and salt (Arnold and Dudzinski 1978, Bryant 1982, Roath and Krueger 1982*b*). When first released into an area at the beginning of the grazing season, livestock should be moved in small groups to selected sites throughout the pasture. Cattle should not be released at a boundary gate and left alone to find areas upon which to congregate, because once a foraging habit is developed it is very difficult to disrupt by herding (Roath and Krueger 1982*b*). Cattle often form subgroups within herds and a subgroup should be dispersed as a unit (Skovlin 1957, 1965; Roath and Krueger 1982*b*). Otherwise, individuals separated from the subgroup will probably return to former territories. The herder should purposely relocate subgroups to alternative grazing sites rather than merely harassing animals to disperse from a preferred site, which can result in cattle returning within hours to their preferred site. Individual animals sometimes do not respond to herding, and these individuals should be selectively culled from a herd (Skovlin 1957, 1965) to facilitate development of a group of animals that readily responds to herding.

Some authors (e.g., Roath and Krueger 1982*b*, Howery et al. 1996) have extended this concept to recommend that selective culling be used to develop a herd of upland-dwelling cattle. This recommendation is based on the hypothesis that certain individuals within a herd prefer or are accustomed to riparian habitats, whereas others prefer or are accustomed to upland habitats. Although a current research study at Montana State University is evaluating the effectiveness of selectively culling cattle that spend too much time in riparian areas (Mosley and Cote 1997), selective culling on this basis should be considered cautiously because its effectiveness is unknown. Some individual herd members do spend disproportionately more time within riparian areas (Roath and Krueger 1982*b*, Howery et al. 1996), but it is likely that in their absence and without diligent herding, the vacated riparian area would simply be reoccupied by other individuals within the herd. This is what occurred in Scotland when Hunter (1960) selectively culled sheep that had occupied the preferred grazing areas within a pasture.

Grazing Systems

The purpose of any grazing system is to help managers attain better control over the timing, frequency, and intensity of grazing. Grazing systems that provide periodic rest or deferment generally keep plants and soils in better condition, but one problem with rotational grazing systems is that topography and fencing limitations sometimes make it difficult to prevent some livestock grazing from occurring during rest or deferment periods. Also, grazing by insects, rodents, and wild ungulates during rest or deferment periods sometimes impedes the recovery that was intended to occur.

Many grazing systems currently in place were designed with upland conditions of primary concern and not specifically for riparian areas. For example, Myers (1989) examined 34 grazing systems in Montana and 25 (74%) showed no improvement in riparian areas over 10-20 years, while most systems showed improvement on the watershed as a whole. Failures in management also occur when a grazing system developed for a certain stream system is applied to another stream/riparian reach with different ecological or management characteristics (Elmore and Kauffman 1994). Grazing systems must be tailored to the characteristics of a particular riparian area.

Use levels tend to be more important than the grazing system (Clary and Webster 1989). Smaller, more homogeneous riparian pastures offer the best opportunity to closely control grazing use (Platts and Nelson 1985*c*), but with one exception formalized grazing systems alone offer little in the way of proven advantages for managing cattle grazing in riparian areas (Marlow 1985, Clary and Webster 1989, Platts 1991, Elmore and Kauffman 1994, Ohmart 1996). The exception is that rest rotation grazing does appear to offer some benefits.

Rotational grazing systems can mitigate impacts to riparian areas by reducing the portion of time the area is occupied by cattle. For example, a three-pasture rotation system by definition will have two-thirds of an area without cattle at any given time during the grazing season.

A deferred-rotation system was evaluated by Gillen et al. (1984). They reported that riparian meadows were highly preferred by cattle, particularly with late-season grazing. In their study, this occurred because forested sites in the pasture had been logged and alternative forage had matured earlier and become unpalatable by the time cattle entered the deferred pasture. The removal of the tree canopy had accelerated plant growth on the logged areas. Deferred rotation, short duration grazing, season-long continuous grazing, and no grazing were compared by Marlow et al. (1989). They did not detect any differences in streambank stability among these grazing systems during three consecutive drought years in southwestern Montana. This suggests that the interaction or timing between grazing and stream discharge events is the critical factor affecting streambank stability in grazed riparian areas. On the same study area, Davis and Marlow (1990) found that the amount of time cattle spent grazing in a riparian area did not differ among deferred rotation and short duration grazing. However, cattle in the short duration system did spend less time ruminating in the riparian area.

Streambank degradation did not differ among no grazing, season-long continuous grazing, 2-pasture deferred rotation, 4-pasture rest rotation, and heavy late-season grazing where wild ungulates were not allowed access (Buckhouse et al. 1981, Bohn and Buckhouse 1986). Where wild ungulates did have access, grazing differed from no grazing, with season-long continuous and deferred rotation more detrimental than rest rotation. On mountain meadows in northeastern California, rest rotation again showed advantages over season-long continuous grazing by increasing plant basal cover (Ratliff et al. 1972). Myers and Swanson (1996*a*) documented improved streambank stability when a rest rotation grazing system replaced heavy, season-long grazing. And Bohn and Buckhouse (1985*a*) found that in mountain meadows rest rotation compared with no grazing did not result in different rates of infiltration and sediment production, but deferred rotation and season-long grazing responded negatively.

Kovalchik and Elmore (1992) subjectively ranked grazing systems for willow-dominated plant communities. They concluded that early-season grazing and winter grazing systems were highly compatible; rotation, rest-rotation, and deferred-rotation grazing systems were moderately compatible; and spring-fall, deferred, late-season, and season-long grazing were incompatible.

Platts (1991) subjectively rated grazing systems for riparian habitats as related to fisheries needs on a scale of 1 to 10. Continuous season-long use rated lowest (1); deferred-rotation (4) and rest-rotation (5-6) rated moderately; and riparian pasture (8), fencing (9), and complete rest or exclosure (10) rated the highest.

Buffer Strips

Buffer strips are bands of ungrazed vegetation adjacent to surface waters that are designed to remove sediment, nutrients, and fecal bacteria carried by overland flow before such runoff reaches surface waters. Buffer strips remove these materials by slowing the velocity of surface runoff to enhance infiltration, deposition of suspended solids, adsorption to plant and soil surfaces, and absorption of solubles by plants (Lee et al. 1989). For these mechanisms to be effective, overland flow through buffer strips must be slow and shallow (Lee et al. 1989). This is one reason why buffer strips are more effective at filtering runoff from sites with lesser slopes than from steeply-sloped sites (Hamlett and Epp 1994). It is also important to note that sediments and sediment-bound nutrients and bacteria that are trapped during low-to-moderate flow may be flushed out if high overland flow occurs during large storm events or snowmelt runoff (Reuter et al. 1992).

Buffer strips have been studied for their effectiveness as filters of cattle excrement from feedlots and dairies. Buffer strip widths from 12.5 to 20 feet were sufficient to filter nutrients and fecal bacteria from these areas of extremely high cattle concentrations (Doyle et al. 1975, Oksendahl 1997), provided that the rate of overland flow was not excessive (Schellinger and Clausen 1992).

In a laboratory experiment with Kentucky bluegrass sod and dairy manure, Larsen et al. (1994) found that a 2-foot wide buffer strip on a 5% slope reduced fecal coliform in runoff by 83% and a 4.5-foot wide buffer strip by 95%. However, all fecal coliform concentrations measured 20 and 30 minutes after manure application were in excess of 200 counts/ml.

Review of research literature discovered no study involving a field experiment of livestock grazing and buffer strip dimensions. Based on Doyle et al. (1975) and Oskendahl's (1997) studies of manure-polluted runoff, it appears likely that a buffer strip of at least 12.5 feet on each side of a stream may be adequate to protect water quality from coliform bacteria and effectively filter nutrients. Soil type, slope, vegetative cover, fecal concentration, and runoff levels all help determine the width of buffer strip that may be needed. Sometimes the sinuosity of the streambank or shoreline dictates that the buffer strip fence is easier to build and maintain when placed greater distances from the edge of the surface water. Water bodies adjoined by steep terrain may need wider strips (Hamlett and Epp 1994). Much more scientific investigation of the relationship between buffer strip width and water quality for cattle grazing is needed.

CHAPTER 2. WHAT ARE BEST MANAGEMENT PRACTICES?

Idaho's water quality law defines a best management practice (BMP) as "practices, techniques or measures developed, or identified, by the designated agency and identified in the state water quality management plan which are determined to be a cost-effective and practicable means of preventing or reducing pollutants generated from nonpoint sources to a level compatible with water quality goals" (Idaho Code § 39-3602(2)). In other words, BMPs are officially approved ways of controlling nonpoint source water pollution. They include maintenance and operational procedures as well as structural and non-structural controls. They must be technically and economically feasible and socially acceptable (IDEQ and ISCC 1993).

In Idaho, the official source of BMPs for agriculture, including cattle grazing, is the *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993). BMPs are recognized in section 319 of the federal Clean Water Act as the primary mechanism to enable achievement of water quality standards when nonpoint sources of pollution are involved. Each state must develop an implementation plan, which may be regulatory or nonregulatory (O'Laughlin 1996). Idaho law requires the implementation of BMPs for mining and forest practices; however, agricultural and livestock grazing BMP implementation takes a nonregulatory approach, which is sometimes described as "voluntary" in nature.

Agricultural and grazing activities are subject to a back-up regulatory program (IDAPA 16.01.02.350, IDEQ and ISCC 1993). If "designated beneficial uses" are impaired or water quality criteria are not met and BMPs are not used, the Idaho Division of Environmental Quality can take enforcement action. However, the agency has agreed to do this only when an imminent and substantial danger to public health and environment exists and the operator refuses to remedy the situation, or when an operation has been demonstrated to be a significant contributor to pollution and the implementation agencies have made every feasible attempt to bring the operation into compliance with voluntary programs, but the operator refuses to comply (IDEQ and ISCC 1993).

BMPs are not a "one size fits all" approach. A BMP is developed for application to a particular site to address a specific nonpoint source pollution concern based on site-specific data gathered and analyzed by a trained and experienced resource specialist (IDEQ and ISCC 1993). BMPs are designed to meet the landowner's objectives and a site-specific water quality goal. Because of the unique combination of site characteristics, water quality goals, component practices, and decision makers, the selected BMP applied to the site will be unique (IDEQ and ISCC 1993).

How Are BMPs Established and Implemented?

For private landowners, a BMP is established and implemented by working with a resource specialist from either the local Soil Conservation District (SCD) of the State of Idaho or the local unit of the USDA Natural Resources Conservation Service (NRCS), or both. The resource specialist presents to the landowner a number of alternative BMPs that not only meet water quality goals, but also meet the landowner's needs and capabilities (IDEQ and ISCC 1993). Natural resource specialists and engineers from these two agencies provide technical assistance for implementation.

Cost-sharing funds for implementing BMPs are available from a number of sources (Table 2.1). Local offices of SCDs or the NRCS can provide landowners with more information about cost-sharing programs. Cost-share programs require a contract between the farmer or rancher and the SCD, and the contract includes an individual water quality plan. In some watersheds and SCDs, groups of landowners participate in Soil Conservation District Water Quality Projects; however, each landowner still has an individual plan. Each water quality plan is tailored for the individual farm or ranch so as to meet site-specific water quality goals. All water quality plans are required to include "BMPs for all critical areas or pollution sources on the participant's land encompassed in the project area ..." (IDAPA 16.01.144000,02b).

Table 2.1. Cost-Sharing Programs for Agriculture and Livestock Grazing BMP Implementation in Idaho.

Program	**Administrative Agencies**
State Agricultural Water Quality Program (SAWQP)	IDEQ, ISCC, SCD
Conservation Operations Program	NRCS
Resource Conservation and Development Program (RC&D)	NRCS
USDA Demonstration and Hydrologic Unit Projects	NRCS, CES, CFSA
Emergency Watershed Protection Program (EWP)	NRCS
Small Watershed and Flood Prevention Program	NRCS
Cooperative River Basin Studies Program (CRBS)	NRCS
Environmental Quality Incentives Program (EQIP)	CFSA, NRCS
Rural Clean Water Program (RCWP)	CFSA, NRCS
Food Security Act of 1985 (FSA)	CFSA, NRCS
Food, Agricultural, Conservation, and Trade Act of 1990 (FACTA)	CFSA, NRCS
Federal Agriculture Improvement and Reform Act of 1996 (FAIRA)	CFSA, NRCS
Clean Water Act Section 319 Demonstration Projects	EPA, IDEQ
Resource Conservation and Rangeland Development Program (RCRDP)	ISCC, SCD

Agencies:
CES—U.S. Dept. of Agriculture, Cooperative Extension Service
CFSA—U.S. Dept. of Agriculture, Consolidated Farm Service Agency
EPA—U.S. Environmental Protection Agency
IDEQ—Idaho Division of Environmental Quality
NRCS—U.S. Dept. of Agriculture, Natural Resources Conservation Service
ISCC—Idaho Soil Conservation Commission
SCD—Soil Conservation District(s), State of Idaho

Source: Adapted from IDEQ and ISCC (1993)

What are BMPs for Cattle Grazing in Riparian Areas?

A BMP is actually comprised of one or more "component practices" that have been adopted by the Idaho Soil Conservation Commission and are listed in the *Idaho Agricultural Pollution Abatement Plan* (IDEQ and ISCC 1993). For example, Figure 2.1 illustrates the development of a riparian/ wetland BMP from component practices for an irrigated pasture. Component practice descriptions provide general guidelines and criteria that are adapted at the local level to fit a specific site. Therefore, it is impossible to list specific BMPs for cattle grazing in riparian areas. The research results reported in Chapter 1 of this report are intended to help resource specialists, landowners, and local SCDs tailor component practices to achieve a BMP that is appropriate for a specific site.

[Continued on Page 35]