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Practical Grazing Management to Maintain or Restore Riparian Functions and Values on Rangelands

Sherman Swanson[1], Sandra Wyman[2], and Carol Evans[3]

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Abstract

Successful rangeland management maintains or restores the ability of riparian plant communities to capture sediment and stabilize streambanks. Management actions are most effective when they are focused on the vegetated streambank closest to the active channel, the greenline, where vegetation most influences erosion, deposition, landform, and water quality. Effective grazing management plans balance grazing periods, especially those with more time for re-grazing, with opportunities for plant growth by adjusting grazing timing, duration, intensity, and/or variation of use and recovery. Emphasizing either: a) schedules of grazing and recovery, or b) limited utilization level within the same growing season, is a fundamental choice which drives management actions, grazing criteria, and methods for short-term monitoring. To meet resource objectives and allow riparian recovery, managers use many tools and practices that allow rather than impede recovery. Economic decisions are based on both evaluation of investments and ongoing or variable costs, themselves justified by reduced expenses, increased production, or improved resource values. Ongoing management adjusts actions using short-term monitoring focused on chosen strategies. Long-term monitoring refocuses management to target priority areas first for needed functions, and then for desired resource values. Once riparian functions are established, management enables further recovery and resilience and provides opportunities for a greater variety of grazing strategies.

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[1] Sherman Swanson, Ph.D. (sswanson@cabr.unr.edu; corresponding author) – Riparian Extension Specialist, University of Nevada Cooperative Extension; Teaching and Research Faculty, College of Agriculture, Biotechnology, and Natural Resources, University of Nevada-Reno, Reno, NV

[2] Sandra Wyman (swyman@blm.gov) – Rangeland Management Specialist, Bureau of Land Management, Prineville, OR

[3] Carol Evans (Carol_Evans@blm.gov) – Fisheries Biologist, Bureau of Land Management, Elko, NV

Table of Contents

Key Points

- *Proper functioning condition assessments for riparian areas inform managers and provide the foundation for management based on both the priority for at-risk areas and the specific vegetation, water, and landform processes needed to either improve or maintain stream channel and riparian functions.*
- *Reducing stocking rates at the pasture level is often not effective at altering livestock use in riparian areas to support riparian functions and allow recovery.*

- *Grazing practices that manage the timing and length of the grazing period, consequent timing and duration of recovery periods, and the intensity of riparian use can be applied to create conditions for riparian plant communities to recover from disturbance or maintain a healthy state.*

- *There is no single riparian grazing management tool, strategy, or combination of those that is always needed or successful.*

- *Strategies of effective management can be simple and descriptive, for example: allowing shorter periods of grazing and longer periods of rest and recovery; strengthening important plants with shorter grazing periods or moderate use during the growing season; allowing sufficient opportunities for growth and recovery before the next grazing period; and, varying when an area is grazed from year to year.*

Introduction

Healthy and productive riparian areas provide many ecosystem services, including enhanced forage, wildlife and fish habitats, diminished flood impacts, and improved water quality. Riparian ecosystems are inherently dynamic systems subject to a variety of natural stresses and disturbances, including grazing, fires, droughts, floods, earthquakes, and stream channel incision (Corenblit et al., 2007; 2009). Riparian plant communities possess a variety of physiologic properties that allow them to both withstand and recover from disturbances, and provide bank and floodplain stability (Corenblit et al., 2007; 2009).

Most rangeland pastures or allotments used for livestock grazing include riparian areas, and managing livestock in these areas is one of the most contentious issues facing rangeland managers (Wyman et al., 2006). In arid or semiarid landscapes, riparian areas provide green forage longer into summer or other dry periods than do surrounding uplands (Parsons et al., 2003). The nutritious green forage and gentle terrain of riparian areas attract herbivores, often resulting in disproportionate use of these areas compared to uplands (Gillen et al., 1985; Marlow & Pogacnik, 1986). In addition to removing photosynthetic material and changing plant structure, large grazing animals exert physical force that can modify stream banks and change riparian and watershed geomorphology (Trimble & Mendel, 1995). Important ecological and economic benefits can therefore be gained from grazing management designed to either maintain or improve riparian condition (Wyman et al., 2006).

Grazing management practices focused on upland rangeland conditions, like range readiness and an emphasis on stocking rate, can result in damage to riparian areas (Platts, 1991). Range readiness was designed for managing season-long grazing impacts and is not as relevant to short-duration and rotational grazing strategies (Laycock, 2003). Because animals often concentrate grazing in riparian areas, adjusting stocking rates across a large pasture with a limited riparian area may do little or nothing to curtail excess riparian use. This is true until the stocking rate becomes appropriate for the areas that are actually grazed (not the whole pasture including unused areas). Similarly, damage from prolonged use will not be curtailed until the timing, duration, intensity, and variation of use and recovery are modified to accomplish riparian management objectives. Effective riparian management is often more difficult where riparian areas comprise a smaller part of a large pasture. The need for riparian-focused management increases in situations where: few alternative off-stream water sources or other attractants are available to draw livestock away from riparian areas; grazing occurs in the hot or dry season; the period of use is excessively long; or, riparian objectives are not being met.

An understanding of the dynamic nature of riparian areas is necessary to accomplish landscape and ranch objectives. Managing natural and human uses and disturbances must account for the current ecosystem functional state, resistance, and resilience and account for the potential risk of riparian degradation (e.g., channel incision). This review will outline major attributes of riparian plant communities and grazing management with a focus on low-gradient stream types which are most vulnerable to grazing-related impacts.

Riparian Classification and Dynamics

Riparian areas vary tremendously over space and time; therefore, many classification systems have been developed to aid communication, interpretation, inventory, and assessment. Classifications describe local geology and topography, soils, ecoregions, geomorphology (e.g., Kondolf et al., 2003; Rosgen, 2006), hydrology (e.g., Weixelman et al., 2011), vegetation (e.g., Kovalchik & Chitwood, 1990; Manning & Padgett, 1995), and ecological sites (e.g., Stringham et al., 2001; Stringham & Repp, 2010). Classifications can aid in determining which stream reaches or lentic riparian systems (i.e., seeps or standing water wetlands) are most susceptible to grazing influences or most capable of natural recovery. Assessments are qualitative evaluations of a large management area based on site-specific potential to support riparian function or resource objectives. No classification can substitute for assessment (e.g., riparian proper functioning condition assessment; Dickard et al., 2015).

Because of their location in the floodplain, riparian systems must adjust to seasonal and yearly variation in water availability, input of materials during floods, and the kinetic energy associated with the movement of water (Myers & Swanson, 1996b). The magnitude, rate, and frequency of these changes vary dramatically among locations (Rosgen, 1994). Recurring stress from fire (Dalldorf et al., 2013), floods, and droughts has caused riparian systems to adapt recovery mechanisms with riparian plants coevolving to facilitate the process (Corenblit et al., 2007; 2009). Riparian improvement occurs when the net recovery of plants (Sarr, 2002; Boyd & Svejcar, 2004) and channel form (Dickard et al., 2015) exceeds damage from grazing (Wyman et al., 2006) and erosion during hydrologic events (Dickard et al., 2015). There is no fixed strategy or timeline of expectations that is always successful (Fitch & Adams, 1998; Sayre et al., 2012). As Sayre et al. (2012) put it, “Rangeland landscapes are extremely heterogeneous; general principles derived from scientific experimentation cannot be easily or generally applied without adjusting to the distinct societal and ecological characteristics of a location.”

Riparian Plant Response to Grazing

Upland and riparian rangeland ecosystems developed with grazing and browsing by a wide array of herbivores. However, without proper management, grazing and browsing can be detrimental. Riparian stabilizing plants cease to replenish root reserves or to grow roots if heavily stressed by excessive defoliations in the same growing season, in contrast with occasionally, lightly, or moderately grazed plants (Clary & Kinney, 2002; Volesky et al., 2011). Weakened roots can result in weak and unstable streambanks (Clary & Kinney, 2002; Langendoen et al., 2009), in contrast with strong root systems that stabilize stream banks (Micheli & Kirchner, 2002; Simon et al., 2006; Pollen-Bankhead & Simon, 2010), especially on fine-grained or loose soil types.

Proper management involves controlling the timing, duration, and intensity of grazing and varying periods of use and recovery. Plants need leaf area to generate carbohydrates for growth and reproduction, and to store for future growth. All perennial plants can recover from some grazing or browsing. Some perennial plants even experience compensatory production, resulting in more annual production with some herbivory than without herbivory (Boyd & Svejcar, 2004; Guillet & Bergström, 2006). Many plants grow well with moderate defoliation. However, too much or prolonged and repeated herbivory in the same growing season weakens plants’ ability to recover in the short term (Case & Kauffman, 1997; Brookshire et al., 2002; Samuelson & Rood, 2011), even though they can recover when defoliation stops for a sufficient period to allow regrowth and recovery (Hochwender et al., 2012; Roche et al., 2014). This regrowth of leaf material can happen relatively quickly in well-vegetated riparian areas with abundant moisture (Figure 1).

The greenline is a “linear grouping of live perennial vascular plants, embedded rock, or anchored wood above the waterline on or near the water’s edge” (Burton et al., 2011). This vegetation encounters the most erosional stress during floods, and has the best opportunity to slow velocity and induce deposition of materials, stabilize banks, and re-create channel pattern, profile, and dimension appropriate for the landscape setting (Rosgen, 2006). Where streambank instability or changes in channel form may arise from channel widening or channel incision, vegetation along the greenline is most critical. Depending on site potential, greenline, riparian, and floodplain plant communities also contribute wood (Myers & Swanson, 1997) and aid floodplain energy dissipation, sediment and nutrient sequestration, and aquifer recharge (Corenblit et al., 2007; 2009). Riparian vegetation in and beyond the greenline is important for resource values such as wildlife habitat and biodiversity, including sage-grouse late brood rearing (Beck & Mitchell, 2000), and livestock forage (Weixelman et al., 2011). Greenline vegetation and riparian functions help support water quality related to nutrients or other chemicals, sediment, temperature, and other qualities (George et al. 2011; Kozlowski et al., 2013; Hall et al., 2014).

Riparian plants are adapted for recovery from natural stresses and changes to riparian conditions and valley form. The adaptive characteristics of riparian plants enable recovery from short-term grazing events and the accumulated stresses from problematic grazing management. Recovery of plant health may be rapid (within a few growing season months) where the physical environment has not changed access to water (Figure 1), even if the plants were weakened (Baker et al., 2005). Where the vegetation composition has changed, systems will recover, though a few years may be required (Stringham et al., 2001). Recovery may require years or decades for longer-term processes of channel and floodplain development (Schumm, 1979; Harvey & Watson, 1986; Stringham et al., 2001; Sarr, 2002; Simon & Rinaldi, 2006). The requirements for, and rates of, recovery processes vary depending on several factors:

1. Type or species of plants present and expected. For example, rhizomatous plants need an opportunity for net growth, whereas woody plants may need an opportunity for prolonged vertical growth to escape browsing of the terminal leaders (Kovalchik & Elmore, 1992), especially near beaver activity. The growing points of grasses and grass-like plants are at the base of plants unless or until growing points get elevated,

Figure 1. Riparian recovery can be rapid where the physical environment has riparian functions and resiliency that maintains water availability for plant growth. Upper Rock Creek, NV, in October 2011 after rest, 2012 with heavy hot-season use by cows w/calves during drought and September 2013, following a year of recovery. This combination of rest and periodic hot-season grazing began in 2004 with a foundation of riparian functions and resilience.

such as on reproductive stems. Intact growing points allow faster growth. Seed-reproducing plants may need an opportunity to set seed and for seedling establishment and growth. Also, plants vary in the soil water or soil oxygen levels necessary for optimal growth (McIlroy & Allen-Diaz, 2012).

2. Growing conditions. The opportunity for regrowth of both woody and herbaceous plants diminishes as the growing season advances (Boyd & Svejcar, 2004; Reece et al., 1994; Guillet & Bergstrom, 2006).
3. Geomorphic setting. Woody vegetation tends to provide essential structure on steeper high energy streams where a higher gradient and coarser substrate keep dissolved oxygen available to woody roots (Kovalchik & Chitwood, 1990). Herbaceous stabilizers such as sedges, rushes, and bulrushes often grow in wet anoxic (without oxygen) soils, provide high root and rhizome density to reinforce soils and resist erosion (Kovalchik & Chitwood, 1990), and provide strength to streambanks against compression (e.g., trampling) (Kleinfelder et al., 1992).
4. Stage in channel evolution after down-cutting. Considerable erosion of the upper banks of incised channels makes space available for riparian vegetation, floodplain, meander, and pool-riffle development (where possible), and eventual aggradation, depending on sediment supply (Leopold et al., 1964; Newman & Swanson, 2008).
5. Time within the cycle of droughts and floods. Times of low stream levels encourage plant growth into channel below stream margins. Flooding periods can give rise to a variety of changes that include: eroding weak banks, depositing sediments to build banks, cleaning spawning gravels, scouring deeper pools, or integrating coarse wood (Myers & Swanson, 1996a; Chopin et al., 2002; Wyman et al., 2006).
6. Time since a major disturbance. Events such as a very large flood or intense fire, or a change in management can accelerate recovery responses with colonizing plants and increasing functions. Recovery then decelerates as there becomes little difference between current condition and potential (Holland et al., 2005).

Grazing Management Considerations

What Makes Grazing Management for Riparian Areas Successful?

Riparian area grazing management can succeed if it enables control of and variation in duration and timing, periods of grazing and recovery, livestock distribution, and intensity of use. Livestock management strategies can be applied to limit stress and provide sufficient opportunity for plant growth and regrowth. Effective grazing management practices prevent repeated or excess damage to streambanks, soil, and plants when they are most susceptible to grazing-related stresses. Rotation or variation in timing of grazing prevents stress in the same season year after year so plants can successfully complete all phases of their annual life cycle. By actively managing livestock, grazing intensity can also be managed to ensure adequate leaf area for growth or regrowth before, during or after grazing. Alternatively, intense grazing with adequate recovery periods can sometimes be applied to increase forage quality (Phillips et al., 1999), increase hoof action to trample “wolfy” plants or excessive thatch, consume undesirable plants, and stimulate regrowth (Zellmer et al., 1993; Hochwender et al., 2012) while minimizing cumulative impacts on palatable stabilizing riparian plants (Wyman et al., 2006) or favored riparian sites.

Grazing managers have access to a wide variety of tools and strategies for riparian-focused management to accomplish objectives and allow recovery. Emphasizing either planned stress with ample recovery periods (Table 1) or decreasing stress with limited levels of use (Table 2), managers have a fundamental choice. That choice drives management actions, criteria for success, and appropriate criteria for short-term monitoring. Collectively, there must be a combination of practices used that allow more recovery, rather than practices that cause excess damage or preclude recovery. For example, occasional hot season use can be mitigated by very short duration grazing or by incorporating periods of rest or recovery into overall grazing management

(Figures 2 & 3), or by elevation as uplands tend to stay greener longer into the growing season at higher rather than at lower elevations, thus delaying the shift of use to riparian areas.

Every individual tool or strategy can be part of an integrated treatment that does or does not meet objectives. The mix and balance needed for the management situation and objectives are most important. This mixed approach with adaptive management has been applied in the Elko Bureau of Land Management (BLM) District in Nevada, resulting in demonstrated improvement in numerous locations (e g., Kozlowski et al., 2013; Booth et al., 2012) (Figures 2, 3, 4, 5, 6, 7, 8 & 9).

Table 1. Comparison of riparian grazing management strategies related to duration and timing of use and recovery periods that often preclude or support riparian function and recovery.

Often Precluding Riparian Functions and Recovery	Supporting Riparian Functions and Allowing Recovery
Long Season of Use – Plants experience repeated defoliation throughout season Platts, 1991; Clary et al., 1996; Saunders & Fausch, 2007; George et al., 2011; Raymond & Vondracek, 2011.	**Short Grazing Period** – Grazed plants are not re-grazed Myers, 1989; Glimp & Swanson, 1994; Lyons et al., 2000; Lucas et al., 2004; Magner et al., 2008; Saunders & Fausch, 2007; Saunders & Fausch, 2007, 2012; Raymond & Vondracek, 2011; Dalldorf et al., 2013.
Little Time for Recovery – Plants without time to regrow before next grazing event Myers, 1989; Fitch and Adams, 1998; Jansen & Robertson, 2001; Lucas et al., 2004; Saunders & Fausch, 2007, 2012; Dalldorf et al., 2013; Kamp et al., 2013.	**Long Recovery Periods** – All plants recover before subsequent grazing event Myers, 1989; Fitch and Adams, 1998; Lyons et al., 2000; Jansen & Robertson, 2001; Lucas et al., 2004; Magner et al., 2008; Saunders & Fausch, 2007, 2012; Dalldorf et al., 2013; Kamp et al. 2013.
Late Season Use – Little time to regrow or amass residual stubble before dormancy Green & Kauffman, 1995; Parsons et al., 2003.	**Regrowth Before Winter** – Vegetation grows and provides residual to protect streambank at high water in spring Myers, 1989; Boyd and Svejcar, 2004.
Consistent Season of Use – Use repeated in the same phenological stage year after year Gillen et al., 1985; Myers, 1989; Masters et al., 1996a, 1996b; Wyman et al., 2006; Schwarte et al., 2011; Boyd & Svejcar, 2012; Dalldorf et al., 2013.	**Vary Season from Year to Year** – Grazing different seasons or phenology stages every year Gillen et al., 1985; Myers, 1989; Masters et al., 1996a, 1996b; Wyman et al., 2006; Schwarte et al., 2011; Boyd & Svejcar, 2012; Dalldorf et al., 2013;
Repeated Growing Season Use – Grazing every year without rest Platts, 1991; Masters et al., 1996b.	**Occasional Growing Season Rest** – Opportunity for plants to regrow leaves and roots Platts, 1991; Masters et al., 1996a, 1996b.
No Woody Recovery – Woody plants stay short and within height accessible to herbivores Kovalchik & Elmore, 1992.	**Woody Plants Allowed to Grow** – Woody plants grow above grazing height Platts, 1991.
Large Pasture – Lacking riparian objectives Platts, 1991; Masters et al., 1996a, 1996b; Fitch and Adams, 1998; Lucas et al., 2004; Wyman et al., 2006.	**Riparian Pasture** – With riparian objectives Platts, 1991; Masters et al., 1996a, 1996b; Lucas et al., 2004; Wyman et al., 2006.

Table 2. Comparison of riparian grazing management tools and strategies addressing distribution and intensity of riparian use. Strategies that preclude riparian function and recovery are compared to those that generally support riparian function and allow recovery.

Often Precluding Riparian Functions and Recovery	Supporting Riparian Functions and Allowing Recovery
Hot or Dry Growing Season Use – Greener vegetation attracts more grazing use in riparian area Parsons et al., 2003; DelCurto et al., 2005; George et al., 2011.	**Cool or Warm Season Use** – Upland vegetation and warmer temperatures attract livestock to uplands Knopf et al., 1988; Myers, 1989; Platts, 1991; Clary et al., 1996; Masters et al., 1996a, 1996b; Lucas et al., 2004; Saunders & Fausch, 2007; George et al., 2011; Raymond & Vondracek, 2011; Booth et al., 2012.
Season-Long Use – Entire growing season access to riparian area so plants frequently experience herbivory Knopf et al., 1988; Platts, 1991; Saunders & Fausch, 2012.	**Graze Early in Season** – While uplands are attractive and riparian plants have ample time for recovery Clary, 1999; Parsons et al., 2003; Crawford et al., 2004; Evans et al., 2004; Pelster et al., 2004; DelCurto et al., 2005; McInnis & McIver, 2009.
Sustained Heavy Use– Inadequate leaf area depletes carbohydrate reserves Clary et al., 1996; Platts, 1991; DelCurto et al., 2005; Jeffress & Roush, 2010; Teuber et al., 2013.	**Moderate to Light Intensity** – Plants maintain leaf area to sustain carbohydrate reserves and growing points Marlow & Pogacnik, 1986; Clary, 1999; Jansen & Robertson, 2001; Crawford et al., 2004; Lucas et al., 2004; Pelster et al., 2004; Jones et al., 2011; George et al., 2011; McIlroy and Allen-Diaz, 2012; Teuber et al., 2013; Freitas et al. 2014;
Selective Use – Graze the best, leave the rest Stuth, 1991.	**Even Use** – All plants grazed regardless of palatability Kodric-Brown & Brown, 2007.
No Riding or Stockmanship -- No management of livestock placement Gillen et al., 1985.	**Riding, Herding, and Stockmanship** – Manage animal placement away from riparian areas Glimp & Swanson, 1994; Masters et al., 1996a, 1996b; Massman, 1998; Wyman et al., 2006; Bailey et al., 2008; George et al., 2011.
Stragglers – Several animals remain after herd is moved and continue riparian use Masters et al., 1996a, 1996b; Wyman et al., 2006.	**Cleaned Pastures** – All livestock moved during pasture rotations to ensure recovery periods for riparian areas Wyman et al., 2006.
Riparian Water Only – May lack upland attractant Miner et al., 1992; Godwin & Miner, 1996; Jansen & Robertson, 2001; McInnis & McIver, 2001; Stillings et al., 2003; Cote, 2004; Ganskopp, 2004; DelCurto et al., 2005; Wyman et al., 2006; Ellison et al., 2009; George et al., 2011; Kamp et al., 2013; Rigge et al. 2013	**Off-Stream Water Access** – Improved distribution Miner et al., 1992; Godwin & Miner, 1996; Jansen & Robertson, 2001; McInnis & McIver, 2001; Stillings et al., 2003; Cote, 2004; Ganskopp, 2004; DelCurto et al., 2005; Wyman et al., 2006; Ellison et al., 2009; George et al., 2011; Kamp et al., 2013; Rigge et al. 2013.
Salt/Supplement Along Creek or Stream– Added attractant to riparian area Masters et al., 1996a, 1996b.	**Salt/Supplement Scattered Across Pasture** – Improved distribution across pasture Bailey & Welling, 1999; McInnis & McIver, 2001; Stillings et al., 2003; Wyman et al., 2006; Bailey et al., 2008; George et al., 2008; George et al., 2011.
Retain Riparian Dwellers – Concentrated distribution within the riparian area Bailey et al., 2006.	**Select for Hill Climbers** – Wider distribution across the pasture Roath & Krueger, 1982; Glimp & Swanson, 1994; Howery et al., 1996; Bailey et al., 2004; Bailey et al., 2006.

Many streams documented in the Elko BLM District started recovery with herbaceous species and later advanced with willows. Others demonstrated the reverse order. Many streams that grew willows were later dammed by beavers and the ponded water greatly expanded riparian areas and functions (Figure 6), often with expanded herbaceous meadows. Green and Kauffman (1995) concluded that influences of herbivory on species diversity and evenness vary from one community to another. Basing management recommendations on one component ignores the inherent complexity of riparian ecosystems. In other words, there is no cookbook approach that will work on all riparian areas (Wyman et al., 2006).

Figure 2. Recovery with periodic hot-season and intensive use. East Fork of Beaver Creek, NV, in 1985 after annual season-long grazing and in 1998 with rest and periodic short-term hot-season and early-season use by cow-calf pairs beginning in 1988.

Figure 3. Holding or gathering pasture in recovery. West Fork of Beaver Creek, NV, in 1988 with annual hot-season grazing, in 1999 after several years' rest, and 2008 with occasional rest or use for holding, and gathering cow-calf pairs, yearlings, or domestic horses

Season and Duration of Grazing and Rest

Managers must evaluate tradeoffs among the timing, duration, and intensity of grazing to ensure the health of important plants, ensuring an appropriate combination of either stress with recovery or limited level of use to decrease stress during the grazing period. Many tools and strategies can keep important plants healthy (Wyman et al., 2006).

Season of Grazing

Managing season of use addresses changes in species preference, plant growth and reproduction, and trampling effects on soils throughout the year. Animals seek the most palatable forage, constantly shifting both areas grazed and plants selected. Parsons et al. (2003) and DelCurto et al. (2005) found that late summer grazing (when uplands were dry and riparian plants were still green) concentrated livestock use on riparian vegetation. Many have found that cattle graze farther from the stream in the early growing season when uplands are green (Figure 5) (Clary, 1999; Parsons et al., 2003; Crawford et al., 2004; Pelster et al., 2004; DelCurto et al., 2005; McInnis & McIver, 2009). Basing stocking rates on the land area actually used during a particular season may yield more reasonable expectations of grazing levels in riparian areas (Marlow & Pogacnik, 1986). Creating use maps post-grazing each year allows the manager to observe areas that are over- or under-utilized and provides guidance for adjusting use patterns in future years.

As animals enter the mid- to late-growing season, dry or rank upland grasses are less palatable and nutritious and often more nutritious riparian forage is available, along with water, shade and cover. These attributes increase hot-season livestock preference for riparian areas, increasing foraging and other impacts (e.g., trampling and defecation) to the riparian area. So, careful management is important to maintain riparian function. Late growing season grazing may transfer use from grasses and sedges to woody species such as willows and poplars (Jones et al., 2011). Grazing in the spring, or later in the fall and winter (Table 2), when riparian areas are cooler, may encourage cattle to seek warmer hillsides (Platts, 1991). See Wyman et al. (2006) and Figure 6 for examples of changes from season-long grazing to cool season grazing treatments that allow for plant recovery and growth.

Altering the timing of grazing from year to year (Table 1) provides recovery for different plant species at various plant growth stages (e.g., vegetative, boot, seed production, and dormancy) and can maintain or improve riparian conditions (Figure 7). This is because plant needs for growth, seed production, vigor, carbohydrate storage, or root maintenance and development, vary throughout the year, and differ among species.

Changing season of use across years also varies the degree of use in specific areas. Cattle often shift their preference to woody plants when herbaceous vegetation becomes rank with old leaves or too short for efficient grazing (Hall & Bryant, 1995). Overuse in late summer or after a long period of use during the

Figure 4. Photo pair from the Elko BLM District, NV, showing riparian improvements with use of a riparian pasture and spring grazing. Dixie Creek with intermittent flow in 1989, annual season-long grazing and with few off-site waters in a large pasture. Recovery of perennial flow by 1994, with April-May grazing in riparian pasture beginning in 1990.

Figure 5. Showing Elko District BLM, NV, riparian improvements with spring grazing. Top: Coyote Creek in 1977 with annual season-long grazing and in 2010 with rest 1994-1996 followed by early-mid use (April to July) by cow-calf pairs alternating with rest every other year. Middle: Maggie Creek in 1986 with annual season-long grazing, and in 2000 with rest in 1994-1997 then 3-4 weeks of grazing in March to June by cow-calf pairs. Bottom: Susie Creek in 1980 with annual season-long grazing and in 1994 with 4 years early use (late March or early April to late April or mid-May) by cow-calf pairs.

growing season (Clary et al., 1996) becomes a larger problem if livestock consume too many terminal leaders of shrubs and young trees, or too many of the older woody stems needed for recovery and maintenance. How much use is too much depends on site potential, woody abundance and shrub or tree size, riparian needs and resource objectives (Holland et al., 2005), how much recovery time is built into the strategy (Myers, 1989), and other herbivory (e.g., by wildlife) (Brookshire et al., 2002). In a study of thirty-four grazing systems in operation for ten to twenty years in southwestern Montana, Myers (1989) found that time provided for post-grazing herbaceous regrowth, shorter duration of use, or lower frequency of fall grazing (31% vs. 51%) were important factors in successful management based on the vigor, regeneration, and utilization of woody species, and bank stability. Some approaches focus on allowing little or no browsing of woody plants for consecutive years to allow time for terminal leaders to grow above grazing height (Platts, 1991).

Duration of Grazing

The length and timing of the recovery period after grazing is important to riparian health and stability. Therefore, recovery periods must be determined based on the intensity, length, and extent of grazing. Longer duration of grazing within a growing season allows plants to be re-grazed more often, and the added stress of repeated defoliation requires more leaf area or longer recovery periods for plant growth and plant community health. Shortening the duration of grazing and providing growing-season rest, deferment, or recovery decreases or mitigates grazing impacts (Dalldorf et al., 2013) (Figure 2). Fortunately, riparian growing periods last longer than those of drier adjacent uplands, allowing greater flexibility in developing effective grazing strategies.

Figure 6. Improvement with spring and fall (cool season) use. Occurred on Susie Creek, NV, which was grazed until 1991 with annual hot-season use by cow-calf pairs. By 1999, spring and fall (cool season) grazing by cow-calf pairs allowed willow recovery. By 2007, beaver occupied the reach and by 2012 recovery is transitioning the area to cattails and by 2014, a meadow.

Figure 7. Elko Nevada District BLM examples of riparian improvement with a mixture of livestock nonuse and use in different seasons. Top: South Fork of Salmon Falls Creek with unknown grazing in 1979. By 1999, after a mixture of rest, early, hot season, and fall use with cow calf pairs and yearlings enabled willow recovery. By 2012, beavers built dams. Middle: East Fork of Beaver Creek in 1986 with annual hot season grazing. By 2011, after rest from 1993-1996 followed by grazing in May to early July for 3 years alternating with 1 year of July to Sept. at low-moderate stocking rate by cow-calf pairs. Bottom: Beaver Creek in 1988 with annual season-long use and in 2008 after a combination of early use, rest, and periodic hot season grazing by cow-calf pairs or yearlings beginning in 1994.

Rest and Grazing Rotations

Many riparian areas have recovered with rest, an entire growing season or a whole year without livestock use, allowing regrowth or providing a jumpstart to recovery processes (Platts, 1991; Masters 1996) (Figures 2, 3, 5, 7 & 9). Rest allows plants preferred by grazing animals to grow without selective defoliation. Resting a pasture for a whole season or year is a management strategy often used by ranchers in situations where managing animal distribution is difficult. Other ranchers or riparian managers use shorter grazing periods within a growing season. Allowing periods of non-use for part of the growing season and varying this recovery period among pastures (i.e., deferred rotation) is often preferred to resting pastures for a whole year (i.e., rest rotation) because unused forage that accumulates during the year-long rest can delay initiation of growth in spring and subsequently decrease palatability of forage plants. Riparian areas that are in poor condition from past or current management may not recover as well with rest rotation versus deferred rotation systems (Platts, 1991; Masters et al. 1996). With a limited number of pastures, rest rotation systems increase the length of time livestock are in pastures in grazed or non-rest years. Additional duration decreases recovery periods and may not allow for adequate recovery, even in the year of rest; this is especially true of woody recovery. Deferred rotation grazing methods include periods of non-use at a different time each year providing recovery for different plant species at different phenological stages to promote plant vigor and recovery.

Figure 8. Cottonwood Creek, NV, 1973 after season-long (7 months) grazing by cow-calf pairs; and in 2009 after variable dates for two weeks by cows or yearlings using stockmanship since 1995.

Stocking Rate Considerations

The rangeland management profession has long emphasized managing stocking rate to keep forage use within carrying capacity, and many riparian grazing studies have continued this emphasis on utilization or stubble heights (Clary and Leininger, 2000) (Table 2). As pointed out above, leaf area is needed for plants to photosynthesize, and maintaining low or moderate utilization levels can preserve leaf area for continued photosynthesis (Clary & Leininger, 2000). However, overuse in riparian areas has been a persistent challenge because of distribution problems centered on the attractiveness of green riparian forage. Over-emphasis on utilization and stocking rate may obscure other ways to keep plants healthy, and riparian areas thriving (Table 1). In larger pastures with smaller riparian areas, the tendency for cattle to concentrate in riparian areas makes livestock management difficult or less certain, especially in dry seasons when riparian vegetation remains green in contrast to the senescent uplands. Uneven distribution makes adjusting stocking rate less effective. Yet, there are numerous ways to influence animal distribution and riparian grazing intensity, even in large pastures with small riparian areas (Table 2).

Similar to utilization or stubble height standards, streambank trampling limits may be seen as a direct restriction of damage, or used as a tool for regulating intensity of use in general. While the problem may seem to be excessive bank trampling, the problem may also be incised streams and dehydrated or weak plants with weak root systems. The solution to weak plants could be any strategy that maintains plant vigor, or adequate recovery periods (Table 1) that allow stabilizing plants to establish and grow next to and into the water, building a new stronger streambank knitted together with stabilizers. Often it is not limiting the trampling, but enabling the recovery that solves the problem.

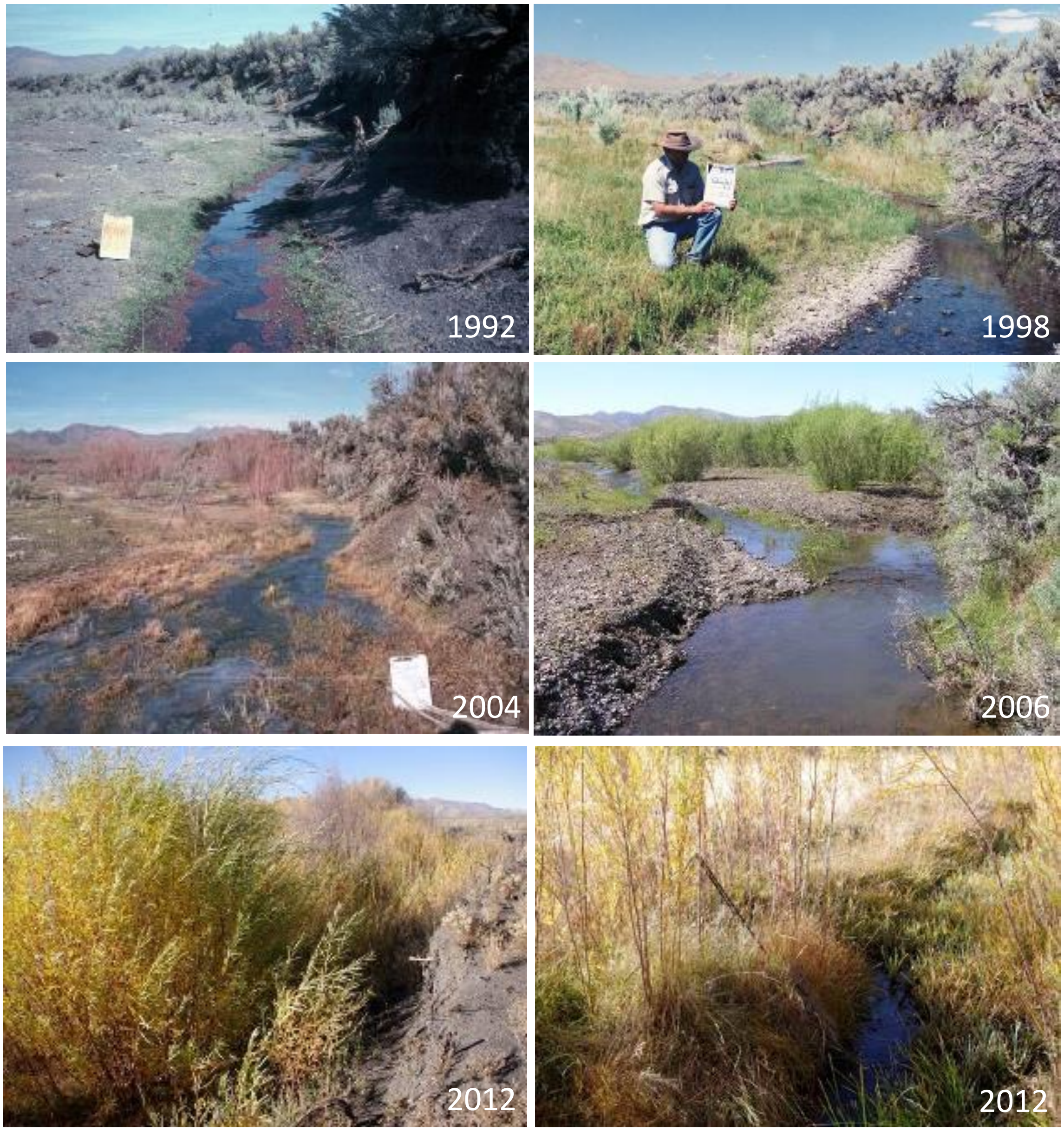

Figure 9. Repeat photos from Indian Jack Creek on the Elko Nevada BLM District in 1992 after season-long grazing by cow-calf pairs; 1998 after rest in 1993-1994 and 1997 and grazing with cow-calf pairs in March to June in 1995-1996 and 1998 as a riparian pasture; 2004 after rest in 2003 and April through July in 2004; 2006 with two years' early season grazing and one year rest for two cycles; 2012 continued recovery with rotation of rest with March-June grazing in 2007, 2009, and 2011; 2012 fire closure rest showing "utilization" cage seen in 2004 and 2006 photos.

Fencing and Pasture Options to Accomplish Riparian Goals

Riparian Pastures

Platts and Nelson (1985) found that timing, duration, and location of grazing can be controlled more effectively in specially managed riparian pastures than in large pastures, providing an easier way to make grazing compatible with other resource uses. Without a riparian pasture, successful treatments for riparian areas may result in only very light use of uplands. Conversely, effective treatments for uplands may result in overuse of limited riparian areas. Fencing limited riparian areas separately from the remainder of the pasture to provide adequate rest or recovery periods (Table 1), or to moderate use intensity for riparian areas (Table 2), may solve the problem, but managers should recognize the cost of fence building and maintenance may be high.

Riparian pastures (Table 1; Figure 4) protect or enhance riparian values while allowing for grazing use. Riparian pastures are generally smaller areas with both upland and riparian vegetation managed together as a unit to achieve riparian objectives (Platts, 1991), or they may contain only riparian vegetation (Wyman et al., 2006). Riparian pastures can be used seasonally in conjunction with rotation strategies, as special-use pastures (such as gathering pastures) receiving bursts of short-duration use, or horse or bull pastures (Figure 3) where stocking for light to moderate grazing (e.g., to a 6-inch stubble height) could be used to improve riparian vegetation and degraded channel conditions (Clary, 1999). Riparian pastures create the opportunity to tightly control stocking rate and season and duration of grazing, to either target or reduce use of important stabilizing plant communities.

Fenced Exclosures

Many miles of riparian areas have been fenced to completely exclude livestock or to allow rest from grazing for one or more years or growing seasons (Table 1). Some allotments or watersheds have been excluded from grazing, and show differences in riparian or aquatic habitats (Myers & Swanson, 1996b; Herbst et al., 2012) or no differences from well-managed grazing (Freitas et al., 2014). Many, but not all, studies have shown dramatic improvements from riparian exclusion, especially in comparison to problematic grazing management (Sarr, 2002). However, many exclosure studies suffer from weak research design (Sarr, 2002) and may not reflect valid comparisons of effects. Also, exclosures often suffer from continued mismanagement of upstream areas that lack the management needed for both watershed and riparian functions and a more steady supply of water and sediment. Or, they risk headcutting when downstream areas incise.

Other Pasture Considerations

Fencing can be an effective tool to control livestock distribution when it is properly located, well-constructed, suitably maintained, and used for application of grazing treatments. Fencing can also be a temporary measure to provide rest and initiate recovery. Fencing water sources at springs and seeps and piping the water to adjacent areas for use is often an effective measure for protecting small riparian areas (Wyman et al., 2006). Designing exclosures with a gate to allow periodic grazing may avoid weed or plant accumulation issues (Kodric-Brown & Brown, 2007; Van Horn et al., 2012).

Permanent fence construction and maintenance is costly and time-consuming. Fence placement near stream banks and stream channels can cause problems where cattle trail along the fence, floods remove the fence, or where the stream meanders through the fence. Fences may also restrict wildlife and livestock movements in an undesirable manner. Marked fences in high-risk areas can prevent wildlife mortalities. Temporary electric fencing is useful for short-term control of grazing. It allows for evaluating alternative placement locations before constructing permanent fencing, breaking up grazing patterns to facilitate transition to new grazing practices, using other parts of the pasture while providing riparian recovery, and also for flexibility in achieving long-term objectives (Wyman et al., 2006).

Managing Livestock Distribution and Riparian Impacts

A number of management tools and techniques can be used in place of or along with fencing. Often times, the use of the following strategies can

Figure 10. Creating upland water sources with a mobile solar powered pump (left) and nose pump mounted on railroad ties (right).

decrease fence and maintenance costs or provide more flexibility in management options.

Livestock Species, Breed, and Individual Variation

Kinds and classes of livestock (i.e., species, age, sex, and reproductive status) influence forage preferences and distribution throughout pastures, depending on terrain, water, and other attractants. Cow-calf pairs tend to concentrate, loaf, and forage in valleys, and may impact riparian areas more than yearling cattle, particularly steers, which tend to range wider and use more upland areas (Wyman et al., 2006) (Table 2). DelCurto et al. (2005) found that cow breed, age, and stage of production all influence distribution. Older cows travel farther from water as long as adequate forage is available in the uplands.

Within herds or breeds, certain individuals spend more time in the valley bottoms while others forage widely (Roath & Krueger, 1982, Howery et al., 1996, Bailey et al., 2004). A three-year study in northern Montana demonstrated that individual animal selection (Table 2) can improve grazing distribution (Bailey et al., 2006). Differences in individual grazing patterns observed in common pastures persisted after cattle were separated from the herd, which led to different riparian stubble heights. If early learning is important to animal behavior (Howery et al., 1996), terrain use could be modified by management and training when replacement cattle are calves.

Sheep and goats may physically damage herbaceous plants less with their nibbling than do cattle and horses, which can dislodge plants with their pulling motion (Wyman et al., 2006). Cattle prefer to harvest grass by wrapping their tongues around clumps, which can only be done when the vegetation is four or more inches tall, thus leaving leaf area for regrowth (Hall & Bryant, 1995). After prolonged use, any herbivore can graze close with their lips and bottom incisors (cattle, sheep, and goats) or lips and upper and lower incisors (horses). Because different animal species have different plant and terrain preferences, the integration of multiple grazing species may improve distribution and plant species composition (Launchbaugh & Walker, 2006).

Figure 11. Cattle attracted by supplements and periodically moved across upland areas graze less in riparian areas.

Prolonged concentration of wild or feral horses can adversely impact riparian meadows (Table 2). Crane et al. (1997) found that riparian sedges were preferred forage for wild horses, and Berger (1986) found meadow use greatly exceeded meadow availability. In various locations, problems have arisen from concentrated use of springs or seeps by feral horses (Jeffress & Roush, 2010). Wild and free-roaming horse and burro management and impact on riparian areas were not even addressed in management handbooks for horses on federal lands until they were revised in 2010 (USDI BLM, 2010). Furthermore, accomplishing appropriate management levels has been politically difficult (National Research Council, 2013). Thus, year after year of season-long grazing by free-roaming horses and burros negates almost all of the management tools in Tables 1 and 2 that can be used with privately owned horses.

Herding

Herded animals offer several options for proper riparian management. Herders control location, timing, intensity, duration, and frequency of use within a grazing season. For example, rather than bedding sheep in a riparian meadow, the herder can move them to uplands or ridge tops. Generally, herders want to keep herds, flocks or bands moving to facilitate forage selectivity. Higher quality herding improves riparian areas and animal gain (Glimp & Swanson, 1994). While herding is generally associated with sheep production, a growing number of cattle producers are using intense herding to manage livestock distribution (Cote, 2004). Skilled stockmanship can aid in animal placement and provide more even grazing distribution, especially in very large pastures if water is well distributed (Cote, 2004; Bailey et al 2006; Wyman et al., 2006).

Turn-Out Location

Placing livestock far from overused riparian areas when moved to a new pasture (turnout) may help regulate the timing, duration, and amount of riparian use in large pastures with adequate stock water (Gillen et al., 1985). Changing turnout locations each year helps vary behavior and use patterns (Wyman et al., 2006). The degree to which livestock can be attracted away from riparian areas depends on timing, topography, vegetation, weather, and behavioral differences (McInnis & McIver, 2001). After turnout, a rider can play a significant role in implementing the strategies in Tables 1 and 2.

Upland and Off-Stream Water, Salt, and Supplements

Water developments in upland areas (Table 2) that lack natural water access can reduce livestock concentration in riparian areas. Moving portable stock tanks (Ganskopp 2001; 2004) or closing access to specific watering points (Wyman et al., 2006) can effectively alter distribution patterns of beef cattle. This improves vegetation use in uplands (DelCurto et al., 2005), and also water quality (Ellison et al., 2009). Rigge et al. (2013) sought optimal placement of off-stream water sources for stream recovery. Tanaka et al. (2007) found that cows having both stream and off-stream water stayed farther away from the stream and used uplands more. Cows and calves gained more weight with off-stream water (Tanaka et al. 2007). The degree to which livestock distribution is influenced by water depends on slope, shade, vegetation, and timing of use, etc.

There are numerous options for offsite water (Figure 10) (Wyman et al., 2006). Livestock prefer to drink from a tank rather than a stream (Chamberlain & Doverspike, 2001) because of problems with depth perception and with steep stream banks or low bank angle, and behaviors adapted for predator avoidance (Wyman et al., 2006). Tanks are also more easily accessed than are many streams, and animals do not have to push through brush, decreasing trampling impacts on young seedlings, sprouts, or saplings (Wyman et al., 2006).

Even within riparian areas or riparian pastures, water developments, ponds, or troughs can reduce stream bank trampling damage (Miner et al., 1992). Tufekcioglu et al. (2013) found that most suspended sediment and phosphorous inputs to streams came from access paths and loafing areas within 15 meters of the stream. However, water developments may concentrate disturbance and create unintended trailing rather than distribute impacts. If feces and urine are concentrating, it is important to consider flow paths and buffering distances from water bodies to strategically locate water, salt, or other supplements to manage water quality (Larsen et al., 1994; Tate et al,. 2003; George et al., 2011). Managers may pipe water from spring developments or ponds to troughs to decrease physical impacts to riparian soil. This may decrease maintenance and extend the life of developments.

Salt and supplements (hay, grain, molasses, protein, etc.) placed in uplands can also improve livestock distribution (McInnis & McIver, 2001; Stillings et al., 2003; Bailey et al., 2008; George et al., 2008) (Table 2) (Figure 11). Providing cattle free-choice off-stream water and trace mineralized salt lessened negative impacts of grazing on cover and streambank stability (McInnis & McIver, 2001). Proper salting improved both distribution and utilization, but not as effectively as water developments (Ganskopp, 2001) or strategic placement of energy or protein supplements in both moderate and difficult terrain (Bailey & Welling, 1999). Practices that reduce fecal and urine deposition in riparian and stream flow generation areas can reduce nutrient and pathogen loading of surface water (George et al., 2011; Roche et al., 2013) and increase the number of grazing days in large pastures by improving livestock distribution.

Reducing Stream Access and Impact

Other tools that can reduce animal impacts to riparian areas include placement of rocks (Wyman et al., 2006) or felled trees (Matney et al., 2005) to shift animal use away from stream banks or to reduce use of specific riparian plants like willows and cottonwoods. Building hardened crossings to provide more secure footing for animals and a gentler streambank for a few meters can concentrate animals and minimize animal impacts along specific stream areas (Massman, 1998). Narrow, rocked or hardened access points to the stream placed within an otherwise fenced stream, but not across a stream, encourages cattle to back away from the stream and deposit manure away from the stream, rather than walk forward and deposit manure in or close to the stream, as they leave the stream after drinking.

Adaptation Needed to Keep Riparian Management on Track

No matter which grazing treatment is selected, success ultimately depends on the livestock managers' support and use of a grazing management plan. Ehrhart and Hansen (1998) concluded that the skill and attention of the manager is more important than the particular management approach used. Design of a grazing treatment differs depending on the location, extent, and condition of the riparian area within the pasture(s), compatibility with the overall ranch management plan, people involved, agency requirements, weather patterns, livestock, and wildlife, etc. (Wyman et al., 2006). Success also depends on continued adaptation over time as riparian and other resources and rangeland management issues and opportunities change, and as people and livestock behaviors adapt.

Riparian areas that function properly are much more resilient and resistant to crossing an ecologic or geomorphic threshold, withstanding grazing pressure, and recovering from short-term impacts (Dickard et al., 2015). Often a functional-at-risk condition with a static or downward trend suggests an initially conservative approach to improve degraded riparian areas. As riparian areas recover, more flexibility in management can be applied and this may facilitate management outside the initially targeted riparian area for other important resource objectives. Considering impacts of grazing on adjoining areas avoids unintended consequences for optimal management of the whole watershed, allotment, or ranch. Monitoring informs "integrated riparian management processes" (Dickard et al., 2015) as riparian areas change through time, regain functions, meet management objectives, require fine tuning for unmet needs or evolving priorities, or regain resilience that allows more flexibility in management.

Appropriate management starts with realistic objectives based on the ecological potential and management expectations for the site, as well as the drivers of system response. Good objectives are measurable, worthy of the cost of management and monitoring, and relevant to management, stream functions, and resource values. For example, management objectives to improve riparian species composition and channel form or water quality could be stated as the proportion of banks dominated by stabilizing plants or plant communities and measured using greenline monitoring methods like those found in Multiple Indicator Monitoring (Burton et al., 2011).

It is important that grazing use indicators and criteria fit the treatments and strategies chosen for implementation (University of Idaho Stubble Height Study Team, 2004), and that they are implemented for a sufficient length of time to determine if they succeed in helping to achieve resource objectives, or at minimum an upward trend toward objectives. To both ensure appropriate management and enable sufficient flexibility to adapt this management as riparian areas, watershed vegetation, management priorities, and professionals' understanding of a specific area change, a plan, environmental assessment, or environmental impact statement could be written around a set of core grazing principles that inform grazing use indicators. Such principles allow for flexibility and success on any use area or in an allotment plan:

1. Strengthen important forage plants with only short periods of use or moderate intensity use during the growing season.
2. Provide sufficient growing season recovery before next use.
3. Graze at a different time from one year to the next.

Economic Considerations

Economic considerations often determine the applicability of a grazing strategy. Riparian management strategies can add net benefits or net costs, depending on requirements for riparian function and how managers meet them. Grazing management for specific objectives generally requires input of labor and materials as well as opportunity costs from forgone animal production (Jeffrey et al., 2014). To some degree, the producer can invest in up-front labor and materials for developing infrastructure, such as fenced pastures, to reduce ongoing labor costs. Controlling season or duration of use requires the ability to place animals in specific areas and keep animals from grazing other areas while those recover. In very large pastures, allotments, or ranches, this can be achieved with a minimum of fences by herding or stockmanship (Cote, 2004). On most ranches, fences often reduce labor for livestock management. The cost of fence building and maintenance varies by location, soils, terrain, and snow depth, as do many other management inputs. These need to be considered when determining ranch management strategies. The benefits of riparian management may include net proceeds to the business as well as a variety of ecosystem services that are more difficult to measure but which increase quality of life, public acceptance, and value of working ranches, while at the same time reducing risk.

Some riparian management strategies increase production or reduce ranch costs. Riparian pastures (Platts, 1991) can extend the green-feed period for weight gain. Earlier grazing can substitute for feeding expensive hay or grazing on leased pasture. When this is followed by rotational grazing on private pastures during breeding, fewer bulls can cover the herd and increase calving rates (Ken Connelly, former manager at University of Nevada Gund Ranch, personal communication, August 4 2006). Control of animals with low-stress livestock handling allows for more intensive use of forage supplies with improved distribution, as does development of livestock waters away from riparian areas (Cote, 2004) and placement of supplements at target areas (Bailey & Stephenson, 2013). Range riders can also recognize problems as they develop, which is an often overlooked benefit of this strategy. Riding and moving cattle to underused areas often extends periods of use in pastures with utilization criteria-based management. These techniques can increase time and use or amount of AUMs in a pasture or allotment before exceeding riparian grazing use criteria. Rotation of animals can increase or decrease parasite and disease problems (Stromberg & Averbeck, 1999), increase or decrease weight gain, and pre-condition forage for other livestock or elk (Clark et al., 2000), sage-grouse (Beck & Mitchell, 2000; Crawford et al., 2004), or other wildlife with hunting, conservation, or recreational value. Accelerated upward trend and improved riparian functions each decrease risk of erosion and water quality issues (Kozlowski et al., 2013), and store water for increased forage production while improving fish and wildlife habitat and recreational or aesthetic values.

Many riparian problems started for economic reasons. Sending livestock to the mountain during the growing season increased ranch capacity, decreased labor costs, and allowed ranchers to focus on hay production. Addressing riparian grazing problems such as over grazing can be expensive. Limiting utilization or leaving residual stubble height without changing dates of use or some other management often reduces AUMs harvested while leaving abundant ungrazed forage in uplands. Then extra hay, grazing land or leases, or decreased herd size may be needed to offset unused forage. For this reason, adjusting stocking rate without changing other management strategies (components) is often the least economical way to correct riparian problems and it may not affect needed resource improvement (Wyman et al., 2006).

Allowing for riparian area recovery may require adjustments to the infrastructure and labor expense. Adjustments or changes in infrastructure may be required for selected strategies. Fence construction and maintenance require labor and materials, and acquiring approval for construction on public land can take years.

Moving and placing animals requires skilled labor, especially without division fences. A successful grazing management strategy requires sufficient water for herd size. Widely scattered livestock can use small troughs or surface water. Without a creek or pond, a large herd grazing the available forage during the optimum grazing period may require a larger trough or, often, a storage tank. While monitoring may save money through early detection of potential problems or by validating successful strategies, monitoring also requires time and labor expenses. These investments may result in either more or less production, resulting in more or less profit. Often opportunity and management costs exceed benefits to the producer, and public values or ecosystem services justify public policies or incentives for enhanced management (Jeffrey et al., 2014).

Summary

Until recent decades, grazing management rarely focused on riparian area functions and values. The need for riparian-focused management varies depending on the setting and characteristics of grazing management throughout the pasture or watershed. Across ecoregions, the timing of precipitation varies from relatively constant to highly seasonal. Where precipitation and periods of moist soil coincide with weather warm enough for plant growth during the grazing period, livestock may graze uplands and go to riparian areas primarily for water. Where upland growing seasons begin after, or end with, warm dry soil, livestock focus grazing use on riparian areas for the green palatable and nutritious forage that grows with ground water discharged throughout the growing season. Grazing timed during this period of differential greenness may greatly exacerbate riparian concentration (Gillen et al., 1985).

Riparian grazing management depends on many factors. The natural resilience of a riparian area varies depending on its geologic, geomorphic, and climatic setting (Schumm, 1979) and past management. The need and opportunity for riparian recovery depends on current functioning condition (Dickard et al., 2015) and the desire to go beyond minimal functions to accomplish restoration or other resource objectives (Wyman et al., 2006). The rate or time frame desired for such remediation varies depending on the history and management context (Dickard et al., 2015). When management strategies identified and validated through an integrated riparian management process allow more recovery time from stress, the resilience of riparian areas has potential for remarkable recovery. Initial riparian function recovery can occur relatively quickly, and as functions recover, resource values also improve quickly (Figure 9). A key indicator and driver of success is recovery or maintenance of adequate stabilizing vegetation on the greenline where strongly rooted plants are most important.

Grazing treatments to encourage plant health may rely on long recovery periods between grazing periods, or on continued photosynthesis from moderate utilization or light stocking. However, the cost in unused forage from light stocking increases with the size of uplands and the degree of differential greenness between uplands and riparian areas. When short seasons of use are applied to pastures with abundant riparian soil moisture, the long growing season allows plants to grow or recover, and intensity of use is less important. Upland grazing strategies often fail to account for livestock distribution concentrated in riparian areas, especially in dry seasons. Riparian utilization standards for large pastures with small riparian areas are difficult to monitor adequately because use levels can change quickly. This leads to riparian failures, or to great expense to ranches that leave upland forage unharvested when cattle are removed and when cattle concentrate in riparian areas. These drawbacks can be mitigated with the use of a variety of grazing management tools, facilitated by water developments, supplement placement, well-placed fences, and stockmanship.

Benefits from more efficient or effective management and the recovery of ecosystem services may or may not enhance profitability. Because of the costs for improving management, numerous state and federal agencies provide financial assistance for infrastructure that enhances riparian habitat and water quality. Various land trusts or other nongovernmental organizations fund riparian conservation through enhanced grazing management or conservation easements to keep ranching in place and to prevent development on or subdivision of valuable private land at the expense of habitats (McAdoo et al., 1986; Maestas et al., 2001), floodplains, and ecosystem services.

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