# A Review of Livestock Impacts on Riparian Ecosystems: Vegetative and Aquatic Consequences and Grazing Management

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***Writer's comment:*** The ENL 104E: Scientific Writing review paper was my most challenging assignment in college. After three years of studying range science, I was asked to report on the state of current research in this field. However, range science is a broad, interdisciplinary field, so choosing one aspect to review was challenging. After hours researching, reviewing, and synthesizing a tremendous amount of literature, I narrowed my research to livestock grazing in riparian areas—a controversial topic in the area of range management and natural resources. In the end, this review paper improved my critical thinking and writing skills and broadened my knowledge in the range science field. My fellow classmates and I will always owe our growth and success to our lecturer. I would like to thank Dr. Demory for dedicating herself to teaching and pushing her students to the next level.

*—Leslie Roche*

*Instructor's comment:*Leslie wrote this paper in response to one of the standard assignments in English 104E: the scientific review paper. The assignment is meant to introduce undergraduate students to one of the research/writing tasks that professional researchers must engage in. Leslie tackled this assignment as a professional would: she identified a topic in her field of range science that needed to be reviewed; she read voraciously on the subject; she analyzed recent research and compared it to older research; and she determined an organizational plan for her paper that would help other researchers in the field to understand how the various studies related to each other and what research still needs to be done. In writing this paper, Leslie also put into practice another lesson professional researchers know: the importance of revision. Leslie demonstrated an impressive persistence in writing draft after draft, to clarify the organization, fine-tune the prose, make the arguments more explicit—and the result is this fine review article.

*—Pamela Demory, English Department*

## Abstract

Riparian ecosystems are often characterized by high biological diversity and productivity. These factors, combined with their generally favorable microclimate, make these zones prime areas for livestock grazing; therefore, riparian habitats are often grazed disproportionately compared to upland areas. This intense use often leads to detrimental impacts on stream and vegetative health. Several research experiments have concluded that rotational grazing and late season grazing have improved riparian conditions relative to previously intensive and continuous grazing. However, others still contend that grazing is detrimental to riparian zones, causing channel widening and trenching, sediment and nutrient loading, and vegetation changes. These contradictory findings may be attributed to abiotic fluctuations, which can influence research results, in natural environments. This paper reviews the current research on livestock impacts and grazing management in riparian systems.


## Introduction

Riparian ecosystems are the most biologically diverse and ecologically productive habitats (Clary and Kinney 2002). They host a variety of aquatic and terrestrial life and produce high levels of vegetative biomass, which is attributed to the commonly high soil moisture and soil fertility in riparian areas (Belsky 1999). The streamside vegetation filters sediments during overland flow, stabilizes streambanks and streambeds, and provides shade, food, and nutrients for local aquatic and terrestrial species (Belsky 1999). Unfortunately, this high biodiversity and terrestrial production also leaves riparian ecosystems vulnerable to increased and often detrimental use: Livestock often concentrate in the lush riparian areas, which leads to increased utilization, trampling, and subsequent soil compaction (Wondzell 2001). Consequently, grazing has damaged 80% of the streams and riparian ecosystems in the western United States (Belsky 1999). In his 1999 review of western United States riparian ecosystems, A.J. Belsky et al. concluded that livestock grazing negatively impacted water quality, stream channel morphology, riparian zone soils, riparian vegetation, and local aquatic and terrestrial species. He reported that some of the studies showed no statistical differences among grazed and ungrazed plots; however, no positive effects were reported. Overall, Belsky (1999) found generalizing grazing effects difficult due to inadequate experimental designs and site variability among the studies. With regards to grazing management, Belsky (1999) reported that the reviewed studies did not contrast the newer grazing systems (e.g. rest rotation, reduced stocking rates, etc.) to ungrazed systems and, therefore, no conclusions about grazing benefits could have been justly drawn. The following is a review of the recent literature following Belsky's 1999 survey of livestock impacts and management in riparian ecosystems. The current research shows trends dissimilar to those found by Belsky; however, experimental design and analysis errors are still present.

## Livestock Impacts

*Livestock Impacts on Riparian Vegetation*

Streambanks, which are subject to particle erosion, compression, and shear, are strengthened by herbaceous plant communities with high root length density and root mass (Clary and Kinney 20002). Above ground vegetative biomass also protects streams and rivers against overland flow and subsequent sediment and nutrient loading (Clary and Kinney 2002). Unfortunately, streambank vegetation and stability is often compromised by disproportionate use by livestock. Excessive livestock trampling decreases soil aggregates, which results in soil compaction, poor root growth, and reduced plant production (Martin and Chambers 2001). Vegetation removal may also result in a net export of nitrogen, which can alter nutrient dynamics and reduce productivity and species diversity (Martin and Chambers 2001).

Nevertheless, several recent studies have also shown some positive impacts of livestock grazing on these riparian systems. In his restoration experiment, Clary (1999) found that light and medium grazing treatments had higher species richness than the ungrazed treatments. He concluded that grazing and water stresses opened the stand for establishing plant species (Clary 1999). Similarly, Sovell et al. (2002) concluded that rotational grazing could serve as a disturbance tool for riparian restoration. Martin and Chambers (2001) reported that plots treated with both clipping and nitrogen, which simulated both cattle grazing and their nitrogenous waste inputs, produced higher vegetative biomass than the control plots. However, this nitrogen addition may have limited success due to accelerated phenological development: Plants in nitrogen plots matured and senesced 2 to 4 weeks earlier than control plants (Martin and Chambers 2001).

In contrast, Scrimgeour and Kendall (2002) found that excluding livestock for a two-year period led to a 50% increase in the proportion of stable streambanks. They reported that in the absence of livestock, vegetation cover increased two-fold relative to when livestock were present (Scrimgeour and Kendall 2002). Clary and Kinney (2002) found that spring foliage growth was 20-43% lower in moderately grazed plots and 51-87% lower in heavily grazed (season-long) plots than in ungrazed plots ten months after the last treatment. Similarly, livestock exclosures have been shown to produce higher rates of riparian recovery than livestock enclosures (Howell 2001). Thus, moderate livestock grazing may benefit certain ecosystems (e.g. as a disturbance tool); however, for riparian recovery—from detrimental use— livestock exclusion may be the best management option.

*Livestock Impacts on Riparian Streams*

Reported impacts of livestock grazing on riparian streams include shallowing and widening of streams, increases in fine sediment, lowering of water tables, and bank trampling and erosion (Howell 2001). Livestock trampling of stream banks can widen channels and vertically erode banks (Wondzell 2001). This widening and trenching affect both aquatic and terrestrial life forms: Trenching subsequently lowers the water table, which reduces water availability to streambank vegetation, and stream shallowing degrades native fish habitats (Howell 2001, Wondzell 2001). In a ten-year restoration experiment, Clary (1999) found that the average amount of stream narrowing was inversely proportional to grazing intensity. He also found that ungrazed pastures experienced the greatest narrowing and the greatest increase in depth (Clary 1999).

Unrestricted livestock grazing in riparian habitats also increases sedimentation, a common nonpoint source pollution (Nerbonne and Vondracek 2001 and Sovell et al. 2000). Grazing in riparian ecosystems reduces streambank vegetation, which exposes the soil to overland flow and subsequent erosion. This erosive material flows into streams and then either suspends in the water, causing high turbidity, or settles to the stream bottom (Nerbonne and Vondracek 2001). The excessive sediment loading serves as a pollutant and negatively affects stream biota: Excessive sediment fills stream pools, alters hydrologic channels, and covers rocky stream bottoms (Lyons et al. 2000). These riparian changes eliminate food, shelter, and spawning grounds for native fishes (Lyons et al. 2000). Howell (2001) reported that several past studies showed a 1.5 fold or greater difference in fish biomass between grazed and ungrazed treatments. However, larger scaled watershed conditions, and not just the adjacent land use management, may also contribute to the reported negative effects (Lyons et al. 2000).

In addition to sediment inputs, excessive livestock grazing is also a major source of nutrient inputs in aquatic systems. Livestock nutrient inputs, through trophic cascades, usually increase benthic algae biomass (Scrimgeour and Kendall 2002). However, Scrimgeour and Kendall (2002) found no consistent pattern in algal biomass in relation to livestock grazing. Concentrations of total and soluble reactive phosphorus were significantly different in two of the three study streams: Both water quality variables were significantly higher in all season grazing treatments than in the livestock-absent controls (Scrimgeour and Kendall 2002). However, the majority of their water quality comparisons showed little significant differences (Scrimgeour and Kendall 2002). Scrimgeour and Kendall's (2002) results may be due to their overall sampling design, which was insufficient, due to treatment autocorrelations, in assessing water quality and algal biomass differences among treatments.

Ultimately, shallowing and widening of streams, increases in fine sediment and nutrients, lowering of water tables, and bank trampling and erosion result from excessive livestock grazing. Therefore, land managers should implement the appropriate specialized grazing systems in order to avoid such detrimental impacts.

## Researching Management

*Grazing Practices and Management in Riparian Zones*

Recent research has shown that specialized grazing practices (e.g. rotational grazing, reduced stocking rate, etc.) may be beneficial to previously heavily grazed systems. Both Clary (1999) and Wondzell (2001) reported that light late grazing was not detrimental to riparian areas: vegetation removal and erosive runoff were minimal in both studies. However, non-detrimental grazing, although an improvement over intensive continuous grazing, may not necessarily improve the riparian ecosystem. Scrimgeour and Kendall (2002) showed that late season grazing did not lead to any improvements in riparian biomass or bank stability; however, they did report that rotational grazing allowed establishment of grassy riparian zones.

Rotational grazing has also shown lower riparian vegetation impact and lower nonpoint source pollutions. Lyons et al. (2000) found lower mean values of percent fines in intensive rotational grazing treatments than in continuous grazing treatments. Similarly, Sovell et al.

(2002) found that mean fecal coliform levels and mean turbidity were significantly higher at continuously grazed sites than at rotationally grazed sites. In addition, Lyons et al. (2000) reported that intensive rotational grazing kept riparian areas in the grassy seral stage while ungrazed grassy buffers change to wooded buffer strips through succession (Lyons et al. 2000). In contrast to the reported positive results in rotational grazing systems, Clary and Kinney (2002) found that total animal use (i.e. animal unit months) of streambank areas had a larger impact on total trampling than the rotational or late grazing systems, which vary the grazing periods. However, this experiment was conducted with simulated grazing techniques; therefore, more information on actual hoof impacts is needed to accurately assess their results for relative impacts on nonpoint source pollution (Clary and Kinney 2002).

Nonpoint source pollution—fecal coliform levels, nutrient and sediment loading, etc.—from livestock grazing may be managed with riparian buffers. Riparian buffer strips can reduce sediment loading of the streambed through filtration and increased bank stability, which reduces channel erosion (Sovell et al. 2002, and Nerbonne and Vondracek 2001). The two prominent types of buffer strips are wooded and grassy; however, several studies have shown significant differences between these two buffer types. Wooded buffer sites are often characterized by steep slopes, bare banks, and little understory vegetation (Sovell et al. 2002). These factors interact to promote high erosion, reduced filtration, and subsequent sediment loading (Sovell et al. 2002). Several studies have found higher percent fines and increased streambank exposure along the wooded buffers than in other treatments (Sovell et al. 2002, Nerbonne and Vondracek 2001). Lyons et al. (2000) also found that wooded buffer strips had higher stream width-depth ratios (i.e. shallow and wide) than continuous grazing, intensive rotational grazing, and grassy buffers, which all showed similar width-depth ratios. However, possible benefits, which were not studied, of wooded buffers might include shade, which moderates water temperatures, and organic inputs for aquatic invertebrate production (Lyons et al. 2000).

In contrast to the wooded buffers, grassy buffers have been shown to effectively filter erosive materials and stabilize riparian streambanks (Nerbonne and Vondracek 2001). In addition to this, Nerbonne and Vondracek (2001) found that the grassy buffers diversified the riparian habitat for both fish and invertebrates. However, streambeds in grazed sites contained intermediate fine particle sediment, reflecting the possibility that grazed buffers have a lower capacity for filtering sediments

(Nerbonne and Vondracek 2001). Scrimgeour and Kendall's (2002) results supported Nerbonne and Vondracek (2001) by showing that reestablishment of grassy riparian zones were beneficial in riparian restoration. In addition, Lyons et al. (2000) found that grassy buffer treatments showed less bank erosion and fine sediment loading than continuous grazing and wooded buffers. Sovell et al. (2002) found that turbidity levels were lower in grassy buffer sites than in the wooded sites. They also reported no differences (neither positive nor negative) in fish density and abundance among the treatments; however, the short period of study might not have been adequately long enough for the fish to respond to chemical and physical changes in the streams (Sovell et al. 2002). In contrast, Lyons et al. (2000) found that intensive rotational grazing and grassy buffers helped improve fish habitats.

In addition to grassy buffers, revegetation practices can improve damaged riparian areas. Martin and Chambers (2001) evaluated aeration and revegetation techniques for riparian meadow systems in central Nevada. They hypothesized that revegetation of native species and aeration of compacted soils would increase riparian habitat productivity and stability (Martin and Chambers 2001). Unfortunately, they found no difference in above ground biomass between the controlled, clipped (i.e. simulated grazing), or aerated treatments. Although aeration did not affect above ground biomass production, there was a reported increase in rooting activity in aerated plots, which may have increased long term biomass production (Martin and Chambers 2001).

Recent research has shown conflicting results in rotational, deferred, and reduced stocking rate grazing systems. However, best management practices for specific riparian zones can counteract the previously detrimental effects of intensive continuous grazing. Riparian restoration experiments—grassy buffers, wooded buffers, revegetation, and aeration—have not shown many significant improvements (with the possible exception of grassy buffers).

*Problems in Applied Research*

Evaluating livestock management in riparian systems can be an arduous task because streams are naturally dynamic. In addition to this, inadequate study designs, replications, and controls can also affect study results and comparisons both in and among experiments. Howell (2001) points out that quantifying livestock use is a measure of many interacting factors, including livestock numbers, livestock distribution, grazing duration, and season. In the previously reviewed papers, there were many extraneous factors and experimental design errors.

Extraneous factors such as spatial and temporal variability within experiments can affect research results. Early seral species, weedy species, and a dry spring affected many of the revegetation plots in Martin and Chambers' (2001) study. Varied water table depths, which delivered differing amounts of water across treatments, also affected revegetation success (Martin and Chambers 2001).

One of the major sources of problems in applied research is experimental design error (Belsky 1999 and Howell 2001). For instance, Scrimgeour and Kendall's (2002) four treatments were located successively along the same stream channel; therefore, grazing impacts on upstream water quality could have affected the downstream sites. After rejecting data sets that showed significant autocorrelations (i.e. variables were influenced by nearby values of the same variable), they were left with small sample sizes of low statistical power (Scrimgeour and Kendall 2002). In a 2002 grazing impact study, Sovell et al used a paired watershed design, which could have avoided upstream-downstream influences; however, they found that upstream practices still might have influenced their results. An additional experimental design error is the length of the study period (Martin and Chambers 2001): Six of the studies reviewed spanned only two or three year time periods. Because these systems are dynamic, long-term experiments must be conducted to assess any yearly fluctuations in climate, precipitation, watertables, etc.

## Conclusion

Riparian streambanks and aquatic habitats can be preserved through grazing management. Several studies showed that rotational grazing allowed vegetative reestablishment in the riparian zones; however, impacts of other specialized grazing systems are still being debated. Unfortunately, due to management objectives, vegetation, geomorphology, and climate differences, some study results may not be directly transferable to all regions (Sovell et al. 2002). Similar to Belsky's (1999) findings, experimental design error and landscape dynamics confounded most of the studies' results. However, in contrast to Belsky's (1999) findings, all of these reviewed papers compared specialized and deferred grazing systems to livestock-absent systems.

Studies that span an extended time (i.e. longer than the status quo of 2-3 years), include paired watersheds, and are designed for minimal autocorrelations are likely to be the most successful in determining livestock impacts and management in riparian ecosystems. Research in applied ecology must account for the natural fluctuations (e.g. temperature, precipitation, climate, etc.) in real world environments: These extraneous factors often compound results and disrupt the research process. Therefore, future research should include the following two objectives: 1. Design replications in comparable watersheds with no autocorrelations, and 2. Develop an experimental base for long-term research of livestock impacts on riparian ecosystems.

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