# Grazing Management Effects on Sediment, Phosphorus, and Pathogen Loading of Pasture Streams

## A.S. Leaflet R2614

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### Summary and Implications

In order to quantify the sources of sediment, phosphorus (P), and pathogen loading of pasture streams, six 30-acre pastures, bisected by a stream, were stocked with 15 fall-calving cows from mid-May through mid-October of two years by continuous stocking with unrestricted stream access (CSU), continuous stocking with stream access restricted to 16-foot wide stabilized crossings (CSR), or rotational stocking (RS). Cows in RS pastures excreted less fecal P than cows in the CSU and CSR pastures. The proportion of water applied and the amounts of sediment and P in precipitation runoff during rainfall simulations were greater from bare sites on the stream banks of CSU or RS pastures than vegetated sites of CSU, RS, or CSR pastures. Amounts of stream bank erosion did not differ between grazing management treatments. When sources of sediment and P were compared, stream bank erosion contributed 99.5 and 94.4% of the sediment and P loading of the stream. At the stocking rate used in this experiment, direct fecal deposition in the pasture stream contributed more P than transport in precipitation runoff. The incidence of fecal pathogens *E. coli* O157:H7, bovine coronavirus, and bovine rotavirus shedding in the feces of the cows in this experiment as well as in the runoff from the rainfall simulations was extremely low. These results suggest that the major source of sediment and P loading of pasture streams is stream bank erosion primarily associated with stream hydrology. Grazing management practices that reduce congregation of grazing cattle near pasture streams will reduce sediment and nutrient loading resulting from direct fecal deposition or transport in precipitation runoff. While fecal pathogens may be potential pollutants of pasture streams, pathogen loading of pasture streams by grazing cattle is infrequent and dependent upon the pathogen shedding, temporal\spatial distribution of grazing cattle, and surface runoff from stream banks, in respective order.

### Introduction

In recent studies, pasturelands have been cited as major contributors of sediment and phosphorus (P) loading of water resources. These pollutants may come from direct fecal deposition, transport in precipitation runoff, and/or stream bank erosion. Allowing cattle uncontrolled access to pasture streams will increase manure deposition in and near the streams and bare ground near the streams, thereby, increasing the risks of sediment, P, and fecal pathogens loading the streams. However, these risks may be lowered by grazing management practices that reduce the proportion of time that cattle are in and near pasture streams.

The objective of this study was to quantify the effects of grazing management on sediment, P, and pathogen loading of pasture streams.

### Materials and Methods

Six 30-acre cool season pastures, containing primarily smooth bromegrass and reed canarygrass, were stocked with 15 fall-calving Angus cows from mid-May through mid-October during the 2008 and 2009 grazing seasons. A 463-foot reach of a continuously flowing stream bisected each pasture. Pastures were divided into two blocks with three treatments per block. Treatments included: continuous stocking with unrestricted stream access (CSU); continuous stocking with stream access restricted to 16-foot wide stabilized crossings (CSR); or rotational stocking (RS). Riparian buffers, 2.25 acres, surrounding the stream crossings in the CSR pastures were not grazed. Rotationally stocked pastures were divided into five paddocks: four upland and one riparian. The riparian paddock was grazed to a minimum sward height of 4 inches or for a maximum of 4 days. Upland paddocks were grazed until half of the live forage dry matter (DM) was removed or for a maximum of 14 days. Live forage mass was estimated with a falling plate meter (4.8 $kg/m^2$) at 24 random locations upon the cattle's entry or exit from each paddock. Cows had ad libitum access to a mineral mixture that contained no P.

Distribution of the cows were measured for 2 weeks monthly with GPS collars. These data were reported in the 2010 Iowa State University Animal Industry Report (A.S. Leaflet R2529). To determine fecal output, two cows in each pasture were pulse-dosed with 30 g of chromium(Cr)-mordanted fiber in June and August of both years. After dosing, fecal samples were collected from 0 to 114 hours post-dosing, dried, ground, and analyzed for Cr. Fecal output was estimated from the passage kinetics of Cr. All fecal samples from each cow in a sampling period were composited, ashed in a muffle furnace, and analyzed for P. Distribution of fecal dry matter (DM) and P within each pasture was assumed to be directly related to the distribution of the cows, as demonstrated in a previous project. In order to measure the incidence of shedding of the fecal pathogens, fresh fecal samples were aseptically collected immediately post-excretion from all 90 cows in June, August, and September of both years and analyzed for bovine enteric viruses (Bovine enterovirus (BEV), Bovine coronavirus (BCV), and Bovine rotavirus (BRV)) and *E. coli* O157:H7 .

In order to quantify the amounts of sediment, P, and fecal pathogens transported to the stream in precipitation runoff, rainfall simulations were conducted in June, August, and October of 2008 and April of 2009 and June, August, and October of 2009 and April of 2010 at three vegetated and three bare locations with similar slopes on the stream banks on each side of the stream in CSU and RS pastures and three vegetated locations on the stream banks on each side of the stream within the riparian buffer in CSR pastures. Drip-type rainfall simulators (1.0 x 0.5 m) were used with a rainfall application rate of 3.3 inches/hour for 1.5 hours. Amounts of precipitation and runoff were recorded and sampled every 10 minutes. At the end of each simulation, sub-samples of each composited sample were taken and analyzed for sediment, P, bovine enteric viruses, and *E. coli* O157:H7.

Stream bank erosion was measured on ten equidistant transects along the stream in each pasture. In 2004, total stream bank area was measured and fiberglass erosion pins, 5/8 x 30 inches, were driven 28 inches perpendicularly into the bank at 1 meter intervals from the side of the stream to the top of the bank. Erosion pins were measured monthly from May through October of each year with a measurement of 21 inches (75% of total length) recorded if an erosion pin was lost to bank erosion. Net erosion and erosion\deposition activity were calculated as the means of the measurement and absolute value of the measurement of each pin in each transect, respectively. Net erosion and erosion\deposition activity and sediment and P loss throughout each grazing season were calculated as the sum of the monthly values. To separate effects of freeze-thaw cycles from effects occurring during the grazing season, data from the grazing season (May to November) were calculated separately from winter data (November to May).

Because the average height of the stream bank was approximately 10 feet, total area of bare ground, cut-banks, and depositional areas on the stream banks was measured within 10 feet of the stream with a tape measure in June, August, and October of 2009 and April of 2010. Vegetated ground cover was considered to be the difference between the total bank area and the area that was bare ground, cut-banks, or depositional areas.

All data were analyzed by the MIXED procedure of SAS with pasture as the experimental unit. When appropriate, differences between means with significant treatment effects in all analyses were determined by comparing the LSMeans using the PDIFF statement along with a Tukey adjustment for multiple comparisons. Significance was determined at a level of $P < 0.10$. Treatment differences for the incidences of the viruses and *E. coli* O157:H7 shed by the cattle or collected in the precipitation runoff were not statistically analyzed because of very low occurrence.

To quantify the sources of sediment, P, and pathogen loading of pasture streams, a model was developed (Figure 1). To calculate the amounts of fecal DM and P excreted directly into the stream, the percentage time that cattle were present in the stream was multiplied by the amount of fecal DM and P excreted and the total number of cows in the pasture and the number of days cows were in the pasture. To predict precipitation runoff from actual rainfall events which occurred over the grazing seasons, prediction equations were developed comparing the amount of simulated precipitation applied to the amount of runoff at 10 minute intervals from each site class within each month and year to produce runoff regression equations. Amounts of daily precipitation throughout the entire grazing season of both years were entered into the prediction equation calculated for the nearest date to estimate predicted runoff from each site class (CSUbare, CSUvegetated, CSRvegetated, RSbase, and RSvegetated). These runoff quantities were multiplied by the means of the sediment and P concentrations in the runoff of each site class to yield the predicted amounts of sediment and P transported from each site class during a runoff event. The amounts of sediment and P transported from rainfall simulations of each site class of a pasture were multiplied by the amount of land in that site class within 10 feet of the stream to calculate the total amounts of sediment and P transported in runoff from the stream bank within each pasture in each month of each grazing season. Although rainfall simulations could not be conducted on the stabilized stream crossings, P and sediment loads in runoff from these areas were calculated using concentrations and rates from the CSUbare site class and multiplied by the area of bank covered with the stabilized crossing to account for sediment and P loading of the runoff from these stream crossings. Previously, runoff from stabilized sites on 3% slopes with rainfall intensities of 2 inches/hour have been reported to be approximately half of that from bare ground. Therefore, sediment and P loads in runoff from CSUbare site class were halved to calculate the sediment and P loss.

To calculate sediment and P losses from cut-banks and depositional areas of stream banks, volume of stream bank sediment lost was calculated by multiplying the area of the bank within each pasture by the net erosion, as measured from the erosion pins each month during the grazing season. To calculate the volume of sediment and P lost via cut-bank erosion, the area of cut-bank within each pasture was multiplied by net erosion measured from transects located on cut-banks. Amounts of sediment and P lost from the total bank or cut-bank areas were calculated by multiplying the volume of sediment lost from the total bank or cut-bank area by the bulk density and total P concentration data of bank soil samples taken from the A and C soil horizons. Total sediment and P loss from the total bank or cut-bank area in each pasture were calculated as the sum of the sediment and P loss from A and C soil horizons on both sides of the stream.

**Results and Discussion**

*Fecal Dry Matter and P Output and Pathogen Shedding*

The amount of fecal DM excreted by the cows did not differ ($P > 0.10$) among treatments (Table 1). Fecal DM output was greater in 2009 than 2008 (Year, $P < 0.05$) and greater in June than August (Month, $P < 0.05$). Mean P concentrations of the feces were greater ($P < 0.05$) in the CSR and CSU than RS treatments. Mean P concentrations of the feces were also greater in August than June (Month, $P < 0.01$), and increased greater in RS treatment feces from June to August than the other treatments (Treatment x Month, $P < 0.01$). As a result of the differences in fecal P concentration, total P excretion in the feces tended to be greater ($P = 0.1110$) for the CSR and CSU treatments than the RS treatments and also differed by year with greater excreted in 2009 (Year, $P = 0.0073$).

Bovine enterovirus was found in feces from 4.4, 28.8, and 41.1% of cows in June, August, and September of 2008, respectively, and 38.9, 18.9, 13.3% of cows in June, August, and September of 2009, respectively (Table 2). Bovine coronavirus was shed in the feces of one cow in August of 2008. *Escherichia coli* O157:H7 and BRV were never detected in the fecal samples during the two years of the experiment.

*Rainfall Simulations*

Precipitation runoff, expressed as a volume (L/hour) or as a proportion of applied precipitation was greater ($P < 0.05$) from bare than vegetated sites across grazing management treatments (Table 2). Also, RSvegetated and CSUvegetated sites had greater ($P < 0.05$) amounts and proportions of runoff than the CSRvegetated site. Similar to runoff, transport of sediment ($P < 0.05$) and P ($P < 0.10$) in runoff were greater from bare than vegetated sites across grazing management treatments, and the RSvegetated and CSUvegetated sites had greater ($P < 0.05$) amounts of sediment and P transported in runoff than the CSRvegetated sites. The proportion of bare ground at each simulation site was the most significant factor for determining the proportion of runoff of applied precipitation and the amounts of sediment and P transport in runoff resulting in the following regressions:

Runoff, % of applied precipitation = 27.83 + 0.5565x ($R^2 = 0.5050$)

Sediment loss, kg·m$^2$ = -218.6 + 61.65x ($R^2 = 0.3811$)

P loss, g·m$^2$ = -68.18 + 150.3x ($R^2 = 0.4302$)

*Escherichia coli* O157:H7, BCV, and BRV were never detected in runoff samples during the two years of the study. Bovine enterovirus, an indicator of fecal contamination, was found in 8.3 and 16.7% of the runoff samples from CSUbare sites in June and October of 2008 and 8.3% of the CSUvegetated sites in April of 2009. No observations of BEV were detected in runoff samples from RSvegetated, RSbare, and CSRvegetated sites.

*Stream Bank Erosion*

There were no significant differences in either net erosion or erosion\deposition activity among treatments or seasons or between years (Figure 2). Averaged over treatments, years, and seasons, the stream banks had a net erosion of 2.0 inches (5.2 cm) and erosion\deposition activity of 4.4 inches (11.1 cm) per season per year.

*Model Results*

Comparisons of the estimations of the annual sediment and P loading of the pasture stream by precipitation runoff, cattle feces, and stream bank erosion show that cut-bank erosion is the greatest contributor to sediment and P loading of pasture streams as losses from cut-banks were approximately 1.5 times the measured losses from the total stream bank erosion (Table 4). Averaged over 2008 and 2009, stream bank erosion accounted for 99.5 and 94.4% of the sediment and P, respectively, transported to the pasture streams. Although amounts of sediment and P loading from direct fecal deposition or precipitation runoff were small when compared to bank erosion, the amount of sediment loading of the stream from direct deposition of feces was 46.4% less than that in precipitation runoff across grazing treatments at a stocking density of 0.097 cows/yard stream. However, the amount of P entering the stream from direct fecal deposition was 32.5% greater than that in precipitation runoff.

Results indicate that while precipitation runoff along stream banks contributed more to sediment loading of a pasture stream than direct fecal deposition, fecal deposition resulted in greater P loading of the stream than precipitation runoff at the stocking rate used in this experiment even though the cows received no supplemental P. Therefore, management strategies like flash grazing of riparian paddocks or restricting stream access to stabilized crossings will assist in reducing sediment loading of pasture streams by maintaining adequate vegetative cover and reducing direct fecal deposition within the stream. However, the amounts of sediment and P entering the stream from stream bank erosion, particularly from cut banks, are considerably greater than those resulting from precipitation runoff or direct fecal deposition. As there were no differences in net stream bank erosion between pastures with different grazing management treatments, it seems that the effects of stream hydrology such as the number and duration of high stream flow events on stream bank erosion supersede those of grazing. However, because the increase in bare ground along stream banks of pastures in which cows have unrestricted stream access have been reported by others to increase the number of freeze-thaw events that occur to the stream banks during the winter, grazing management practices that maintain an adequate amount of vegetative cover seem desirable.

Shedding of pathogens in the present study was rare, occurring only once throughout the entire study, when BCV was shed by one cow. However, in 2007, the year prior to the study, *E. coli* O157:H7 was recovered from 12 of the 90 cows during the September collection with 10 of these cows present in one of the RS pastures (unpublished data). The presence of Bovine enterovirus was analyzed because it has been proposed as a good indicator of fecal contamination. Results of this study showed that shedding of BEV was highly variable, but was high enough to be infrequently detected in runoff samples. Additionally, as cattle were not stocked on the pastures prior to the rainfall simulation conducted in April 2009, BEV was either able to survive the winter or it was shed by another host source. This study shows that viruses shed by cattle may be transmitted through surface runoff, with a greater number transmitted on bare compared to vegetated ground. Therefore, the major factors in controlling the risk of pathogen loading of pasture streams, in order of importance, are the occurrence of pathogen shedding, the temporal\spatial distribution of grazing cattle, and surface runoff.

## Conclusion

Estimations of annual sediment and P loading into the pasture stream show that stream bank erosion via cut-bank erosion is the greatest contributor of sediment and phosphorus to the pasture stream. Improvements in sediment and P loading from precipitation runoff may result by use of cattle-excluded riparian buffers; however, the greatest differences in sediment and P loading of runoff occur between bare and vegetated ground on stream banks in grazed pastures. Minimizing the amount of bare ground on the stream banks is critical to minimize the amounts of sediment and P in precipitation runoff and may be attained by use of rotational stocking as well as riparian buffers. Additionally, pathogen loading of pasture streams by grazing cattle was infrequent and dependent upon the pathogen shedding, temporal\spatial distribution of grazing cattle, and surface runoff from stream banks, in respective order.

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**Figure 1. Modeling the effects of the temporal/spatial distribution of grazing cows on sediment, phosphorus loading of pasture streams.**

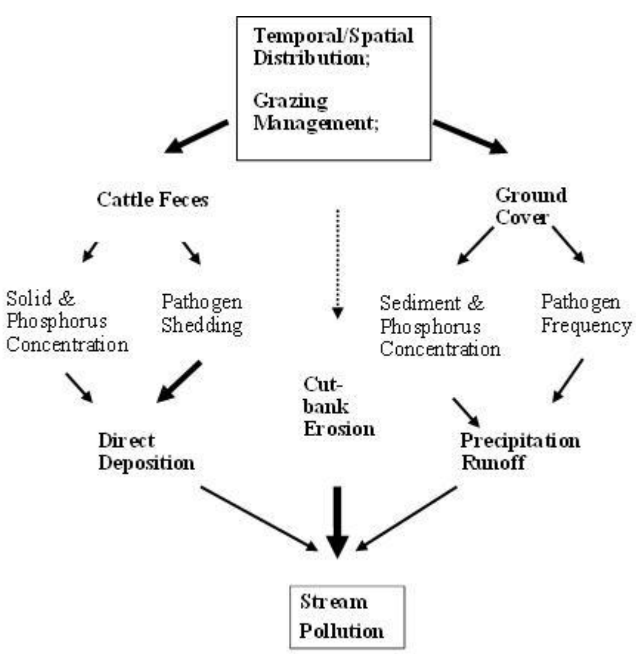

**Table 1. Effects of grazing management on fecal excretion of dry matter and phosphorus per cow over two years.**

| Item | Month | Treatment[a] | | |
|---|---|---|---|---|
| | | CSU | CSR | RS |
| Fecal DM, kg/day | June | 7.02 | 7.94 | 7.54 |
| | August | 6.72 | 6.84 | 6.11 |
| Fecal phosphorus, g/kg | June | 6.41[b] | 6.05[b] | 4.84[c] |
| | August | 6.77[b] | 6.38[b] | 5.74[c] |
| Fecal phosphorus, g/day | June | 44.7 | 47.8 | 36.5 |
| | August | 44.7 | 43.3 | 35.3 |

[a] Continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), rotational stocking (RS).
[bc]Means within a row with different letters differ (P < 0.10).

**Table 2. Incidence of bacterial and viral shedding in the feces of cattle.**

| Item[a] | 2008 June | 2008 August | 2008 September | 2009 June | 2009 August | 2009 September |
|---|---|---|---|---|---|---|
| E. *coli* O157:H7 | 0[b] | 0 | 0 | 0 | 0 | 0 |
| BCV | 0 | 1 | 0 | 0 | 0 | 0 |
| BRV | 0 | 0 | 0 | 0 | 0 | 0 |
| BEV | 4 | 26 | 37 | 35 | 17 | 12 |

[a] *Escherichia coli* O157:H7, Bovine coronavirus (BCV), Bovine rotavirus (BRV), Bovine enterovirus (BEV)
[b] n = 90 cows sampled

**Table 3. Effects of grazing treatment and ground cover on rainfall simulation characteristics.**

| Item | Treatment[a] | | | | |
|---|---|---|---|---|---|
| | CSUvegetated | CSUbare | CSRvegetated | RSvegetated | RSbare |
| Runoff, l/hr | 14.98[b] | 32.09[c] | 6.35[d] | 14.01[b] | 28.89[c] |
| Runoff, % | 36.55[b] | 78.71[c] | 15.32[d] | 33.98[b] | 70.76[c] |
| Sediment, kg/ha | 112.3[b] | 3983.2[c] | 14.2[d] | 111.9[b] | 1290.2[c] |
| Phosphorus, g/ha | 536.2b | 11085.7[c] | 64.5d | 495.7[b] | 3565.4c |

[a]Continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), rotational stocking (RS), simulation on vegetated (veg) or bare (bare) ground.
[bcd]Means within a row with different letters differ (P < 0.10).

**Figure 2. Effects of grazing management on net erosion and erosion/deposition activity during the winter and grazing seasons.**

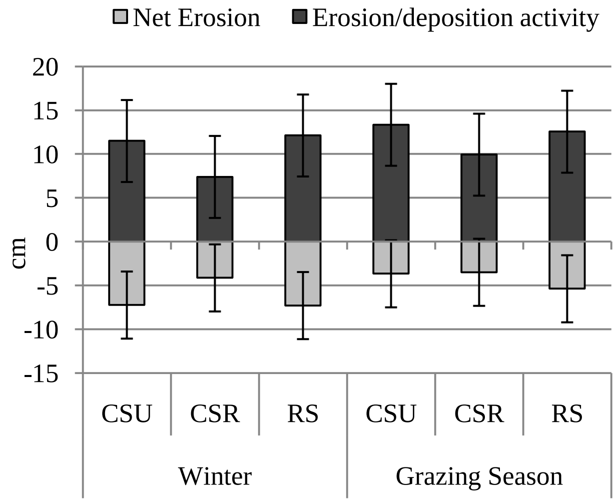


**Table 4. Estimates of sediment and phosphorus loading of pasture streams from stream bank runoff, cattle feces, and stream bank erosion in 2008 and 2009.**

| | | Sediment, kg | | | Phosphorus, g | | |
|---|---|---|---|---|---|---|---|
| Item | Treatment[a] | 2008 | 2009 | Cut-banks[c] | 2008 | 2009 | Cut-banks[c] |
| Runoff[b] | CSU | 554.72 | 257.04 | - | 1122.26 | 812.45 | - |
| | CSR | 55.47 | 8.67 | - | 179.62 | 59.59 | - |
| | RS | 371.91 | 82.02 | - | 933.59 | 343.08 | - |
| Cattle feces[d] | CSU | 267.98[e] | 298.61 | - | 1795.48 | 1884.47 | - |
| | CSR | 41.35 | 77.64 | - | 256.07 | 476.90 | - |
| | RS[f] | 0 | 25.59 | - | 0 | 147.09 | - |
| Net Erosion- | | ×10³ | | | | | |
| Grazing season | CSU | 85.84 | 37.95 | 54.87 | 20.33 | 9.16 | 13.29 |
| | CSR | 84.92 | -4.11 | 13.78 | 21.03 | -0.29 | 2.85 |
| | RS | 188.25 | 30.40 | 49.96 | 42.22 | 7.95 | 9.59 |
| Winter | CSU | 49.12 | 170.08 | 412.26 | 11.47 | 42.90 | 99.80 |
| | CSR | 11.10 | 89.75 | 97.09 | 2.63 | 23.49 | 19.87 |
| | RS | 136.28 | 98.07 | 131.36 | 25.66 | 21.95 | 28.66 |

[a] Continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR), rotational stocking (RS), simulation on vegetated or bare ground.

[b] Runoff data includes precipitation occurring from May to Oct 31, 2008, and April 1 to Oct 31, 2009, precipitation for April, 2009 retrieved from NOAA weather station in Marshalltown, IA (approx. 15 mi. from study site). Based on 141-m stream reach of site pastures with a 3-m bank height.

[c] Amounts estimated to be lost from transects located on cut-banks in 2009

[d] Based on 15 cows stocked on a 12.1-ha pasture.

[e] Total feces deposited into stream.

[f] Cattle were not stocked riparian area at the same time as location determination except for one September in 2009.