Water Quality Effect of Rangeland Beef Cattle Excrement

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Nonpoint source pollution is a new term that rangeland managers must address. Concerns regarding rangeland cattle excrement impacts on water quality have focused on nutrient (nitrogen and phosphorus) and pathogen loading to water bodies.

Some studies have attempted to compare cattle excrement deposited on the range to human waste deposited in a septic system (Lahonton 1985, DWR 1971). An important point to keep in mind when making this comparison is that humans import their food sources into a watershed while cattle predominantly consume forage produced in the watershed. Cattle export nutrients out of the watershed in the form of body mass. Beef calves that gain 2 to 2.5 pounds per day, of which 2.4% is nitrogen, 0.8 % is phosphorus (Azevedo and Stout 1974), illustrate the amount of nutrients that can be removed from grazed watersheds. Nitrogen exported in tissues of domestic ungulates has been estimated to be 17% of the N in ingested forage (Dean et al. 1975). Thus, assuming 70% moisture and 10% crude protein forage, for every ton of forage consumed about 1.6 pounds of nitrogen is removed from the system.

We do know, for instance, that input of nutrients by rainfall can be significant. Olness et al. (1975) found that the rangeland watershed received more total inorganic nitrogen in rainfall than was lost with surface runoff. Ritter (1986) found that both nitrogen and phosphorus contributed by rainfall was greater than the rates occurring in stream flow. Menzel et al. (1978) during a 4-year study found rainfall added four times the nitrogen compared to nitrogen discharged in runoff from rotational grazed pastures and about equaled the amount discharged from continuously grazed pastures.

Evaluation of rangeland cattle excrement impacts on water quality require consideration of natural variability in the hydrologic cycle, the nutrient cycles, and the pathogen cycle as well as how grazing modifies each of these processes. Figure 1. illustrates the complex processes of

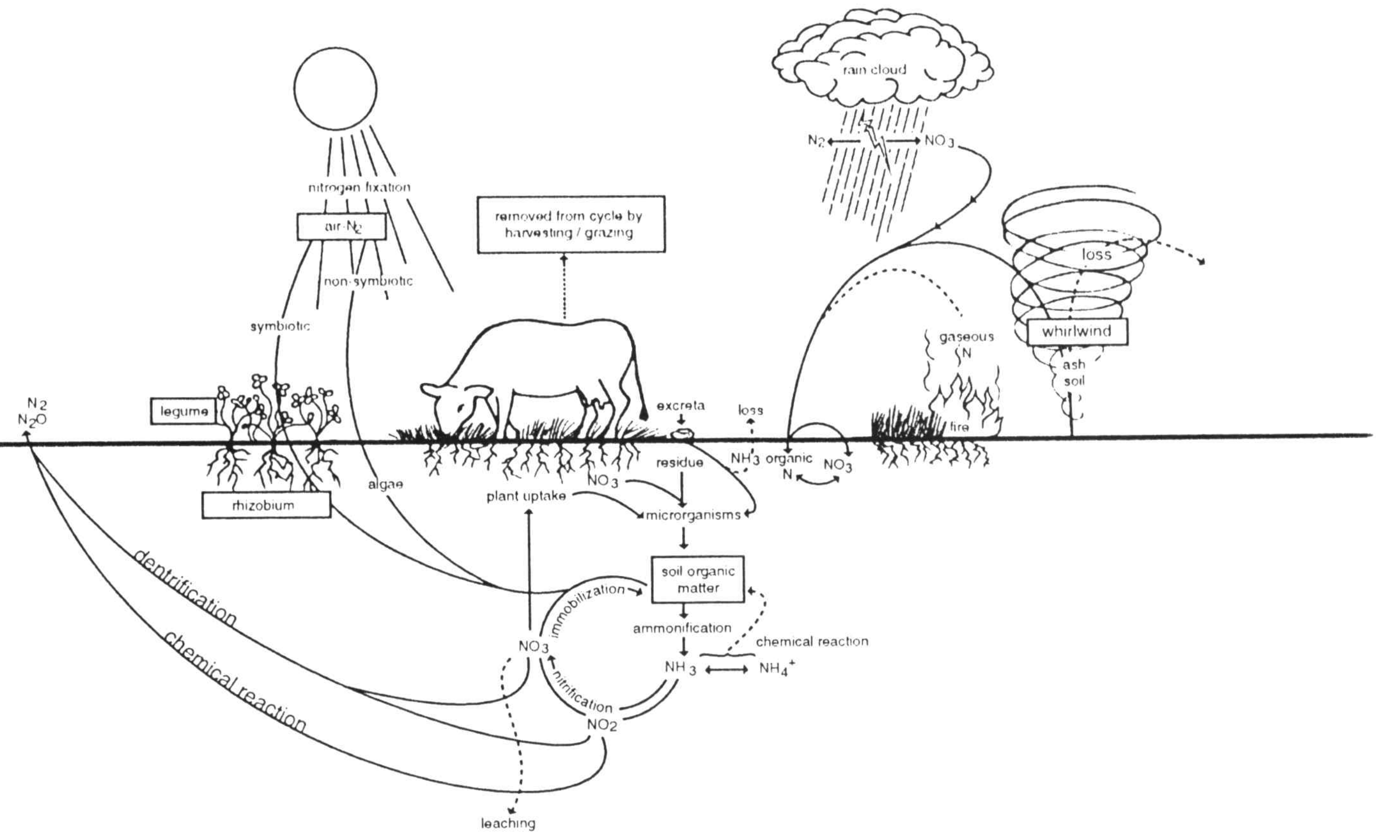


Fig. 1

the nitrogen cycle on a watershed, and the role of herbivores in the nitrogen cycle.

For instance, to understand and quantify the fate of nitrogen on a grazed rangeland watershed several things must be considered:

1.) Quality and quantity of the forage.
2.) Retention by the animal.
3.) Losses through volatilization and leaching of NH^3.
4.) Soil incorporation.
5.) Plant uptake.
6.) Spatial distribution of the feces and urine.

All of these factors make it difficult to quantify the amount of nutrient and pathogen loading that is attributable to rangeland beef cattle on a watershed.

Components of Range Cattle Excrement

The amount of excreted feces will depend on forage intake (driven by body size and physiological function) and digestibility. The actual amount of urine produced daily varies according to production (growth, lactation, or conception), air temperature, and water consumption. (NRC 1984). A review of range forage intakes by Cordova et al. (1978) showed that they were highly variable ranging from 40 to 90 g Dry Matter/Weight(kg)$^{.75}$. Several studies in the western United States estimates intake ranging from 1 to 2.8% of body weight. Many water quality studies (Lahonton 1985, DWR 1979) are based on confined beef cattle excretion data, which should be used as only crude first estimates of rangeland cattle excretion. The following are values used by agricultural engineers based on a wide range of confined beef cattle diets and conditions. Beef cattle produce 30 to 49 pounds of urine and 29 and 72 lb. of feces per day. For every ton of live animal mass, beef cattle excrete 0.748 lbs. of Kjeldahl nitrogen, 0.189 lbs. of ammonia nitrogen, and 0.20 lbs. of phosphorus per day (ASAE 1992). Azevedo and Stout (1974) give the range of percent of fresh weight to dry matter of 15–27%. The range in confined beef cattle output was 29 to 60 lbs. of wet feces and 4.6 to 10.2 lbs. on a dry matter basis.

Actual rangeland fecal output studies using collection bags illustrate the amount of variation found under rangeland conditions (Table 1). Authors report their findings on a daily fecal output on a dry matter basis. Connor et al. (1963) was the only one to publish the dry matter digested percents which were 40.4 for Southern Nevada and 53.3 for Northern Nevada.

Nitrogen, phosphorus, and pathogens in grazed rangeland watersheds

Nitrogen

Cattle intake nitrogen mainly in the form of plant protein. Nitrogen is lost through eructation, belching, and excretion. The amount of nitrogen consumed by beef cattle that is utilized depends on the demands for growth, maintenance, reproduction, and lactation. This leads to a wide variation in reported utilization. Young calves utilize about 42% of consumed nitrogen (Salter and Schollenbergen 1939). Woodmansee et al. (1981) stated that cattle commonly retain 15 to 20% nitrogen of ingested forage. While Afzal and Adams (1992) indicated that typically 75% of the ingested N is returned in dung and urine. Azevedo and Stout (1974) reported nitrogen was excreted in urine (47.6%) and feces (52.4%) by weight. However, many researchers suggest urea accounts for about 75% of the excreted nitrogen. Excreted nitrogen, mainly in the form of urea, is rapidly hydrolyzed by ubiquitous urea-decomposing enzymes yielding ammonia. More than 80% of the nitrogen in urine may be lost by volatilization. Under simulated feedlot conditions, 85 to 90% of nitrogen in urine was lost as ammonia. Under ambient conditions losses are probably about 50%, which is the often used value. Nitrogen in feces that is not volatilized is slowly released from complex organic compounds present in manure as a result of microbial activity. The microorganisms which decompose manure demand a carbon-to-nitrogen ratio of less than 15 or 20 before ammonia can be split off and released from nitrogenous organic compounds in sufficient quantities for good plant growth. As decomposition proceeds, the various organic constituents of the substrate are attacked at different rates. Stewart (1970) reported that 37.3% of the nitrogen present in fresh feces was volatilized within one week.

Table 1 - Fecal Output Studies

Animal Weight (Lbs.)	Daily Fecal Output (Lbs.)	Location	Forage	Month	Author
460	3.78	S. Nevada	desert shrub	Jul. to Oct.	Conner et al. 1963
460	2.68	N. Nevada	sagebrush/grass	Jun. to Sept.	Conner et al. 1963
605	5.1 – 7	E. Oregon	crested wheatgrass	Apr. to May	Handl et al. 1972
605	5.1 – 7	E. Oregon	crested wheatgrass	Jun.	Handl et al. 1972
726	5.9	Nebraska	tall wheatgrass	Sept.	Adams at al. 1991
880	5.5	Nebraska	meadow	Jul.	Hollingsworth at al. 1995
880	8.4	Nebraska	meadow	Sept.	Hollingsworth et al. 1995
880	7.9	Nebraska	meadow	Oct.	Hollingsworth et al. 1995

Eagle Lake, Laseen County, Calif.

Buckhouse and Gifford (1976) found .02% of a semi arid range covered with bovine feces under a stocking rate of 4.9 acres/AUM. Uneven distribution of excreta may affect the nitrogen cycling in the soil-plant-animal system.

Wilkinson and Lowery (1973) reported soil N is affected in an area .97 square feet around each defecation 3.0 square feet around each urination. Grass growth was affected within an area of 10.76 square feet around each urination spot. Woodmansee et al. (1981) estimated that in low productivity systems, the amount of nitrogen added in one urine patch may be 10 times greater that the uptake capacity of the plants, and in highly productive systems, the amount of nitrogen added may be three times the uptake capacity. Nitrogen not taken up by the plants may be immobilized by soil microorganisms or eventually transferred to soil organic matter. Ammonium may be absorbed onto soil colloids or fixed and lost from the rapid cycling pools, but would slowly become available. Afzal and Adams (1992) found that total mineral nitrogen under feces was always shallow (0–.78 inches). The depth of total mineral nitrogen from urine changed with time. The change in form of total mineral nitrogen to nitrate and depth was observed at 56 days after simulated urine application with an increase of nitrate from 61% in the 0 to .78 inches depth to 98% in the 1.57 to 2.36 inches depth. Dormaar et al. (1990) found that grazing did not change the total nitrogen in the Ah horizon, but the forms were different with higher ammonia and nitrate present. Nitrate is susceptible to loss by leaching if precipitation is heavy, but in most grasslands such losses are probably small (Woodmansee et al. 1981). Most elements in feces of large animals are bound in relatively resistant organic fractions (Floate and Torrance 1970). The bulk of bound elements remains for many years at the surface in feces (Angel and Wicklow 1975). Fecal nitrogen is very efficient for plant growth because of the slow release (Dormaar et al.1990). Cattle grazing removes herbage from large areas in a pasture, but deposits feces in a small area.

Phosphorus

Phosphorus is an essential nutrient for growth, maintenance, lactation, and reproduction of cattle. Phosphorus and calcium are important in the formation of bones. Dietary phosphorus retained by the animal varies from 78% for growing calves to 58% for lactating cows (NRC 1984). Every 2.2 pounds of calf gain contains nine grams of phosphorus, while every 2.2 pounds of cow gain contains six grams. Most excreted phosphorus (97.3%) is in the feces. Of the nutrients present in manure, phosphorus is the second most resistant to leaching. In general, phosphorus from applied manure is not leached from soils (Azevedo and Stout 1974). Phosphorus is rapidly hydrolyzed and chemically precipitated or absorbed by other soil minerals. Most soils are able to rapidly tie up large amounts of this element in forms not readily available to plants. Most soil phosphorus is tied up chemically in compounds of limited solubility. In neutral to alkaline soils, calcium phosphate is formed, while in acid soil, iron and aluminum phosphates are produced.

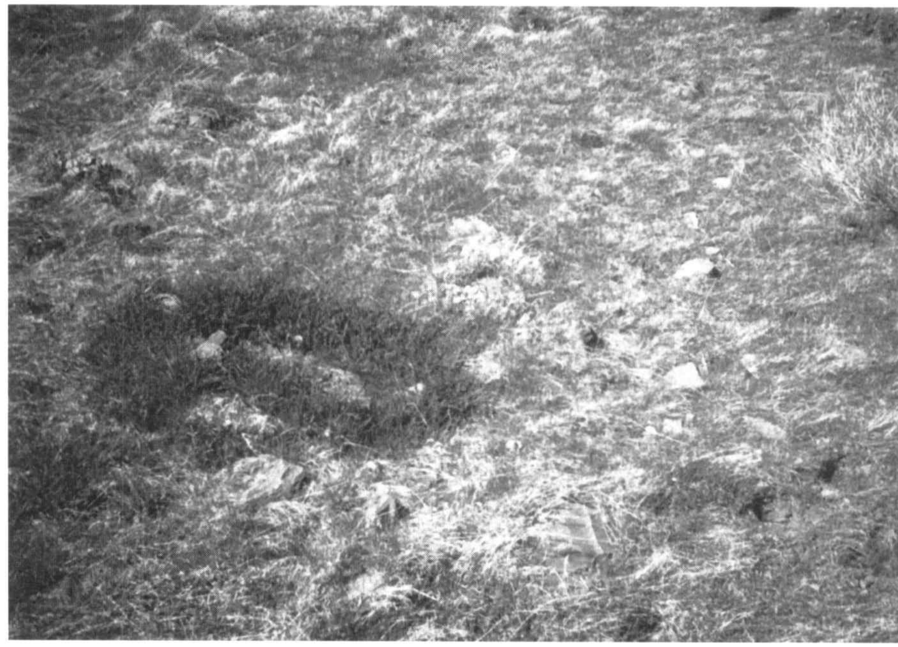
Pathogens

The primary pathogenic bacteria found in beef cattle excrement includes *Escherichia coli, Leptospira interrogans, Salmonella spp., Campylobacter jejuni* and *Yersinia enterocolitica* (Gary et al. 1983, Altekruse et al. 1994, Whipp et al. 1994). The primary water-borne protozoa potentially transmitted by cattle excrement includes *Cryptosporidia parvum* and *Giardia duodenalis* (also known as *Giardia lamblia*) (Fayer and Ungar 1986, Craun 1990, Atwill 1996). *C. parvum* is a tiny protozoal parasite that can cause gastrointestinal illness in a wide variety of mammals, including humans, cattle, sheep, goats, pigs, and horses. It also occurs in various wildlife species such as deer, raccoons, opossums, rabbits, rats, mice, and squirrels (Fayer and Ungar 1986). In cattle, shedding of the parasite is usually limited to calves, but there are a few reports of subclinical shedding in adult cattle (Lorenzo et al. 1993). Dairy calves are commonly infected with *C. parvum* and *G. duodenals* (Ongerth and Stibbs 1989, Xiao 1994), but little is known of their distribution in beef cattle herds, particularly in those herds located on open range.

Water Quality Impacts Related to Rangeland Beef Cattle Excrement

Nutrients

Hathaway and Todd (1993), studied the contribution of different cultural activities in the Wood River sub basin in eastern Oregon. They found that continuously grazed irrigated meadows did not increase the nitrogen load of streams. Daily phosphorus load was found to be lower downstream of a grazed area than it was downstream of an ungrazed area. Gary et al. (1983) studied moderately grazed pastures bisected by a small perennial stream in central Colorado. Only minor effects on water quality were detected during a two-year study. Cow excretion was monitored for an eleven hour period both years and 6.7 to 10.5% of the defications and 6.3 to 9% of the urinations were deposited directly in the stream.



Grass response to urination.

Nitrate nitrogen did not increase, and ammonia nitrogen increased significantly only once during this study. Tanner and Terry (1991) found no significate differences in N, P, chlorophyll, dissolved oxygen, and pH of surface water collected from light to moderately grazed and ungrazed wetlands in south Florida. Dahlgren and Singer (1991) found that grazing of northern California oak woodlands had no effect on major nutrients. Coltharp and Darling (1975) found no difference in water chemical levels between grazed and ungrazed areas along three mountain streams. Robbins (1979) stated that all the available data indicate that pollutant yields from rangeland are not directly related to the number of animals or amount of waste involved, but are related to hydrological and management factors involving erosion/sedimentation.

Pathogens

Detailed studies that attempt to link rangeland cattle grazing with the presence of water-borne pathogenic bacteria have for the most part not been done (Atwill 1996). Instead, indicator bacteria have been used. These studies need to be interpreted with some caution since indicator bacteria have been shown to be poorly correlated with some pathogenic bacteria such as *Campylobacter jejuni* (Carter et al. 1987, Bohn and Buckhouse 1985). An increase in indicator bacteria in waterways, due to cattle grazing has been documented in many studies (Gary et al. 1983, Robbins 1979, Dixon et al. 1979, Stephenson and Street 1978). However grazing has also been found to have little or no effect on fecal indicator counts (Buckhouse and Gifford 1976). Fecal indicators may not always signify the presence of pathogens in the water column (Bohn and Buckhouse 1985). When contamination does occur, it may be temporary and short-lived (Gary et al. 1983, Robbins 1979), or may persist for several months. (Stephenson and Street 1978). Furthermore, concentrations tend to decrease downstream (Robbins 1979).

A special concern for bacterial pollutants is their ability to survive in the environment. Bacteria such as *Salmonella newport* and E. coli have been shown to survive several months in freshwater sediments (Burton et al. 1987). Fecal coliforms may survive up to two months in soil, but in the protective medium of feces, can persist up to a year (Bohn and Buckhouse 1985). Bottom sediments have been found to harbor concentrations of indicator organisms up to 760 times greater than the overlying water (Stephenson and Rychert 1982).

Studies that carefully evaluate the association between rangeland cattle and the presence of these water-borne protozoa have not been done. The majority of the existing literature on water-born protozoa deals with dairy cattle, or was conducted in laboratory settings. These studies do not explicitly state how the cattle were managed nor define the cattle's proximity to contaminated water bodies. Madore et al. (1987) measured 5,800 *Cryptosporidium* oocysts/liter in irrigation canal water running through agricultural acreage with cattle pastures compared to 127 oocysts/liter in river water subject to human recreation and 0.8 oocysts/liter for stream water exposed to ranch land runoff. Unfortunately, the authors do not specify if the cattle were beef or dairy cattle or if the species of *Cryptosporidia* was that of human health concern, *parvum*. Presently, there are no data that indicate rangeland cattle are a significant threat to water quality by *parvum* (Atwill 1996).

Spatial Distribution of Cattle Excrement on Rangeland Watersheds

Nonpoint pollution caused by cattle excrement may be aggravated or ameliorated by the proximity of deposition to water bodies. Deposition outside of riparian areas may pose no pathogen or nutrient problems (Blackburn et al. 1982). Larsen et al. (1993) utilized a rainfall simulator in a laboratory environment to assess the effectiveness of vegetative filter strips to attenuate fecal coliforms, a questionable indicator of pathogens. Results during a 30 minute simulation indicate that distance of the fecal material up slope from the collection point significantly influences loading. In a situation where a stream was the only source of water and cattle spent 65% of the day within 328 feet of the stream channel 6.7 to 10.5% of defecations and 6.3 to 9.0% of urinations were deposited directly into the stream (Gary et al. 1983). Larsen et al. (1988) found that free ranging cattle deposited an average of 3.4% of their feces in the stream in August and 1.7% in November.

Strategy for influencing livestock distribution

Livestock's distribution within a watershed can be manipulated using sound range management practices such as salting, water location, fencing, and selecting against cattle that graze riparian areas. Salt, mineral or protein supplements placed next to the streams can result in direct pollution of the water as well as increase cattle dung, urine and trampling next to the stream. Salt should be placed in areas away from stream courses to help distribute cattle. It is best to familiarize animals with the location of salt by driving them there, especially in an area not frequently grazed. Alternative water sources, such as windmill or solar powered wells, reservoirs, and guzzlers, can be developed in upland areas to draw cattle away from streams. Miner et al. (1992) found that a water trough 328 feet from a stream during the winter reduced the amount of time cattle spent in a stream by 90%. In the spring time, Clawson (1993) found that water trough placement reduced the range of stream use from (3.9–8.3) to (.9–4.7) minutes/cow/day. He also found that a water gap completely eliminated fecal deposition into the stream. Livestock distribution away from riparian areas may be improved through training and selection (Gillen et al. 1984, Howery 1993, Roath and Krueger 1982, Walker 1995). Subdividing large pastures to exert more control over the frequency and timing of grazing can be used to improve grazing distribution. Rotational grazing management can be used. Continuously grazed rangelands contributed at least four times more nitrogen and phosphorous to the watershed compared to rotationally grazed rangelands. (Khaleel et al.1979).

Conclusions

Nutrients

Water quality data should be examined carefully before assigning a cause and effect relationship between cattle grazing and non point pollution. Natural background levels of nutrient and pathogen loading can be quite high during storm events. Non point pollution from pastured and rangeland livestock depends on the stocking rate, length of grazing period, the season of use, manure deposition sites and concentration. Normally, pastures and rangelands have not presented water quality problems caused by cattle excrement, except under special circumstances. Several studies have concluded that cattle excrement contributes negligible nutrient pollution to waterways (Hathaway and Todd 1993, Robbins 1979, Dixon 1979, Tanner 1991, Coaltharp and Darling 1975, Milne 1976). Unfortunately, none of the studies defined the treatments well enough to describe the intensity and timing of grazing. The main water quality concerns are from cattle feces and urine deposited directly into the water. Potential problems occur in cases where animals congregate for feeding, watering, resting, in proximity to waterways, (Khaleel et al. 1979).

There is little scientific evidence that excrement from beef cattle on rangelands significantly impacts water quality. When significant nutrient contaminations do occur, especially phosphorus, they are more likely explained by erosion and sediment processes in the watershed (Khaleel et al. 1979, Robbins 1979). Cattle can effect the erosion and sediment process through vegetation removal.

Pathogens

The scientific evidence implicating beef cattle as a significant source of *C. parvum* or *G. duodenalis* for surface water is incomplete and contradictory. Given the lack of scientific investigation, it would be premature to claim that rangeland cattle production is the leading source of *C. parvum* or *G. duodenalis* for surface water contamination (Atwill 1996). Rangeland beef cattle excrement may increase pathogen contamination in water ways beyond background levels, but studies have shown that background levels are not zero. Wildlife species, including muskrats, coyotes, mule deer, waterfowl, elk, etc. shed pathogenic bacteria such as *Campylobacter jejuni* (Altekruse et al. 1994). *Giardia* has been repeatedly isolated from wildlife (Thompson and Reynoldson 1993). Furthermore, high counts of indicator bacteria are often found upstream from grazed areas and are attributed to wildlife (Gary et al. 1983). Concentrations of *Cryptosporidium* oocysts from pristine surface waters have been 0.005-18 oocysts/L, indicating that this organism occurs naturally in pristine watersheds (Sterling and Arrowood 1993).

Management Implication

Rangeland water quality can be managed by implementing spatial distribution of cattle through salting, upland water developments, fences for pasture rotation, and even by training or selection of the cattle grazed. These methods address the deposition of excrement near waterways, and also other, hydrologic, ecologic, and economic issues.

Future Direction

Future research needs to be focused directly on monitoring grazing impacts on nutrient and pathogen dynamics at the watershed scale. Clearly defining the site conditions, grazing management, and excrement depositional patterns on the watershed are critical for interpreting and applying this information.

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