Cattle grazing impact on surface water quality in a Colorado Front Range stream

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ABSTRACT: Cattle grazing in pastures bisected by a small perennial stream in central Colorado had only minor effects on water quality during two years of study. Suspended solids and nitrate nitrogen did not increase significantly, and ammonia nitrogen increased significantly only once under moderate rates of grazing. Indicator bacteria densities in the stream water were significantly higher when at least 150 cattle were grazing. After removal of cattle or when 40 head of cattle were grazing, bacterial counts dropped to levels similar to those in an adjacent, ungrazed pasture. About 5 percent of the total manure produced by cattle contributed to pollution and/or enrichment of the stream.

HIGH concentrations of domestic livestock, mainly cattle, have more impacts on the physical, chemical, and bacteriological properties of stream water than most other watershed uses (*16*). Over the last century, nearly all meadows along perennial streams in Colorado's Front Range have been used heavily by cattle and other livestock. In 1940, about 300,000 head of cows, excluding calves, grazed the region (*5*). Today, according to the Colorado Department of Agriculture, range cows number less than 120,000 head in the counties along the Front Range. Because of the great influx of people, however, it is not known if the presence of grazing cattle may limit certain uses of stream water.

Cattle wastes, feces, and urine, deposited in or near streams or entrained or dissolved in runoff reaching streams, may contribute to nitrogen (N), phosphorus (P), and other nutrient concentrations in streams (*2*, *7*, *10*, *17*, *19*, *21*). Cattle wastes may also affect the bacteriological quality of stream water (*7*, *14*, *18*, *22*). Various pathogens from cattle wastes are known to be transmitted to humans, although infrequently, via water-based recreation (*6*).

Also, livestock trampling and grazing near streambanks may increase bank sloughing and downstream sedimentation and reduce the quantity and quality of riparian vegetation needed as food, shade, and cover for fisheries and other aquatic biota (*1*, *11*, *12*, *16*, *20*).

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The primary purpose of our study was to quantify the impacts of seasonal cattle grazing on the chemical and bacteriological characteristics of surface water in a typical stream in the Colorado Front Range. A secondary objective was to determine whether local grazing management practices should be changed to maintain or enhance existing stream water quality.

Study area

The study was conducted along a 2.6-kilometer (1.6-mile) section of Trout Creek, a perennial stream flowing through the Manitou Experimental Forest, about 45 kilometers (28 miles) northwest of Colorado Springs. The area is in a mountain park surrounded by ponderosa pine (*Pinus ponderosa* Dougl. ex Laws), similar to many other Front Range parks (Figure 1).

Our study involved adjacent pastures, bisected by Trout Creek, a north-flowing tributary of the South Platte River (Figure 2). The upper pasture included about 75 hectares (185 acres), the lower pasture about 85 hectares (210 acres) of grazable area. Each pasture had about 1.28-kilometers (0.8-mile) of stream channel. Mean elevation of the pastures is 2,340 meters (7,675 feet). Annual precipitation averages 400 millimeters (15.8 inches); about two-thirds of which occurs during the April-to-September growing season. Streamflow during the 2 years of study was measured with two 4-foot (1.22-meter) throat-width Parshall flumes and water-level recorders located at the upstream and downstream ends of the first pasture. Summer daytime temperatures seldom exceed 33°C (91°F). Winters usually are open and cold, with air temperatures occasionally as low as −35°C (−31°F).

The floodplain in each pasture ranged from 100 to 200 meters (328 to 656 feet) in width. Surface soil over the floodplain is black loam or gravelly loam up to 60 centimeters (24 inches) thick; it is derived from loose, gravelly Pikes Peak granite. The stream has meandered over much of the floodplain in response to periodic flooding and beaver activity. Beavers were not present during the study. However, drained beaver ponds in the upper pasture contributed varying amounts of sediment and organic debris during the first year of the study. Unstable and easily erodible streambanks up to 3 meters (9.8 feet) high were present in both pastures.

Floodplain vegetation, which occupied less than 10 percent of the pasture area, consisted primarily of sparse to thick willow (*Salix* spp.) stands, Kentucky bluegrass (*Poa pratensis* L.), wheatgrasses (*Agropyron* spp.), clovers (*Trifolium* spp.), sedges (*Carex* spp.), bulrushes (*Scirpus* spp.), rushes (*Juncus* spp.), reedgrasses (*Calamagrostis* spp.), buttercups (*Ranunculus* spp.), iris (Iris spp.), yellow blossom sweetclover (*Melilotus officinalis* L.), and dandelions (*Taraxacum* spp.). Sandbars were also scattered along the stream bottom. Herbaceous plant cover on the dry terraces above the floodplain was mainly Arizona fescue (*Festuca arizonica* Vasey), mountain muhly [*Muhlenbergia montana* (Nutt.) Hitchc.], blue grama [*Bouteloua gracilis* (H.B.K.) Lag.], and sleepygrass (*Stipa robusta* Vasey), along with open ponderosa pine forest.

Study methods

The upper and lower pastures were used for years as holding areas for cows and calves before they were distributed to other pastures for grazing trials. Our study was conducted during eight time periods, over a 2-year period, when cattle were present and absent in these holding pastures. The stocking rates in the two pastures ranged from 40 to 150 cattle. Grazing pressure was moderate. Cattle movement over the pastures was unrestricted.

Cattle movements and activities. To gain some qualitative insight as to how cattle may or may not pollute the stream, we observed their movements and activities on several occasions while they were in the lower study pasture. The procedure consisted of following an easily recognizable cow, for an arbitrary 11-hour period, from 7 a.m. to 6 p.m. We maintained a distance from the cow such that she would not be frightened or excited. Every five minutes, we recorded the location of the cows in the pasture relative to the stream; physical activities, such as walking, standing, drinking, and crossing of the stream; and frequency of urination and defecation. We observed a total of 13 different cows, 4 in

Figure 1. Trout Creek floodplain, upland grassland, and ponderosa pine forest.

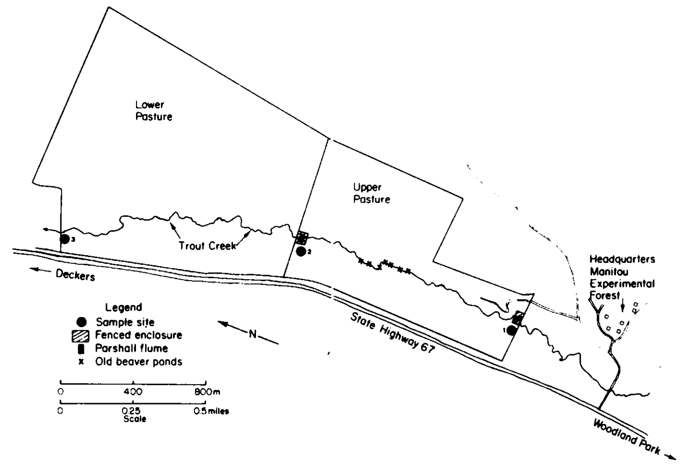

Figure 2. Arrangement of pastures and location of water sampling sites.

May and June 1978 and 9 in June 1979.

Manure production. To estimate the amount of cattle manure that had the greatest chance of contributing directly to enrichment and/or pollution of Trout Creek, manure was collected for three time periods within a 3-meter (9.8 foot) horizontal strip along both sides of the creek in the lower pasture. The total length of the stream channel (Figure 2) was about 2 kilometers (1.2 miles). The manure was later air dried and weighed. We used the weights, along with other data, to estimate quantities of organic wastes contributed per cow unit.

Stream characteristics and water sampling. The headwaters of Trout Creek are more than 30 kilometers upstream from the study area. Winter snow accumulation is relatively low or absent over most of the upstream drainage area. Streamflow in Trout Creek originates mainly from spring and summer rains. Streamflow on the average is also relatively low in proportion to the size of the upstream drainage area. During the first year of study, 1977, daily discharge through the study pastures ranged from 23 liters per second (0.8 cubic feet/second) on July 18 to 500 liters per second (17.7 cubic feet/second) on July 26. Average daily discharge during the study periods in 1977 was 82 liters per second (2.9 cubic feet/second).

In 1978, about July 20, continuous flow ceased in Trout Creek for the first time since 1956. High flow, 183 liters per second (6.5 cubic feet/second), occurred on May 1, and mean daily discharge from April 18 to July 19 that year was 64 liters per second (2.3 cubic feet/second).

Comparisons of streamflow records obtained from the Parshall flumes indicated virtually no difference in daily discharge at either end of the upper pasture. Thus, we based all water quality comparisons on sample sites "above and below" grazing or periods of no grazing. We made no attempt to flow-weight chemical constituents over a season because of the narrow seasonal range in streamflow volume. Total dissolved solids in stream water are generally lowered by rainfall or snowmelt water and raised by the addition of wastewater effluents and runoff from feedlots and fertilized fields and pastures (*15*).

The ground cover on both pastures above the stream channel was relatively good. Any surface runoff that may have occurred was apparently confined to the immediate vicinity of the streams. Based on earlier infiltration studies in the area, about 2.5 centimeters (1 inch) of rain from high-intensity storms are required to produce surface runoff (*9*). We observed no storms of this size in the area during our periods of study.

We took water samples for analysis at the head of the upper pasture (site 1), near the end of the upper pasture (site 2), and at the end of the lower pasture (site 3) (Figure 2). Domestic livestock had not grazed the floodplain for more than 1.8 kilometers (1.1 miles) upstream from site 1 to Manitou Park Lake (surface area 5 hectares) for more than 10 years. Water samples (one at each site) were collected at 7- to 10-day intervals during all study periods, except between June 15-25, 1977, when we collected samples at 2- to 3-day intervals to determine if water quality changes occurred immediately after cattle removal. Water samples were taken in sterilized bottles in the morning and analyzed or processed the same day for suspended solids (gravimetric filtration), ammonia-nitrogen (colorimetrically using Nessler reagent), nitrate-nitrogen (colorimetrically using modification of cadmium reduction), fecal coliforms, and fecal streptococci (membrane filtration techniques).

We used analysis of variance to examine water quality differences between the three main sampling sites. Further comparisons, using Tukey's tests ($\alpha = 0.05$), then were made of site means for each of the eight study periods to identify homogeneous and heterogeneous groupings.

Results and discussion

Cattle movement. Trout Creek was the only source of water for the cattle, and observations of their distribution in the lower pasture were in relation to the stream. The 75 cows and their calves were usually widely distributed, depending on forage palatability and availability, but they generally traveled over the pasture as a well-dispersed herd. The cattle spent 65 to 75 percent of the 11-hour observation periods grazing.

Figure 3 shows the relative distribution of the cattle for selected days during 2 years. The cattle spent most of their time in the lush meadow along the floodplain (Figure 1). More than 65 percent of the day was spent within 100 meters (328 feet) of the stream. Casual observations during all other grazing periods and in both pastures in other years indicated that the cattle continued to graze and stay in about the same relative locations as shown in figure 3.

The cattle also spent about 5 percent of the day in or adjacent to the stream, including the time spent drinking, crossing the stream, and standing in the stream. Thus, considering time spent in and near the stream channel and its small total area in relation to the whole pasture, the potential for cattle to contribute large amounts of manure and urine to the stream and to detach large amounts of bank material or stream sediments appeared great.

Defecation and urination. Observations of the distribution and frequency of waste discharges provided evidence as to how streams may be enriched and/or polluted by cattle (Table 1). Qualitative data (Table 1) indicated that 6.7 to 10.5 percent of the defecations and 6.3 to 9.0 percent of the urinations were deposited in the stream. The discharge of wastes usually took place soon after drinking.

Quantities of feces and urine were not determined, but discharge frequencies of wastes were considerably lower than observed for range cattle elsewhere. In Oklahoma (*8*), it was observed that cows on excellent-condition rangeland averaged 12.2 defecations and 4.6 urinations per 15.3-hour period. The qualitative values in table 1 parallel the findings shown in figure 3, further indicating that range cattle may contribute to stream pollution.

Manure production. Most range and pasture grazing studies assume that manure is distributed uniformly in a light application, liquids are absorbed in the soil, and the vegetative cover uses the added nutrients and inhibits erosion (*17*). Thus, water pollution control agencies have shown little interest in unconfined cattle.

Our weight estimates of manure (Table 2) contradict this assumption about manure distribution. Recovered manure for three observation periods ranged from 4.1 to 5.8 percent of total expected manure from an estimated 1.7 percent of the pasture area (3-meter-wide strip on each side of the stream, plus 3-meter-wide stream). Had it been possible to account for manure known to have been deposited directly in the stream, as previously shown in table 1, the manure recovery percentages would have been larger, perhaps as much as 50 percent more (assuming a stream width of 3 meters and similar manure distribution).

At our study site, manure depositions beyond the 3-meter limit would most likely never reach the stream except during times of major floods. The physiological necessity for drinking water, increased somewhat because of lactating cows, and the quality of riparian zone forage and browse brought the cattle to the stream several times a day. Chance deposition of their waste products near the stream, based on manure collection and direct observations, was apparently greater and more concentrated than in other grazed areas of the pasture. The amounts of manure recovered provided further evidence of pollution potential under conditions of the study.

Water quality. Unlike continuous or-

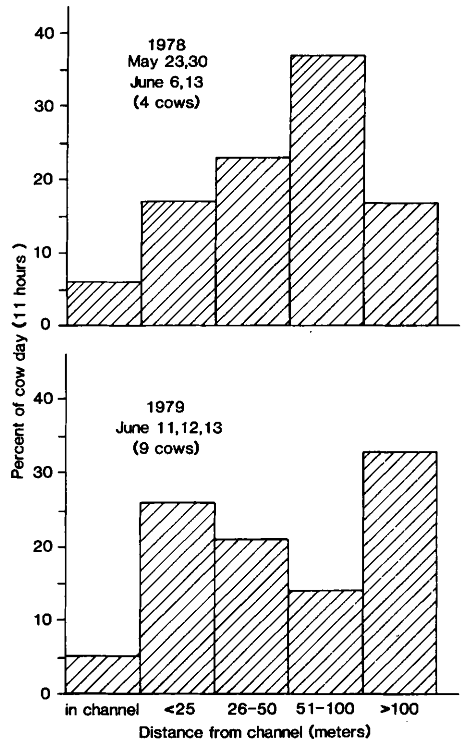

Figure 3. Location of cattle in relation to Trout Creek for an 11-hour observation period.

ganic additions from a point source, such as effluent from sewage lagoons, sporadic additions of cattle manure and urine to stream water may go undetected because of almost immediate dilution. Low-frequency and low-intensity water sampling also makes it difficult to assess if and how range cattle affect stream water quality. However, periodic sampling, as done in

Table 1. Summary of waste discharges for four cows observed in 1978 and for nine cows observed in 1979.

Activity of Cows (11-hour period)	1978	1979
Defecations/cow		
Total (number)	4.75	4.89
Deposited in stream	0.50	0.33
Percentage	10.5	6.7
Urinations/cow		
Total	4.00	4.89
Deposited in stream	0.25	0.44
Percentage	6.3	9.0

our study, provided knowledge of average water quality for an important and typical multiple-use stream on the Colorado Front Range.

From April 15 through June 14, 1977, the cows and calves had been in the lower pasture for more than 45 days before collection of the initial water samples (Table 3). Based on six water samples taken during this period, mean suspended solids ranged from 16 milligrams per liter at site 1 to 67 milligrams per liter at site 2 (Table 3), indicating significant differences among sites. Physical inspection along the stream clearly revealed that mud flats behind the drained beaver ponds between sites 1 and 2, not the cattle, were the source of the elevated levels of suspended solids at site 2. After initial erosion of the mud flats in June, when stream discharge was about 255 liters per second (9 cubic feet/second) for a few days, mean suspended solids returned to base levels of less than 15 milligrams per liter for the remaining study periods.

Water having average suspended solids below 80 milligrams per liter does not generally harm fish and other aquatic life (*15*). Cattle usually crossed the stream in fewer than 10 major places and only temporarily increased suspended solids. The coarse-textured, gravelly material from the stream bottom settled rapidly within a few meters downstream. The sediment movement caused by cattle crossing the stream and their trampling near the stream banks appeared insignificant when compared with the amount of sediment transported during periodic floods. We observed concentrations of suspended solids greater than 800 milligrams per liter during the most recent flood for the same reach of Trout Creek. [In unpublished data, stream discharge exceeded 2,000 liters per second (70 cubic feet/second) for several days.]

In rural areas much like the present study area, detectable ammonia nitrogen (NH_3-N) and nitrate nitrogen (NO_3-N) in stream water generally originate either from leakage of septic tanks, effluent from wastewater treatment plants, runoff from barnyards and feedlots, or runoff from fer-

Table 2. Estimated manure production (total solid waste) for 75 cows and 75 calves and recovered manure from two 3-meter-wide (10-foot) strips adjacent to Trout Creek.

Manure Deposition Period	Number of Days	Estimated Total Manure Production* (kg)	Recovered Manure (kg)	(%)
May 4 - May 30, 1979	26	9,155.3	378.4	4.1
May 31 - June 7, 1979	7	2,464.9	130.5	5.3
June 8 - June 15, 1979	7	2,464.9	142.3	5.8

*Based on 3.13 kilograms (6.9 pounds) of total solids for 1,000 pounds live weight of beef feeder per day (adapted from "Livestock Waste Facilities Handbook MWPS-18," Midwest Plan Service, Ames, Iowa 50011). Estimates are based on 112.5 cow units (75 cows plus 75 calves, calf equals 0.5 cow unit).

tilized pastures and croplands. In natural, unpolluted streams there is usually dynamic equilibrium between breakdown of organic nitrogen contained in dead plant and animal material by nitrifying bacteria and use by new and existing plants. When nitrogen-rich pollutants reach a stream, they simply act as fertilizers and, in excessive amounts, may encourage algal blooms, kill fish, and cause early eutrophication of streams and lakes (*10*).

Streams known to be unpolluted generally have nonionized NH_3-N concentrations of less than 200 micrograms per liter (*15*). After release of NH_3-N ions into streams, the ions readily oxidize to ammonium nitrogen (NH_4-N), and concentrations of NH_4-N ions below about 300 micrograms per liter usually are not toxic to aquatic life (*15*).

Mean concentrations of NH_3-N during the eight study periods ranged from 140 micrograms per liter at the downstream site in the lower pasture (Site 3) between June 15 and June 25, 1978, to 420 micrograms per liter for the downstream site in the upper pasture (Site 2) between March 4 and April 20, 1978 (Table 3). Cattle were not present in either pasture during these two study periods. In only one of four cattle grazing periods did the presence of cattle appear to increase the NH_3-N concentration significantly. This increase occurred during the June 25 through August 16, 1978, study period, when 40 head of cattle were in the upper pasture. Concentrations of NH_3-N at the upstream site of the upper pasture (site 1) indicated, in general, that the source of NH_3-N apparently was unrelated to grazing and/or no grazing treatments. The major upstream source was perhaps decaying organic debris contained in innumerable old beaver dams covered by flood-derived alluvium.

NO_3-N is the most completely oxidized and most stable form of N in surface waters. As mentioned, the main environmental problem with NO_3-N is that, at sustained concentrations above 300 micrograms per liter, it acts as a fertilizer for algal blooms (*15*). NO_3-N in stream water is generally not high enough to constitute a health problem. In drinking water, concentrations of NO_3-N below about 10,000 micrograms per liter, as N, are acceptable for children; below 50,000 micrograms per liter, there is no known hazard to adults (*15*). Mean NO_3-N concentrations, under conditions of our study, ranged from 84 micrograms per liter at site 3 between June 15 and June 25, 1977, when cattle were not present, to 524 micrograms per liter at site 2 between June 25 and August 16, 1978, when 40 head of cattle were located between site 1 and site 2 (Table 3).

As discussed, NH_3-N concentrations rose significantly during the same June 25 through August 16, 1978, period. Site comparisons in table 3 indicated a trend of increased NO_3-N concentrations when cattle were present. However, mean NO_3-N concentrations were not different statistically during any of the four periods when cattle were present. The major inputs of NO_3-N apparently were from diffuse sources upstream from site 1. Minor inputs came from all along the stream bisecting the two pastures, including unknown contributions because of the cattle.

Counts of two indicator bacteria (fecal coliforms and fecal streptococci), determined by routine laboratory procedures (*3*), were made in water samples obtained during the eight study periods. These bacteria are always present in the intestinal tracts of warm-blooded animals and are eliminated in large numbers in fecal waste. The indicator bacteria are not usually pathogenic themselves and do not generally multiply outside the intestines, but they are often found in the company of intestinal pathogens affecting man and other mammals.

The presence of cattle in either pasture generally increased the numbers of fecal coliforms from 1.6 to 12.5 times and the numbers of fecal streptococci from 1.5 to 3.8 times over those normally recovered from Trout Creek (Table 3). However, sig-

Table 3. Summary of physical, chemical, and bacteriological characteristics of stream water during grazing and nongrazing periods.

Parameters and Livestock	1977 Study Sites 1*	1977 Study Sites 2†	1977 Study Sites 3‡	1978 Study Sites 1	1978 Study Sites 2	1978 Study Sites 3
Sampling period	April 15 - June 14(6 samples)			March 4 - April 20 (4 samples)		
Suspended solids, mg/1	16(± 7)§	67(± 38)‖	56(± 46)	6(± 4)	12(± 9)	5(± 2)
Ammonia nitrogen, μg/1	273(± 89)	294(± 103)	308(± 109)	288(± 150)	420(± 81)	287(± 107)
Nitrate nitrogen, μg/1	298(± 216)	354(± 352)	427(± 152)	220(± 158)	245(± 223)	243(± 40)
Fecal coliforms, colonies/100 ml	12(± 11)	21(± 15)	156(± 88)§	16 -	19 -	24 -
Fecal streptococci, colonies/100 ml	70(± 45)	60(± 15)	227(± 140)§	14(± 10)	16(± 12)	15(± 10)
Cattle (location, number)	150 head between sites 2 and 3			No cattle present		
Sampling period	June 15 - June 24 (5 samples)			April 21 - June 14 (7 samples)		
Suspended solids, mg/1	8(± 3)	13(± 7)	5(± 1)	6(± 2)	7(± 4)	6(± 6)
Ammonia nitrogen, μg/1	250(± 65)	332(± 124)	284(± 48)	293(± 311)	277(± 188)	212(± 117)
Nitrate nitrogen, μg/1	158(± 55)	110(± 87)	84(± 71)	201(± 69)	254(± 130)	397(± 255)
Fecal coliforms, colonies/100 ml	24(± 18)	28(± 18)	47(± 29)	6(± 6)	11(± 15)	137(± 199)§
Fecal streptococci, colonies/100 ml	229(± 301)	236(± 247)	265(± 189)	206(± 327)	80(± 70)	138(± 126)
Cattle (location, number)	No cattle present			150 head between sites 2 and 3		
Sampling period	June 25 - October 14 (11 samples)			June 15 - June 25 (2 samples)		
Suspended solids, mg/1	7(± 5)	13(± 15)	7(± 13)	5 -	8 -	0 -
Ammonia nitrogen, μg/1	286(± 41)	311(± 49)	281(± 71)	210 -	230 -	140 -
Nitrate nitrogen, μg/1	187(± 75)	189(± 136)	164(± 106)	300 -	270 -	190 -
Fecal coliforms, colonies/100 ml	63(± 56)	180(± 163)	93(± 122)	10(± 5)	10(± 6)	70(± 54)
Fecal streptococci, colonies/100 ml	275(± 212)	342(± 241)	260(± 249)	225(± 120)	189(± 58)	297(± 245)
Cattle (location, number)	40 head between sites 1 and 2			No cattle present		
Sampling period	October 15 - November 12 (3 samples)			June 25 - August 16 (8 samples)		
Suspended solids, mg/1	4(± 2)	7(± 5)	5(± 5)	5(± 4)	2(± 1)	3(± 3)
Ammonia nitrogen, μg/1	367(± 12)	343(± 61)	373(± 15)	184(± 48)	230(± 39)§	179(± 47)
Nitrate nitrogen, μg/1	260(± 90)	327(± 117)	187(± 96)	350(± 129)	524(± 200)	413(± 149)
Fecal coliforms, colonies/100 ml	6(± 4)	9(± 8)	9(± 8)	92(± 158)	143(± 129)	101(± 207)
Fecal streptococci, colonies/100 ml	51(± 25)	44(± 18)	99(± 118)	588(± 622)	877(± 420)	929(± 786)
Cattle (location, number)	No cattle present			40 head between sites 1 and 2		

*Upstream end of upper pasture.
†Downstream end of upper pasture.
‡Downstream end of lower pasture.
§Mean significantly different from other site means ($\alpha = 0.05$).
‖Standard deviation.

nificantly higher counts of fecal coliforms or fecal streptococci were observed only when 150 cattle were present in a pasture. Relatively high counts of bacteria upstream from the grazed pastures (Site 1) were attributed to wild animals, birds, and the soil.

Fecal coliforms/fecal streptococci ratios during the eight study periods ranged from 0.02 to 1.6. Ratios greater than about 2.5 usually indicate the source of fecal organisms are predominantly from human wastes. Ratios less than about 1.0 usually indicate that domestic livestock and other animals are the source of pollution (*13*). Bacteria counts at all sites were lower generally during the early spring and late fall study periods.

One cow produces and eliminates daily an estimated 5.4 billion fecal coliforms and some 31 billion fecal streptococci (*23*). Based on these estimates, it is not surprising that the presence of cows usually is associated with elevated numbers of indicator bacteria in streams. The recovery of fecal coliforms and fecal streptococci from Trout Creek indicated that intestinal waste products either from cattle or other animals had reached the stream.

Potential but relatively rare waterborne bacterial diseases transmissable from cattle manure and urine are salmonellosis, leptospirosis, anthrax, and brucellosis (*6*). Under bacteriological standards adopted by the State of Colorado, water in Trout Creek (Table 3) remained acceptable during all study periods for recreation class I-primary contact water (waters having < 200 fecal coliforms/100 milliliters), but was never suitable for drinking (water having < 1 fecal coliform/100 milliliters) (*4*).

Management implications

Seasonal cattle grazing at moderate stocking rates on open ranges bisected by a perennial stream contributed some manure and urine directly to the stream. The potential manure contribution to the stream was probably more than 5 percent of total manure production. The measured physical, chemical, and bacteriological properties of stream water indicated only minor, local reductions in water quality when cattle were present.

Furthermore, our study did not provide significant evidence of major, long-term, cumulative impairment of water quality resulting from past seasonal use and moderate stocking rates in the area. The regional potential for livestock wastes to contaminate streams has been greatly reduced during the past 40 years. Based on the reduced stocking rates along the Colorado Front Range, better grazing practices, and generally adequate streamflow for manure and urine dilution, permanent removal of cattle from the floodplains does not seem justified now for water quality maintenance.

REFERENCES CITED

1. Ames, C. 1977. *Wildlife conflicts in riparian management: Grazing.* In A *Symposium on the Importance, Preservation and Management of Riparian Habitat.* Gen. Tech. Rpt. RM-43. Rocky Mt. Forest and Range Exp. Sta., For. Serv., Fort Collins, Colo. p. 49-51.
2. Armstrong, D. E., and G. A. Rohlick. 1970. *Effects of agricultural pollution on eutrophication.* In T. E. Willrich and G. E. Smith [eds.] *Agricultural Practices and Water Quality.* Iowa State Univ. Press, Ames. pp. 313-330.
3. Bordner, R., and J. Winter, eds. 1978. *Microbiological methods for monitoring the environment water and wastes.* EPA-600/8-78-017. U.S. Environ. Protection Agency, Cincinnati, Ohio. 338 pp.
4. Colorado Water Quality Control Commission. 1978. *Water quality standards for Colorado.* Colo. Dept. Health, Denver. 44 pp.
5. Currie, P. O. 1975. *Grazing management of ponderosa-pine bunchgrass ranges of the central Rocky Mountains: The status of our knowledge.* Res. Paper RM-159. Rocky Mt. For. and Range Exp. Sta., For. Serv., Fort Collins, Colo. 24 pp.
6. Diesch, S. L. 1970. *Disease transmission of water-borne organisms of animal origin.* In T. E. Willrich and G. E. Smith [eds.] *Agricultural Practices and Water Quality.* Iowa State Univ. Press, Ames. p. 265-285.
7. Doran, J. W., J. S. Schepers, and N. P. Swanson. 1981. *Chemical and bacteriological quality of pasture runoff.* J. Soil and Water Cons. 36(3): 166-171.
8. Dwyer, D. D. 1961. *Activities and grazing preferences of cows with calves in northern Osage County.* Bull. B-588. Okla. Agr. Exp. Sta., Stillwater. 61 pp.
9. Gary, H. L. 1975. *Watershed management problems and opportunities for the Colorado Front Range ponderosa pine zone: The status of our knowledge.* Res. Pap. RM-139. Rocky Mtn. For. and Range Exp. Sta., For. Serv., Fort Collins, Colo. 32 pp.
10. Goldberg, M. C. 1970. *Sources of nitrogen in water supplies.* In T. E. Willrich and G. E. Smith [eds.] *Agricultural Practices and Water Quality.* Iowa State Univ. Press, Ames. pp. 94-124.
11. Holt, R. F., R. H. Dowdy, and D. R. Timmons. 1970. *Chemistry of sediment in water.* In T. E. Willrich and G. E. Smith [eds.] *Agricultural Practices and Water Quality.* Iowa State Univ. Press, Ames.
12. Johnson, H. P., and W. C. Moldenhauer. 1970. *Pollution by sediment: Sources and the detachment and transport process.* In T. E. Willrich and G. E. Smith [eds.] *Agricultural Practices and Water Quality.* Iowa State Univ. Press, Ames. pp. 3-17.
13. Kenner, B. S., H. F. Clark, and P. W. Kabler. 1960. *Fecal streptococci. I. Quantification in feces.* Am. J. Public Health 50: 1,553-1,559.
14. Kunkle, S. H., and J. R. Meiman. 1967. *Water quality of mountain watersheds.* Hydrology Pap. No. 21. Colo. State Univ., Fort Collins. 53 pp.
15. McKee, J. W., and H. W. Wolf, eds. 1963. *Water quality criteria.* Pub. 3-A (revised). Calif. State Water Resources Control Bd., Sacramento. 548 pp.
16. Meehan, W. R., and W. S. Platts. 1978. *Livestock grazing and the aquatic environment.* J. Soil and Water Cons. 33(6): 274-278.
17. Miner, J. R., and T. L. Willrich. 1970. *Livestock operations and field-spread manure as sources of pollutants.* In T. E. Willrich and G. E. Smith [eds.] *Agricultural Practices and Water Quality.* Iowa State Univ. Press, Ames. pp. 231-240.
18. Morrison, S. M., and J. F. Fair. 1966. *Influence of environment on stream microbial dynamics.* Hydrol. Paper No. 13. Colo. State Univ., Fort Collins. 21 pp.
19. Oglesby, R. T. 1971. *Farmland runoff.* In *Agricultural Wastes: Principles and Guidelines for Practical Solutions.* Cornell Univ., Ithaca, N.Y. pp. 15-19.
20. Platts, William S. 1978. *Livestock interactions with fish and aquatic environments: Problems in evaluation.* In Trans., 43rd North Am. Wildlife and Natural Resources Conf. Wildl. Manage. Inst., Washington, D.C. pp. 498-504.
21. Schepers, J. S., and D. D. Francis. 1982. *Chemical water quality of runoff from grazing land in Nebraska: I. Influence of grazing livestock.* J. Environ. Qual. 11: 351-354.
22. Stephenson, G. R., and L. V. Street. 1978. *Bacterial variations in streams from a southwest Idaho rangeland watershed.* J. Environ. Qual. 7: 150-157.
23. U.S. Environmental Protection Agency. 1976. *Water quality and pollutant source monitoring: Field and laboratory procedure training manual.* EPA-430/1-76-010. U.S. Environ. Protection Agency, Cincinnati, Ohio. □