Water Quality Implications of Cattle Grazing on a Semiarid Watershed in Southeastern Utah

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Highlight: During 1973 and 1974 wildland water quality analyses were performed on a semiarid, chained and seeded, pinyon-juniper site in southeastern Utah. The area was treated in 1967 and protected from grazing until 1974. In 1974 livestock grazing was introduced and investigations continued to determine if any deleterious land use effects were present from fecal contamination by cattle. No significant changes were noted in fecal and total coliform production (fecal pollution bacterial indicators) from grazing use. There is an element of risk involved whenever data generated from a small area are projected to larger land areas. However, it appears that this level of livestock grazing (2 ha/AUM) did not constitute a public health hazard in terms of fecal pollution indicators on the semiarid watershed.

Pinyon-juniper (*Pinus* spp. and *Juniperus* spp.) vegetative type conversions have been made on millions of acres of semiarid rangeland. Chaining, which involves mechanically uprooting the trees with a large anchor chain suspended between two crawler tractors, is a frequently employed technique. In Arizona alone, almost a million acres of woodland have received some vegetation treatment between 1950 and 1960 (Dortignac, 1960). Yet many of the hydrological aspects of such vegetation conversion are poorly understood. The secondary treatment effects of grazing these treated areas are even less well understood.

Our population is continuing to grow. Recreational demands on public lands are accelerating. Arid land use planning and zoning ordinances may well be on the horizon. Natural resource managers are faced with decisions of extreme importance, and in many cases they are hampered by an incomplete knowledge of the physical factors which are taking place on the lands under their control. For instance, should cattle be allowed on public lands? Are there public health implications that need to be considered in conjunction with grazing?

With such problems in mind, a study designed to answer some questions about secondary treatment of pinyon-juniper chainings was undertaken. The objective was to determine the

impact of grazing by domestic livestock on fecal pollution indicator bacteria from a pinyon-juniper site which had been chained with debris windrowed.

Literature Review

Wildland water quality studies are rare, or only peripherally associated with true wildland situations, and studies of this nature dealing with semiarid, ephemeral watersheds are nonexistent.

Wildlands may be defined as those remote areas which are not developed for agriculture, other than forestry, and are usually public lands in the western states (Darling, 1973, p. 14).

According to the Public Land Law Review Commission (1970) nearly one-half of the 273 million acres of public rangeland in the eleven western states is grazed at one time or another by domestic livestock. Recreational use of many of these same lands is rapidly increasing as leisure time, increased affluence, greater mobility, and urban pressures grow (Outdoor Recreation Resources Review Commission, 1962). The Public Land Law Review Commission (1970) further notes that grazing is permitted on nearly one-quarter of the land areas which have been withdrawn for recreation. Apparently, therefore, a potential for domestic animal fecal pollution and ensuing health hazards exists on high density recreational wildland which is grazed.

Diesch (1970) has reported that numerous diseases can be transmitted from one warm blooded organism to another via water. Commonly observed diseases related to contamination of water supplies from cattle feedlots are salmonellosis and leptospirosis. A leptospirosis outbreak among several young people in Iowa was traced to their swimming hole on the Cedar River. Leptospirosis-infected cattle had access to the river upstream from the swimming hole (Willrich, 1967). Bryon (undated) has also reported a leptospirosis outbreak associated with a swimming hole near Columbus, Georgia. Cattle, swine, and dogs found to have a *Leptospirosis canicola* infection all had access to the stream which fed the swimming hole.

Geldreich (1970) has concluded that the frequent occurrence of pathogens in domestic animals and wildlife supports concern about fecal contamination from all warm blooded animal sources.

Kunkle (1970) related bacterial densities to patterns of land use in Vermont. He found an increase in fecal coliform counts when cattle were adjacent to the stream as opposed to further away. However, he determined that only a "minor fraction of

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The report is submitted as Technical Article No. 1999, Utah Agricultural Experiment Station (Project 749). Support is also acknowledged from the Office of Water Research and Technology, Grant A-022-Utah.

Manuscript received April 5, 1975.

the total available live bovine fecal material ever washed into the stream." He concluded, therefore, that only the area immediately adjacent to the stream, rather than the entire watershed, is of major importance in terms of introducing this sort of pollution into the stream.

Working with a wildland stream in Colorado, Morrison and Fair (1966) attempted to determine several environmental effects on microbial dynamics. They did note, as a peripheral observation, that cattle grazing adjacent to the stream caused an increase in coliform counts.

Kunkle and Meiman (1967) studied the Little South Fork of the Cache la Poudre River in Colorado in order to assess several water quality characteristics. They found that fecal coliforms proved to be a better indicator of watershed impact than turbidity and suspended sediment.

The same team also investigated the water quality impact of grazing on a mountain meadow. They found that the indicator bacteria produced evidence of more pollution in a grazed watershed than in a natural ungrazed catchment (Meiman and Kunkle, 1967).

Slawson and Everett (1973) found that the water quality of the main stream Colorado River was relatively constant in terms of chemical and biological parameters. However, the tributary streams showed extreme temporal variability in these parameters as a result of summer rain and flood patterns. They concluded that the side streams pose a definite health hazard to unwary travelers.

Kunkle and Meiman (1968) also investigated the variation in bacterial numbers with time. They noted a daily variation with afternoon lows and evening highs. This cycle followed the cyclic diurnal stream stage, with the high bacterial counts correlating to high streamflow. They also noted an extreme bacterial die-off contributed to the low bacterial counts observed during the late afternoons.

Mack (1974) demonstrated, however, that coliform bacteria can persist and even multiply in natural waters. He also noted that multiplication was greater at 35°C than at lower temperatures. Hendricks and Morrison (1967) have also reported the enteric bacteria's ability to multiply and grow in cold mountain streams. They suggest that the river's self-purification mechanism plays a role in suppressing the unrestrained growth of these organisms, however.

Walter and Bottman (1967) studied a pair of watersheds near Bozeman, Montana. They noted that one of the watersheds which had been protected from public use for over 40 years consistently showed higher bacterial counts than the adjacent watershed, which was open to the public. Stuart et al. (1971) observed the same watershed and theorized that the higher bacterial counts could be attributed to higher wildlife numbers. Apparently the wildlife favored this watershed due to its protected or "refuge" status. Bissonette et al. (1970) employing a serological technique attempted to isolate the source of bacterial contamination on the same closed or refuge watershed. They concluded that the sources of contamination were indeed wild animals.

Skinner et al. (1972) observing a mountain watershed in Wyoming noted a seasonal fluctuation in bacterial numbers. The authors found increasing concentrations of bacteria as the snowmelt hydrograph advanced toward its peak. They further speculated that increased bacterial numbers were correlated with grazing periods of domestic livestock and wildlife numbers.

In a recent wildland study in northern Utah, Darling and

Coltharp (1973) found significant increases in bacterial counts during periods of cattle and sheep grazing at stream locations immediately downstream from the grazing activity. Bacterial counts in streams draining the grazed watersheds reached seasonal maximum values during the grazing period, while counts from a nearby ungrazed watershed remained relatively low and constant. In evaluating the health hazard implications of livestock grazing on public wildlands they recommended that direct access of livestock to important water supply streams be prevented (Coltharp and Darling, 1973). Fencing of stream channels would provide a buffer zone between the stream and the livestock. Livestock watering places should be developed away from the live stream. They further recommend that rather than suggesting a curtailment of livestock grazing on public lands, the recreating public be advised of the possible dangers involved in drinking untreated stream water.

Study Area and Treatments

The study site is located near Coyote Flat, approximately 1 km west of Utah Highway 261, between Natural Bridges National Monument and Mexican Hat, Utah, and approximately 70 km west of Blanding, Utah. It is at an elevation of 2,150 m and within the confines of the Colorado Plateau.

The soil at this location is derived from a sandstone parent material and extends to a depth of approximately 1.5 m. The pH of the soil is slightly basic, averaging about 8.0. Organic matter content is low, slightly less than 2.0%. Soil texture is a sandy loam, with few rocks present (Gifford, 1973).

Primary treatment was applied to the site in the fall of 1967, namely chaining and windrowing of debris. The windrowed treatment was drill seeded to crested wheatgrass (*Agropyron cristatum*) at 9.1 kg/ha (8 lb/acre). The study area was then fenced to exclude livestock.

During June, 1974, secondary treatment was established. Six head of 2-year-old bulls and four mature cows (three with nursing calves) were allowed to graze the chained-with-debris-windrowed location for 2 weeks. The cattle were stocked at the rate of 2 ha/AUM. This is comparable to stocking rates which local Bureau of Land Management officials attempt to attain on well-established crested wheatgrass seedings near the study site (Assistant Area Manager Ken Moore, 1974, personal communication).

Under undisturbed conditions mature juniper trees (*Juniperus osteosperma*) made up 24% of canopy cover (500 trees/ha) while pinyon pine (*Pinus edulis*) composed about 8% (200 trees/ha). Shrub cover, consisting primarily of big sagebrush (*Artemisia tridentata*) was less than 1%. Bare ground, including some cryptogam species, and litter composed the balance (Gifford, 1973).

The chained-with-debris-windrowed treatment had from 13–73% ($\bar{x}$ = 40.94%) total cover of which 4–45% ($\bar{x}$ = 23.09%) was litter and 1–35% ($\bar{x}$ = 17.25%) was crested wheatgrass cover. These cover measurements are based on small plot percentage cover values. Each of the .23-m² runoff plots was evaluated for total cover using 100 systematically located points per plot.

After the cattle were removed the area was composed of 5–55% ($\bar{x}$ = 31.78%) total cover, of which 4–39% ($\bar{x}$ = 21.22%) was litter, and 0–26% ($\bar{x}$ = 10.56%) was crested wheatgrass cover. This represents a vegetative production of approximately 319 kg/ha and a subsequent consumptive use of 177 kg/ha or 55.5% utilization.

Methods

Field Procedure

A Rocky Mountain infiltrometer (Dortignac, 1951) was

used to generate runoff from small, moveable plots, each plot being 0.23 m² in size.

All plots were pre-wet prior to application of simulated rainfall in order to eliminate confounding effects of antecedent moisture. Artificial rainfall was then applied to the plots at a rate of approximately 7 cm per hour for 28 minutes. Both runoff and rainfall were collected initially, after 3 minutes, and subsequently at 5-minute intervals during the rainfall period.

Six samples per treatment area per treatment date were run. Two randomly located clusters of three plots were located within the observed areas (undisturbed woodland and chained with debris windrowed). Each of the six observations were considered independent samples and were treated as such in all data manipulations.

Parameters Analyzed

Each sample of the runoff water was tested for indicator bacteria (fecal and total coliform) using the multiple tube and evaluated temperature tests as outlined in *Standard Methods* (American Public Health Association, 1971) and *A Laboratory Manual for Aquatic Microbiology* (Post, 1971).

Since it was difficult to use distilled water as the artificial rainfall source, local water from Natural Bridges National Monument was used. This water was drawn from one of the two deep wells located at the Monument and stored in a large 50,000 gallon metal tank. The artificial rainfall water was transported from the Natural Bridges storage tank to the plots in three 55-gallon metal drums and a 300-gallon trailer mounted water tank. Runoff water samples were collected for analysis after they had passed over the soil surface and into containers at the base of the plot.

Samples of "rainfall" were collected concurrently by placing a 1000-ml beaker on an elevated stand and catching drops of water as they fell. This "rainfall" water was then analyzed in the same fashion as the runoff water.

Bacterial analyses were performed using a Most Probable Number (MPN) (American Public Health Association, 1971). The principle involved in this technique is that coliform bacteria will produce gas from the fermentation of lactose in a broth medium within a given time at a specific incubation temperature. Presumptive and confirmed tests for coliform were performed routinely at the field laboratory.

The multiple tube (MPN) technique was chosen over the membrane filter technique due to the heavy sediment load present in the water samples, which interfered with filtration and suppressed bacterial growth on the filters. Pre-filtration to remove the sediment was unacceptable since that would also remove any bacteria adhering to the sediment particles (Post, 1973, personal communication). Kitrell and Furfari (1963) noted a similar situation when they observed that bacteria may be effectively removed from water if they are absorbed on soil particles which subsequently settle out of suspension.

Results and Discussion

There were no significant differences for fecal indicator bacteria averages between grazed and ungrazed treatments, time, or years; and only the year/time interaction of the related interactions showed significance at the .05 level.

Both the total and fecal coliform counts per 100 ml are relatively low in the runoff water produced by simulated rainstorm from the Rocky Mountain infiltrometer. However, the low numbers do not necessarily meet the Public Health Service standard of <1 coliform/100 ml for drinking water (Public Health Service, 1962). An increased variability in bacteria numbers was noted in 1974, when the debris-windrowed area was grazed by cattle, however.

Why is an area subjected to cattle grazing registering such low coliform counts? Do the bacteria die rapidly after being deposited on hot soil surfaces and subjected to intense sunlight?

Apparently coliform bacteria are able to survive intense sunlight and heat for at least one summer. A bacterial longevity experiment was conducted concurrently with the other research to determine if the bacteria would remain viable under local conditions throughout the entire grazing season. A fresh "cow pie" (fecal material) was marked and periodic samples were taken from it over an 18-week period to determine bacterial viability. Each sample (approximately 16 cc volume) was suspended in 100 ml of distilled water for 1 hour. At the end of the hour the supernatant was withdrawn and processed according to the standard method for the MPN bacteria test. The results of this experiment are delineated in Table 1. The coliforms within this slurry were able to persist in numbers in excess of 1,100/ml of slurry for at least 7 weeks. At approximately 9 weeks under ambient conditions, some variation in bacterial die-off was noticed. Fecal coliforms, which are present in lower numbers than total coliforms, began to show a decline in population several weeks earlier than the total coliforms. The atypical pattern expressed during the eleventh week is attributed to natural variation in bacteria numbers within the feces itself as the bacteria numbers begin to decline.

Table 1. Total and fecal coliform bacteria (no./ml) found in bovine feces exposed to ambient weather conditions from 0 to 18 weeks in southeastern Utah.

Week	Total coliform	Fecal coliform	Date of sample
0	>1,100	>1,100	June 19, 1974
1	>1,100	>1,100	June 25, 1974
3	>1,100	>1,100	July 9, 1974
7	>1,100	>1,100	August 4, 1974
9	>1,100	290	August 20, 1974
11	9.3	9.3	September 3, 1974
18	>1,100	53	October 22, 1974

*Based on 16 cc of bovine fecal material suspended in 100 ml of distilled water.

Post (1974, personal communication) has speculated that the bacterial life span under such conditions could be as long as several seasons since the bacteria are able to maintain life for several years if they are desiccated quickly while being held within a protective media. This may have been the case on the study site, since the cow manure containing the bacteria dries within 3 or 4 days under the summer sun and subsequently remains intact for several months or even years.

Apparently then, the low bacterial counts must be associated with a low density of bacterial sources. In this study, 102 plots 9.6 ft² were analyzed for percentage of feces coverage on the debris-windrowed watershed. This survey indicated that only 0.2% of the area was covered by manure at this level of grazing per season (2 ha/AUM). If the manure itself is taken as a point source for pollution, then it is apparent that only a very small percentage of any given watershed area is contributing indicator bacteria.

Figure 1 shows the results of another experiment testing the bacterial relationship between 1-month-old manure and increasing distances from it. A series of three infiltrometer plots were located so that one plot was centered around the fecal deposit. The next two were centered 0.5 and 1.0 m away from the feces, respectively. A high intensity simulated storm

Fig. 1. Spatial relationship between coliform bacteria and distance from month-old bovine feces.

was created above the plots with the Rocky Mountain infiltrometer. The resultant runoff was collected and analyzed for total fecal coliform bacteria.

At a distance of 1 m from the feces very few fecal coliforms were present (average of approximately 23 organisms/100 ml) total coliforms were observed. Apparently only the feces themselves and an area within perhaps a meter radius of soil surrounding them are subjected to any degree of fecal bacteria pollution from grazing livestock. Even including the adjacent area associated with pollution sources, only about 4.9% of this particular grazed area could be classified as a source area.

It seems, therefore, that unless the feces are deposited in or adjacent to a streambed there is little danger of significant bacterial contamination resulting from livestock grazing on semiarid watersheds similar to those included in this study. Even those feces deposited in the streambeds and gullies of these dry, ephemeral watersheds may not constitute a problem, since Gifford (1973) has noted that little, if any, water runs off from similar areas during any given year, particularly in debris-in-place chainings. (Gifford's studies have, however, been confined to areas of less than 20% slope and fairly deep soils. His findings do not refer to steep slopes, shallow soils, or slick rock areas. They are applicable, however, since livestock tend to favor the flatter, better vegetated sites, rather than the steeper, rougher areas.)

Summary and Conclusions

During the summers of 1973 and 1974, a water quality study was conducted in San Juan County, southeastern Utah. The area chosen for the study was a 7-year-old pinyon-juniper chaining project. The site had been chained and the debris bulldozed into windrows. It was seeded to crested wheatgrass in the fall of 1967. An "undisturbed" woodland area situated

adjacent to the chaining was maintained and served as a control area.

During the 1973 field season, water quality baseline data were collected from the area. Secondary treatment, consisting of livestock grazing of the chained-with-debris-windrowed location was implemented during the spring of 1974. Water quality information was subsequently collected during 1974 in order to evaluate the changes which occurred on the sites relative to the treatment it had received.

A Rocky Mountain infiltrometer was used to create simulated, high intensity rainstorms on the area. Resultant runoff was analyzed for the several water quality parameters in question.

Results of the study indicate, first of all, that it is indeed possible to record levels of bacteria (which would seemingly have the potential to wash from upland watershed areas into streams) through use of the Rocky Mountain infiltrometer. Secondly, it appears the potential public health hazard of livestock grazing on semiarid open range on gentle slopes is minimal. While the bacteria present in the livestock fecal material remains viable for at least one grazing season, they are apparently confined within the fecal material itself. The actual watershed area which is occupied by fecal material may only be in the order of 0.2% during that year's grazing season, based upon a grazing use rate of 2 ha/AUM, though approximately 4.9% of the area may be within a 1-m radius of the feces.

Under dry rangeland conditions, such as experienced in much of the southwestern United States, permanent flowing streams are rare. More frequently, the area is perennially dry, with an occasional flash flood providing a short-lived, ephemeral water flow. Cattle are maintained in these locations by hauling water to established watering troughs or by developing water catchment ponds at local springs. Therefore, there is little or no effective stream bank area from which the bacteria can be flushed into a water course. Moreover, on most chainings, and in particular on debris-in-place chainings, it is doubtful that runoff water ever flows any distance overland. Due to high water retention and detention storage potentials, very little rainfall coming into these debris-in-place areas ever runs off.

It is difficult to extrapolate from the results observed under small plot measurements to an entire watershed. The reactions of the whole, integrated system may well be different from those observed as components of this system. Nevertheless, with these risks and hazards in mind, one must at least attempt to draw some practical conclusions. In terms of livestock grazing, no apparent negative public health hazards were demonstrated through observation of the small runoff plots established on an area grazed at the rate of 2 ha/AUM. While additional factors may cause significant alteration of this pattern on the watershed as a whole, there is no evidence based on this study to indicate any significant public health problems presented by cattle grazing on open range similar, at least, to the sites and grazing rates included in these observations.

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