# Change in Bacterial Populations Downstream in a Wyoming Mountain Drainage Basin

QUENTIN D. SKINNER, JOHN C. ADAMS, ALAN A. BEETLE, AND GLENN P. ROEHRKASSE

**Abstract**

**Ten bacteriological tests were utilized to monitor different bacterial populations found in water samples taken from streams draining high mountain rangeland. Livestock grazing and recreation constituted the major uses of the study area. Vegetation types were typical of those found in other sub-alpine and alpine zones in the central Rocky Mountains. Results show differences in counts of bacteria between sampling sites along individual streams sampled with the exception of those organisms capable of reducing nitrate were not significant. A seasonal variation in the numbers of bacteria were found between streams. This variation is not fully explained by drainage basin areas or related to runoff. In contrast, within each stream counts varied with season and could be related to runoff. Bacterial populations which indicate fecal pollution were low and probably derived from animals not man. Wet meadows and bog areas under snow may be possible sources for sulfate reducing bacteria and those organisms capable of reducing nitrate.**

Ten bacteriological tests were utilized to monitor bacterial populations found in water samples taken from streams draining high mountain rangeland. Skinner et al. (1974a, 1974b) sampled each population weekly over 2 years. The purpose of this study was to verify if water taken from sampling sites by Skinner et al. (1974, 1974b) and bacterial numbers were representative of each stream from headwater to each downstream tributary during different summer months. Bacterial tests were selected which are associated with fecal pollution, mineralizing cycles, and environmental conditions.

Enteric bacteria, those indigenous to the intestinal tract of warm-blooded animals, consistently serve as indicators of fecal pollution to receiving waters (Morrison and Fair 1966, Fair and Morrison 1967, Carswell et al. 1969, Stuart et al. 1971, Skinner et al. 1974a, Stuart et al. 1976, Milne 1976, Buckhouse and Gifford 1976, Stephenson and Street 1978, Varness et al. 1978 and Doran and Linn 1979). Specific bacterial groups analyzed by these authors include fecal coliforms (FC), fecal streptococci (FS), or both. Ratios between FC/FS were often calculated to delineate original source of fecal bacteria between mammal or human users of rangeland.

Bacterial populations indigenous to natural waters and those capable of growing only within discrete temperature ranges have been monitored in streams draining rangeland (Skinner et al. 1974b, Stuart et al. 1976). Organisms sampled from water and enumerated by the standard plate count procedure at 35° C, represent those capable of originating from warm-blooded animal sources. Plate counts incubated at 20° C are utilized to enumerate bacteria associated with the water's surrounding environment (Amer. Pub. Health Ass. 1976).

Authors are associate professor, Division of Range Management; associate professor, Microbiology and Veterinary Medicine; professor, Division of Range Management; professor, Agriculture Substation, University of Wyoming, Laramie 82071.

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Bacteria capable of fluorescing under long wave radiation (fluorescent bacteria) have been found in significant numbers in surface waters (Collins 1963, Silvey and Roach 1964). Johnstone (1970), Skinner et al. (1974b), and Skinner et al. (in press) have all monitored streams for these bacteria to detect differences in eutrophication of receiving waters.

Skinner et al. (1974b) monitored bacteria capable of reducing nitrate to nitrogen gas and sulfate to hydrogen sulfide within well aerated mountain streams. The presence and metabolic activity of these organisms in an aerated environment was questionable because sulfate reducing bacteria are strict anaerobes. These reducing bacteria and their relationship to the presence of oxygen in soil and water has since been studied (Betlach and Tiedge 1981, Ingvorsen et al. 1981, Rake and Eagon 1980, Ryden et al. 1979, Keeney et al. 1979, Howorth and Teal 1979, Jorgensen 1979). Even though oxygen may be present, anaerobic microniches exist in wet soils thereby allowing survival of organisms associated with the anoxic portion of the nitrogen and sulfate cycles (Howarth and Teal 1979, Sorensen et al. 1979, Jorgensen 1977). Because anaerobic conditions may be created in soil pore space by water replacing air, water logged soils may increase reducing bacterial populations and activity. For example, Ryden et al. (1979) have shown fluctuations in the amount of nitrate reducing activity in pastures with variation in soil moisture. Higher activity occurred with increased soil moisture. Percolation or runoff of water from wet upland areas may in part explain their presence in well-aerated receiving streams. Interchange of stream water and bank storage may exist, carrying with it bacteria and chemicals (Morrison and Fair 1966 and Wesche 1982).

## Study Area

This study was conducted within the Wyoming Water Research Center's (WWRC) Nash Fork Watershed Observatory located within the Medicine Bow Mountains, approximately 50 km west of Laramie, Albany County, Wyo. The watershed encompasses 1,904 ha and varies in elevation from 2,774 m to 3,573 m. Located within the watershed are 3 drainage basins which are Sally Creek, Telephone Creek, and Nash Fork. Sally and Telephone creeks join the Nash Fork and continue as the Nash Fork through the study area boundary (Fig. 1).

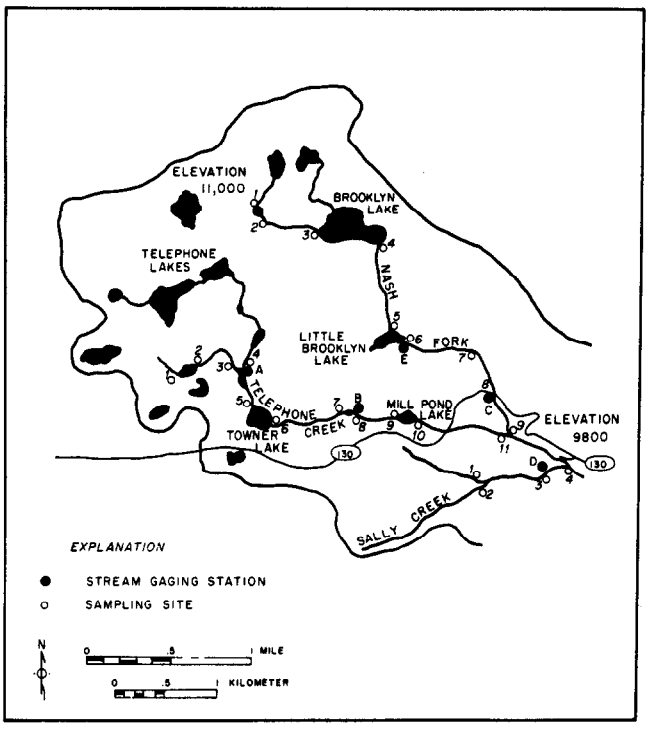


**Fig. 1.** *Study area and sampling sites located on Nash Fork, Telephone Creek, and Sally Creek; Nash Fork Study Area.*

Vegetation is montane to sub-alpine and has been described by Hanna (1934) and Oosting and Reed (1952). Lodgepole pine *(Pinus contorta)* is largely confined to areas between 2,774 m and 3,201 m in elevation. Spruce-fir *(Picea engelmanni - Abies lasiocarpa)* forests are prevalent between 2,987 m and 3,201 m. Aspen *(Populus tremuloides)* is limited within the area. Krummholz is found at higher elevations. Grasses and forbs increase with elevation and are dominant above 3,475 m. The greater part of the study area and all lakes occur between 2,987 m and 3,475 m.

Stream flow is measured at 6 stream gaging stations: 1 located on Sally Creek, 2 occurring on Telephone Creek, and 3 on Nash Fork Creek. In addition, air temperature, wind velocity, precipitation, evaporation, and solar radiation are monitored at selected sites within the watershed.

The climate of the research area is typical of sub-alpine zones. From 1966 to 1971 the average annual mean temperature and precipitation at the confluence of Sally Creek and Nash Fork were −1.67 C° and 13.1 cm. Average wind speeds at a gage height of 3.77 m range from 3.2 km per hour in forested areas to 6.2 km to 40 km per hour in open areas. Precipitation is largely in the form of snow and the prevailing wind direction is from west to northwest. Hydrologic data are presented in Table 1 (From Rechard and Smith 1972).

Sheep graze on the Telephone and Nash Fork drainages at higher elevations. Elk, deer, and small mammals are present throughout the entire watershed in preferred habitats. The study area is accessible by a paved highway and by a secondary system of unpaved roads. Numerous trails are present showing limited use by hikers and horseback riders. Public campgrounds, picnic areas, privately owned cabins, a tourist lodge, ski area, and science camp are present.

## Materials and Methods

### *Sampling*

A 2-year baseline data set collected by Skinner et al. (1974a, 1974b) was utilized to check any irregularity in findings to be presented. Data from this study agreed with the basic data set in bacterial numbers and trend.

Selected sites for determining the bacteriology of the Nash Fork Research Area were located on Sally Creek, Telephone Creek, and Nash Fork above their confluence (Fig. 1). All base line data samples were collected at site 8 Nashfork, sites 4 and 7 Telephone Creek, and site 4 Sally Creek. Three additional sites were added for Sally Creek, 9 for Telephone Creek, and 8 for Nash Fork to complete this study.

Water samples were collected 3 times at all sites during the summer of 1972. The first collection was taken during early July and the others during early and late August. Sterilized screw-capped 1-liter wide-mouth polypropylene bottles were used in obtaining grab samples. These were packed in ice and transported to the laboratory in Laramie for analysis. Samples were processed within 5 hours of collection.

### *Bacteria Tests:*

Bacteria were enumerated following procedures described by Skinner et al. (1974a, 1974b). Total counts of aerobic heterotrophs were obtained by the spread plate technique on Henrici's medium as modified by Stark and McCoy (1938). Bacterial plates were incubated at 20° C. Colonies fluorescing under long wave ultraviolet radiation were also recorded from the spread plates. Plate counts using tryptone glucose extract Agar (Difco) were done according to Amer. Pub. Health Ass. (1976). Plates were incubated at 35 and 20 C. Total coliforms and nitrate reducing bacteria were enumerated by the 5-tube most probable number technique. Procedures followed Amer. Pub. Health Ass. (1976) for enumerat-

**Table 1. Hydrologic data, Nash Fork Study Area.**

| Stream | Annual mean flow $m^3$ | Annual medium flow $m^3$ | Annual maximum flow $m^3$ | Annual minimum flow $m^3$ |
|---|---|---|---|---|
| Sally Creek | 1,504,845 | 1,397,832 | 2,195,594 | 1,048,458 |
| Telephone Creek at Mill Pond | 5,674,009 | 6,537,444 | 7,406,880 | 3,207,048 |
| Telephone Creek above Towner Lake | 4,193,832 | 4,440,528 | 5,550,660 | 2,713,656 |
| Nash Fork above Brooklyn Lodge | 6,290,748 | 6,414,096 | 7,647,576 | 4,810,572 |
| Nash Fork below Ski Area | 12,704,844 | 12,334,800 | 19,612,332 | 7,277,532 |

ing total coliforms and using nitrate broth (Difco) for nitrate reducing bacteria. The presence of nitrite was determined by following the Manual of Microbiological Methods (1957) for test tubes in which trapped gas was not present. The membrane filter technique Amer. Pub. Health Ass. (1976) was followed for enumerating fecal coliforms using MFC Broth (BBL) saturated pads and for fecal streptococci using KF Agar. Gridded filters with a pore size of 0.45 micrometers were utilized for entrapment of bacteria. Sulfate reducing bacteria were determined using molten iron sulfide agar *(Oxoid)* as modified by Mara and Williams (1970) and counted by the 3-tube method.

*Statistics:*

Bacterial test data were statistically analyzed using analysis of variance procedures for differences among streams, among sampling sites, and among sampling periods. Duncan's new multiple-range test was used to separate differences among streams, sampling sites, and periods where significant $F$ values were found at an $\alpha$ of 0.05.

## Results and Discussion

*Sampling Sites*

With the exception of those organisms capable of reducing nitrate to gas there was no significant difference between sites along each stream. Consequently one could have sampled 9 bacteria populations at the confluence of each stream and enumerated organisms indicative of potential pollution or bacterial populations dynamics. Results give the impression that sensitivity of using these bacteria to measure differences in user pressure along a single stream course is slight. The distance of flow from near the headwater to the confluence of a second stream is not great enough to significantly change numbers of organisms found under this sampling scheme.

Number of organisms capable of reducing nitrate were different between sites along the Nash Fork (Fig. 2). There is evidently

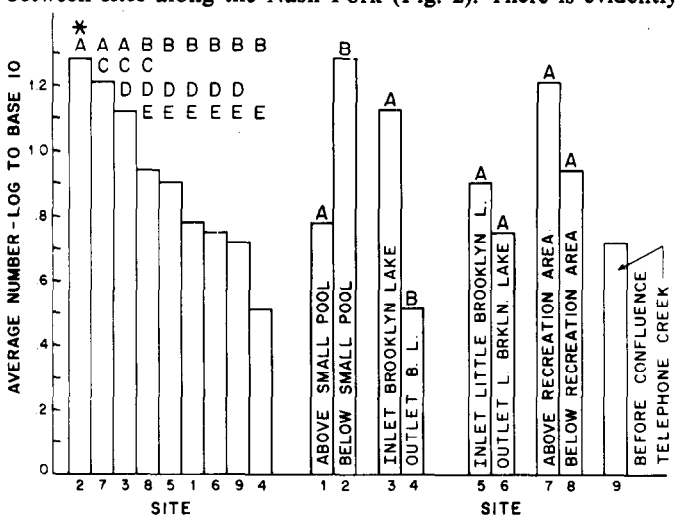


**Fig. 2.** *Average number of organisms/100 ml for each sampling site located on Nash Fork for those organisms capable of reducing nitrate to gas. *Like letters from left to right above bars are not significantly different at P0.05.*

enough stream distance to change the number of these organisms between sampling sites. The source for these organisms is not clear. There is a possibility that these bacteria are associated with bed load sediment and riparian zones. Streams with stream flow-bank storage interchange could yield different numbers in receiving waters. The value of monitoring for bacteria capable of reducing nitrate has not been determined from a range management view. If these bacteria are associated with riparian zones and if one is dedicated to studying riparian habitat then these organisms may be of value as an indicator for change in soil moisture and nutrient turnover as inferred from Ryden et al. (1979).

Bacteria in streams, lakes, or reservoirs may settle out of water and become incorporated into bottom sediments (Carswell et al. 1969, Stephenson and Rychert 1982, Skinner et al. (In Press)). If settling does occur, bacterial counts may be higher at the inlet than the outlet. This may in part explain difference between bacterial counts at sites 3 and 4 (Fig. 2). Bacterial counts at sites 5 and 6, although not significantly different, tend to follow a high and low count between inlet and outlet, respectively. Bacterial count at sites 1 and 2 show an opposite trend. Sites 1 and 2 are located on a shallow pond compared to sites 3 and 4. Currents caused by waves may cause sediment disturbance and thereby cause increased counts at site 1 as inferred from Stephenson and Rychert (1982).

Bacterial counts at sites 7 and 8 were not different. However, from the outlet of Little Brooklyn Lake to site 7, a sharp increase in numbers of organisms occurred. The increase was great enough to make bacterial counts at site 7 equivalent to those found at sites 2 and 3. A possible explanation for the higher numbers found at site 7 may be associated with the drainage or interchange of water from water-logged soils. As the Nash Fork travels from site 6, the outlet of Little Brooklyn Lake, to site 7 above the campground, it meanders through an extended wet meadow. Interchange of stream water with water from the meadow could again account for the higher counts of nitrate reducing bacteria found at site 7.

Site 2 was located near the headwaters of Nash Fork and was closely associated with snowmelt from the perennial snow banks found in sub-alpine and alpine regions of the study area. Bog areas both directly below snow banks and closely associated with the pond were prevalent. Percolation of water through these bogs could account for the large numbers of nitrate reducing bacteria found at site 2. Sites 3 and 8 were only a short distance from sites 2 and 7, respectively. A slight drop in numbers of organisms could be expected due to a settling effect and absence of water-logged soils near the stream.

Settling of organisms representing other bacteria tests carried out in this study but showing no difference between sites on each stream may very well be explained by sampling bottom sediments. Irrespective of distance from site to site downstream ponding of stream flow may very well mask any difference in results because of settling of organisms. The authors concur with Stephenson and Rychert (1982) that true evaluation of bacteria counts in stream flow should be correlated with bacteria counts in sediments where deposition may occur. Only then may one grasp a true picture for monitoring user pressure or watershed condition on any one stream using bacteria.

*Sampling Periods*

Change in bacterial counts during summer sampling periods (Table 2) followed the 2-year trend in base line data reported by Skinner et al. (1974a, 1974b). No significant differences were recorded between data sets.

Variation in means for plate counts at 20° C, fluorescent bacteria, organisms capable of reducing nitrate to gas, and sulfate reducing bacteria could be explained by differences in runoff within each stream. During early July, runoff was twice that in early August and more than triple that of late August. In general counts recorded for these bacterial populations followed the hydrograph with high numbers in July and low numbers in late August. Sulfate reducing bacterial counts were an exception being highest during low flow.

The above bacteriological tests were incubated at 20° C and therefore could represent organisms classified as faculative psychrophiles, which are capable of living and reproducing at colder temperatures. Consequently, bacteria surviving the winter snow cover, spring thaws, and cold waters of the sub-alpine and alpine habitats would be represented in the runoff samples. As the runoff decreased, the organisms being washed in from the surrounding terrestrial habitats would also be expected to decrease whereas, during late August, only organisms indigenous to the streams would likely be included in the samplings and actual counts should remain somewhat constant with runoff.

The reverse trend (an increase in counts as runoff decreased for those organisms capable of reducing sulfate) could be explained by observing the physical conditions of habitats conducive to sulfate reduction. During early July, runoff into wet meadows is such that the oxygen level of the soils could be replenished to a degree that the population of sulfate reducers would decline due to the presence of oxygen. As runoff decreases in August and water tables stabilize within wet meadows, stagnation and low oxygen levels in soils could develop. This condition would enhance growth of sulfate reducing bacteria; however, reduced flow would perhaps scour fewer cells from the stream bottom. Any interchange of waters between stream and wet meadows would increase the populations of sulfate reducing bacteria in late August. In addition, as soil temperatures increase through summer months, activity of reducing organisms may increase (Ingvorsen et al. 1981, Keeney et al. 1979).

Counts for fecal coliforms (Nash Fork) and total coliforms as well as plate counts at 35° C (Telephone Creek) were higher during early August. At no time was the ratio of fecal coliforms to fecal streptococci greater than 4 and it was generally less than 0.7. This would indicate that fecal contamination was not from man, but from animals (Geldrich 1972, Doran, and Linn 1979). Stream water travel time from any point of pollution from the headwaters to the confluence with Nash Fork is less than 24 hours for all 3 streams.

*Streams*

Differences combining all sampling periods were computed and significant differences were recorded for total and fecal coliforms, fecal streptococci, plate counts at 20° C and 35° C, sulfate reducing bacteria, those organisms capable of reducing nitrate to nitrite and nitrate to gas (Fig. 3).

Sally Creek is contained for the most part in a natural area. The Nash Fork and Telephone Creek drainages, in contrast, are subjected to recreational activities, activities associated with people owning private homes within the areas, and sheep grazing. Bacteriological tests designed to monitor fecal pollution indicated little fecal contamination was present during the 3 sampling periods for all streams. Fecal streptococci were more numerous than fecal coliforms. Ratios of calculated mean numbers of fecal coliforms to mean numbers of fecal streptococci found from water samples taken from Nash Fork (0.16), Telephone Creek (0.053), and Sally Creek (0.004) indicated that animals not humans were the major source for fecal pollution. These numbers correspond to those found by Doran and Linn (1979) where a ratio of 0.05 was indicative of wildlife sources and ratios above 0.1 were characteristic of grazing cattle. The mean number of fecal streptococci was highest at Sally Creek. Inhabitants such as wildlife within the natural area contribute fecal organisms to Sally Creek at a level equivalent to those areas grazed by sheep and used by recreators within the Nash Fork and Telephone Creek drainage basins. Stuart et al. (1970, 1976) found a similar relationship between grazing and recreational use.

Plate counts at 20° C for Nash Fork and Telephone Creek were 2.46 and 4.40 times higher than for Sally Creek, respectively. For plate counts at 35° C, Nash Fork was 3.86 times higher and Tele-

**Table 2. Average number of organisms/100 ml for the three sampling periods; early July, early August and late August. Nash Fork Study Area.**

| | Nash Fork sampling period | | | Telephone Creek sampling period | | | Sally Creek sampling period | | |
|---|---|---|---|---|---|---|---|---|---|
| Bacteria test | Counts early July | Counts early August | Counts late August | Counts early July | Counts early August | Counts late August | Counts early July | Counts early August | Counts late August |
| Total coliforms | A* 1.40 | A 1.23 | A 1.48 | A .80 | B 1.42 | B 1.12 | A .16 | A .69 | A 1.20 |
| Fecal coliforms | B -.81 | A .37 | B -.29 | A -.84 | A -.38 | A -.85 | A -.82 | A 0 | A 0 |
| Fecal streptococci | A .49 | A .88 | A .89 | A .44 | A .93 | A .50 | A 1.24 | A 1.11 | A .10 |
| Total count | A 6.17 | A 6.61 | A 6.09 | A 6.22 | B 6.71 | A 6.33 | A 5.13 | A 5.13 | A 5.87 |
| Plate count 20 C | A 4.70 | B 4.58 | B 4.38 | A 4.98 | A 4.86 | B 4.43 | A 4.22 | A 4.25 | A 4.01 |
| Plate count 35 C | A 3.82 | A 3.84 | A 3.50 | B 3.59 | A 3.98 | B 3.27 | A 3.06 | A 3.15 | A 3.26 |
| Fluorescent colonies | A 4.0 | B 3.55 | B 3.41 | A 3.93 | B 3.41 | B 3.27 | A 3.89 | B 3.46 | B 3.51 |
| Sulfate reducers | A 2.14 | B 2.91 | B 2.93 | B 2.32 | A 3.01 | A 3.27 | A 2.30 | A 2.90 | A 2.82 |
| Nitrate to nitrite | A 4.85 | A 5.11 | A 4.74 | A 4.68 | A 4.83 | A 4.47 | A 4.34 | A 4.47 | A 4.57 |
| Nitrate to gas | A 1.21 | B .96 | B .89 | A 1.91 | B 1.36 | B 1.42 | A 2.48 | A 2.31 | A 2.44 |

*Like letters above values are not significantly different at an 0.05.

Counts are recorded as log to base 10.

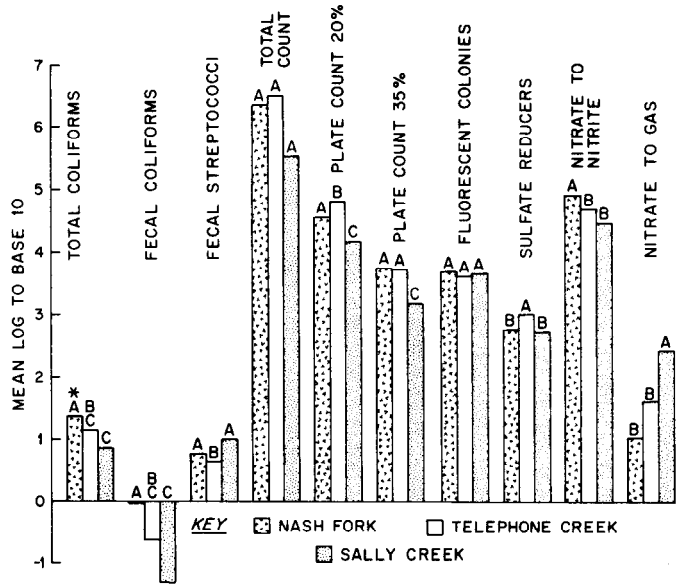


**Fig. 3** *Mean number of organisms for samples taken from Nash Fork, Telephone Creek, and Sally Creek for all sampling periods; Nash Fork Study Area. *Like letters above bars are not significantly different at P0.05.*

phone Creek was 3.62 times higher than Sally Creek. The abundance of organisms capable of reducing nitrate to nitrite in the Nash Fork and Telephone Creek were 2.89 and 1.68 times greater than that found in Sally Creek. The differences in the total number of organisms found could possibly reflect differences in the total areas of drainage and the amount of runoff for each stream. For example, the mean runoff per drainage basin during July and August for Sally Creek, Nash Fork, and Telephone Creek was 60 mm, 194.3 mm, and 188.7 mm respectively. Runoff for Telephone Creek, therefore, was 3.24 times greater than for Sally Creek whereas Nash Fork was 3.15 times greater. The Telephone Creek drainage basin is 1.78 times larger than the drainage basin for Sally Creek while the drainage basin for Nash Fork is 2.17 times larger.

To examine the influence of drainage area and bacteria counts in different streams, increase in runoff between each stream was multiplied by the increase in area (Table 3). This increase in area and runoff could indicate an expected increase in number of organisms in Telephone Creek and Nashfork over those found in Sally Creek. Testing this relationship is illustrated using total counts

**Table 3. The actual and computed times greater numbers of organisms were and should have been within Nash Fork and Telephone Creek over those found and expected to be found in Sally Creek by using areas of drainage basins and runoff during July and August as parameters.**

| | Actual* | | Computed** | |
|---|---|---|---|---|
| | Nash Fork | Telephone Creek | Nash Fork | Telephone Creek |
| Total counts | 6.73 | 9.16 | 6.83 | 5.78 |
| Plate counts 20°C | 2.46 | 4.40 | 6.83 | 5.78 |
| Plate counts 35°C | 3.85 | 3.62 | 6.83 | 5.78 |
| Fluorescent colonies | 1.09 | 0.93 | 6.83 | 5.78 |
| Sulfate reducers | 1.07 | 1.83 | 6.83 | 5.78 |
| Nitrate to nitrite | 2.89 | 1.68 | 6.82 | 5.78 |
| Nitrate to gas | 0.03 | 0.16 | 6.83 | 5.78 |
| Total coliforms | 3.24 | 1.88 | 6.83 | 5.78 |
| Fecal coliforms | 19.00 | 7.6 | 6.83 | 5.78 |
| Fecal streptococci | 0.58 | 0.41 | 6.83 | 5.78 |

*Actual times greater bacteria counts were in Nashfork and Telephone Creek versus Sally Creek.
**Computed times greater bacteria counts should be by multiplying differences in drainage basin and differences in runoff for Nashfork and Telephone Creek versus Sally Creek.

plate counts at 20°C and 35‡ and those organisms capable of reducing nitrate to nitrite.

The product 5.78 for Telephone Creek and 6.83 for Nash Fork represents the computed times greater counts should be versus those that could be expected for Sally Creek by using only drainage basin areas and runoff for July and August. Drainage basin area and amount of runoff do not seem to account for differences in counts for streams within this study locality. Lower counts found within Sally Creek must be due to factors other than the size of drainage basins and runoff.

Fluorescent colonies for all streams were equivalent and responded in the same manner during each sampling period. Sally Creek's equal response as to number of organisms counted in other streams would suggest that ecological characteristics of the basin were such that more fluorescent organisms were present per unit volume of water within Sally Creek. The same would be true for sulfate reducing bacteria and those organisms capable of reducing nitrate to gas. A possible explanation for these higher numbers could be the wet meadows from which Sally Creek originates. The other two streams were fed during the latter part of the summer from snow fields and although they traverse wet meadows along their course, they were not dependent on them as the sole source for water.

### *Interactions*

Significant interactions between streams within sampling periods for fecal coliforms, fecal streptococci, and plate counts at 20 and 35°C were found. The authors can offer no further explanation for differences in plate counts at 20 and 35°C than were discussed for sampling periods. Explanation for the variation of pollution indicators between streams within sampling periods could be differences in stream flow or differences in patterns of use by wildlife and humans.

During early July, several elk were sighted at different times within the Sally Creek drainage. With spring runoff still high compared to later sampling dates, one could expect fecal organisms to be higher with elk use. During early August, fecal coliforms were not found in Sally Creek but fecal streptococci remained high (Table 2). Spring runoff had ended but the University of Wyoming Science Camp was in session. The lack of fecal coliforms would indicate animal pollution instead of man. Contact with the stream bank and disturbances of animal feces by student activity studying Sally Creek and other animals could account for the contamination. During late August, the stream flow was lower than during early August, the Science Camp was closed, and no sightings of elk or elk signs were observed. This could account for the drop in counts for fecal streptococci in Sally Creek in the late sampling period.

Higher counts recorded for Nash Fork and Telephone Creek for fecal organisms during early August could be accounted for use of their respective drainage basins by recreationists and wildlife. During early July, snow and colder air temperatures tend to discourage heavy use at higher elevations for recreation. By early August, temperatures have warmed up, camping facilities are dry, and the waters within streams are still high enough to provide enjoyable fishing. Human and animal activity through wet habitats of higher elevations still influenced by runoff from snowmelt could provide the means by which the monitored organisms entered Telephone Creek and Nash Fork.

In contrast, during late August, many wet habitats found at higher elevations during early August dry up because of declining snowmelt and runoff. It could, therefore, be more difficult for organisms associated with fecal contamination to enter the stream systems. Consequently, one could expect a decrease in these organisms during late August if, in fact, recreation and animal travel are maintained at a level equivalent to that of the early August sampling period. Recreation pressure did decline but sheep grazing was observed during the late sampling. The sheep, however, seemed to graze the dry meadows and krummholz more than moist meadows.

They avoided the wet meadows and bog areas which would have allowed fecal organisms access to stream water.

## Summary and Conclusions

Ten bacteriological tests were used for monitoring any differences in bacteria populations along 3 mountain streams. Numbers of total coliforms, fecal coliforms, fecal streptococci, total counts for aerobic heterotrophs determined on Henrici's agar at 20° C, plate counts at 35° C and 20° C, fluorescent bacteria, sulfate reducing bacteria, those organisms capable of reducing nitrate to nitrite, and those organisms capable of reducing nitrate to gas were collected. The study was conducted within the Medicine Bow National Forest approximately 50 km west of Laramie, Albany County, Wyo. Separate water samples were taken during early July, early August, and late August at 9 sites on 1 stream, 11 sites on another, and 4 sites on the last. Sampling sites were distributed from near head water to confluence with each downstream tributary.

Selecting a representative sampling location for collecting bacteria utilized for monitoring water quality of streams is often subject to question. This study shows that in streams sampled there were no differences in 9 of 10 bacteria populations studied along an individual stream course within an intense 3-period sampling scheme. Enteric bacteria and total bacteria counts often utilized to survey nonpoint and point source pollution did not vary significantly between sampling sites. Bacteria capable of reducing nitrate to gas did. Differences in numbers of nitrate reducing bacteria suggest that settling of these bacteria may occur in ponds and lakes. Consistent increase of nitrate reducing bacteria and the presence of sulfate reducing bacteria between ponds further suggest riparian zones and areas of water logged soils may be a contributing source for these organisms in well-aerated receiving waters. A seasonal variation in numbers of bacteria was found between streams drainage a high mountain watershed. Differences may or may not be related to runoff. Bacteria serving as indicators of fecal pollution were low. Source of fecal pollution by animals not man seemed to be responsible.

## Literature Cited


**American Public Health Association, American Water Works Association, Water Pollution Control Federation. 1976.** Standard Methods for the Examination of Water and Waste-Water. Amer. Pub. Health Ass., New York, N.Y.

**Betlach, M.R., and J.M. Tiedje. 1981.** Kinetic explanation for accumulation of nitrite, nitric oxide, and nitrous oxide during bacterial denitrification. Appl. and Environ. Microbiol. 42:1074-1084.

**Buckhouse, J.C., and G.F. Gifford. 1976.** Water quality implications of cattle grazing on a semiarid watershed in southeastern Utah. J. Range Manage. 29:109-113.

**Carswell, K.J., J.M. Symons, and G.G. Robeck. 1969.** Research on recreational use of watersheds and reservoirs. J. Amer. Water Works Ass. 61:297-304.

**Collins, V.G. 1963.** The distribution and existing bacteria in fresh water. Proc. Soc. Water Examination and Treatment. Sutton, England 12:40-73.

**Doran, J.W., and D.M. Linn. 1979.** Bacteriological quality of runoff water from pastureland. Appl. and Environ. Microbiol. 37:985-991.

**Difco Laboratories. 1953.** Difco Manual of Dehydrated Culture Media and Reagents for Microbiological and Clinical Laboratory Procedures. Ninth Ed. Difco Lab. Inc., Detroit, Mich.

**Fair, J.F., and S.M. Morrison. 1967.** Recovery of bacterial pathogens from high quality surface water. Water Resources Res. 3:799-803.

**Geldreich, E.E. 1972.** Buffalo lake recreational water quality: A study in bacteriological data interpretation. Water Resources 6:913-924.

**Hanna, L.A. 1934.** The major plant communities of the headwater area of the Little Laramie River, Wyoming. Wyo. Univ. Pub. in Sci. 1:243-266.

**Howarth, R.W., and J.M. Teal. 1979.** Sulfate reduction in a New England salt marsh. Limmol. and Oceanogr. 24:999-1013.

**Ingvorsen, K., J.G. Zeikus, and T.D. Brock. 1981.** Dynamics of bacterial sulfate reduction in a eutrophic lake. Appl. and Environ. Microbiol. 42:1029-1036.

**Johnstone, D.L. 1970.** Bacterial ecology of the Spokane River. Ph.D. Thesis. Washington State Univ. Pullman.

**Jorgensen, B.B. 1977.** Bacterial sulfate reduction within reduced microniches of oxidized marine sediments. Mar. Biol. 41:7-17.

**Jorgensen, B.B. 1979.** The sulfur cycle of a coastal marine sediment. Limnol. Oceanogr. 22:814-832.

**Keeney, D.R., I.R. Fillery, and G.P. Marx. 1979.** Effect of temperature on the gaseous nitrogen products of denitrification in a silt loam soil. Soil Sci. Soc. Amer. J. 43:1124-1128.

**Mara, D.D., and D.J.A. Williams. 1970.** The evaluation of media used to enumerate sulphate reducing bacteria. J. Applied Bact. 33:543-552.

**Milne, C.M. 1976.** Effect of a livestock wintering operation on a western mountain stream. Trans. of Amer. Soc. of Agr. Eng. 19:749-752.

**Morrison, S.M., and J.F. Fair. 1966.** Influence of environment on stream microbial dynamics. Hydrology Pap. 13. Colorado State Univ., Fort Collins.

**Oosting, H.J., and J.F. Reed. 1952.** Virgin spruce-fir of the Medicine Bow Mountains, Wyoming. Ecol. Monogr. 22:69-91.

**Rake, J.B. and R.G. Eagon. 1980.** Inhibition, but not uncoupling, of respiratory energy coupling of three bacterial species by nitrate. J. Bact. 144:975-982.

**Rechard, P.A., and V.E. Smith. 1972.** Physical and hydrometeorological characteristics of the Snowy Range Observatory. Water Res. Ser. 30, Univ. Wyoming, Laramie.

**Ryden, J.C., L.J. Lund, and D.D. Focht. 1979.** Direct measurement of dentrification loss from soils: I. Laboratory evaluation of acetylene inhibition of nitrons oxide reduction. Soil Sci. Soc. Amer. J. 43:104-118.

**Silvey, J.K., and A.W. Roach. 1964.** Investigation of the microgiological cycle in surface waters. J. Amer. Water Works Ass. 56:60-71.

**Skinner, Q.D., J.C. Adams, P.A. Rechard, and A.A. Beetle. 1974a.** Summer use of a mountain watershed on bacterial water quality. J. Environ. Qual. 4:325-329.

**Skinner, Q.D., J.C. Adams, P.A. Rechard, and A.A. Beetle. 1974b.** Enumeration of selective bacterial populations in a high mountain watershed. Canadian J. Microbiol. 20:1487-1492.

**Skinner, Q.D., M.A. Smith, J.E. Speck, and J.C. Adams. 1984.** Stream water quality as influences by beaver within grazing systems in Wyoming. J. Range Manage. (In Press).

**Sorensen J., B.B. Jorgensen, N.P. Revsbech. 1979.** A comparison of oxygen, nitrate, and sulfate respiration in coastal marine sediments. Microbiol. Ecol. 5:105-115.

**Stephenson, G.R., and L.V. Street. 1978.** Bacterial variations in streams from a southwest Idaho rangeland watershed. J. Environ. Qual. 7:150-157.

**Stephenson, G.R., and R.C. Rychert. 1982.** Bottom sediment: A reservoir of Escherichia coli in range land streams. J. Range Manage. 35:119-123.

**Stuart, D.G., G.K. Bissonette, T.D. Goodrich, and W.G. Walter. 1971.** Effect of multiple use on water quality of high mountain watersheds: bacteriological investigations of mountain streams. Appl. Microbiol. 22:1048-1054.

**Stuart, S.A., G.A. McFeters, J.E. Schillinger, and D.G. Stuart. 1976.** Aquatic indicator bacteria in the high alpine zone. Appl. and Environ. Microbiol. 31:163-167.

**Varness, K.J., R.E. Pacha, and R.F. Lapen. 1978.** Effects of dispersed activities on the microbiological quality of forest surface water. Appl. and Environ. Microbiol. 36:95-104.

**Wesche, L.B. 1982.** Relationships between surface and ground water quality in an alluvial valley floor. M.S. Thesis. WRRI, Univ. of Wyoming, Laramie.