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A SURVEY OF BACTERIAL WATER QUALITY IN ABRAMS CREEK, GREAT SMOKY MOUNTAINS NATIONAL PARK

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ABSTRACT

The purpose of this investigation was to estimate the numbers of total coliforms, fecal coliforms, and fecal streptococcus bacteria in Abrams Creek in the Great Smoky Mountains National Park from May to August 1977. The investigation was part of an extensive assessment of water quality of Abrams Creek.

The majority of the bacteria probably originated from nonhuman sources, but human contamination was evident at several sampling stations. The numbers of bacteria were variable between stations and sampling periods. Nonetheless, the water quality of the creek in Cades Cove was not suitable for primary contact use during some months based upon criteria established by the Environmental Protection Agency for total coliform bacteria and fecal coliform bacteria.

INTRODUCTION

Abrams Creek is a major stream in the Great Smoky Mountains National Park (Fig. 1). The headwaters of this stream (referred to as Anthony Creek) drain the north face of Mount Squires, 4,958 feet above mean sea level (MSL), flowing mostly through second growth forest. At an elevation of about 1,900 feet above MSL, the stream, now called Abrams Creek, enters an historical pastoral area—Cades Cove. The stream flows for a distance of about six miles in the Cove before flowing again through second growth forest. About 18 miles downstream from the cove, the creek discharges into Chilhowee Lake (874 feet above MSL).

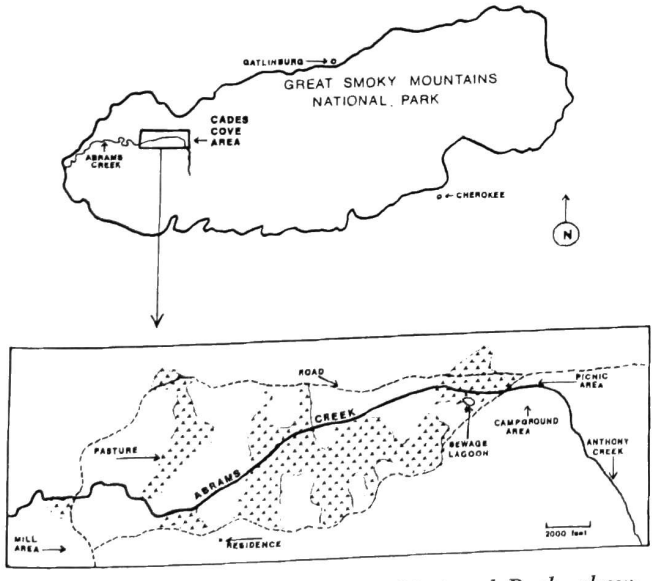

FIG. 1. *Great Smoky Mountains National Park, showing Cades Cove, pasture areas, and Abrams Creek.*

The Abrams Creek drainage is visited by thousands of park visitors each year, mostly in summer. The preponderance of visitor traffic is centralized in the Cades Cove area. People are attracted to the cove because this scenic historical area has pastures, pioneer cabins, a grain mill, picnic area, campground, and other attractions, such as fishing and swimming, which are readily accessible by automobile (Fig. 1). Visitors to the cove are also able to observe an abundance of wildlife, including squirrels, turkeys, deer, wild European boar, skunks, ground hogs, and bear.

The pastures in the cove are still used for cattle grazing and for haying by descendents of the cove settlers. The cattle obtain most of their drinking water directly from the creek and tributaries at specific sites. The number of cattle in the cove was reduced from 1,200 to 500 late in 1976.

Owing to the potential environmental impacts from visitor traffic and cattle, the water quality of Abrams Creek in Cades Cove was investigated by Kelly (1974) and Silsbee et al. (1976). The former examined temperature and turbidity, while the latter determined numbers of fecal coliform and fecal streptococcus bacteria in the creek as part of a survey of the backcountry water quality of streams in the park in 1976. The results of both studies showed that the water quality of Abrams Creek deteriorated in the cove.

A management policy of the National Park Service is to conserve, perpetuate, and restore, when necessary, park resources. The basis of this policy is to manage natural processes on the ecosystem level. Although historic areas in parks, such as Cades Cove, depart from this concept, the Service attempts to manage these areas by emphasizing a balance between the resource alterations and the associated changes of natural processes. But the deteriorated condition of Abrams Creek noted by Kelly and Silsbee suggests an imbalance in Cades Cove. In view of the present conditions, an ecological survey of Abrams Creek was conducted in 1977 to assist in the development of appropriate management programs for the cove. Part of this survey included estimates of the numbers of total coliforms, fecal coliforms, and fecal streptococcus bacteria from May to August. These bacterial types are often used to establish water quality (U.S. Environmental Protection Agency 1975).

METHODS

Bacteriological water samples were collected, without replication, once each month from May through August at 37 stations, including stations on Abrams Creek and its primary tributaries (Fig. 2). Some of the stations were located at strategic sites, such as near the campground, picnic area, sewage lagoon, residence, mill, and pastures.

Water was collected in sterile polypropylene bottles and kept

on ice until processed—less than six hours after samples were collected—in the laboratory, using the membrane filtration method (Anonymous 1975). Total coliform plates were cultured on Endo broth for 24 hours at 35°C. Fecal coliforms were cultured on MF-C broth for 24 hours at 44-5°C. Fecal streptococcus were cultured on KF streptococcus agar for 48 hours at 35°C. Thirty milliliters of stream water were filtered for total coliform plates and fecal coliform plates; 50 milliliters were filtered for fecal streptococcus plates. Following incubation, the colonies were counted under fluorescent illumination. Colonies were expressed as numbers per 100 milliliters of water.

Sample days, randomly selected, were scheduled for about the middle of each month, but sampling was sometimes delayed due to precipitation and the resulting increased discharge of the creek. Nonetheless, the discharge of the creek was nearly the same during each sampling period (Mathews 1978). Flows at stations 34, 9, and 26 were reduced as compared to stations immediately upstream and downstream due to subterranean flow in that area of the cove. The creek water began entering the ground near station 4. The creek was dry at station 26 in July and August.

The ratio of fecal coliforms to fecal streptococcus was used as an index of the mammalian sources of the bacteria (Geldreich 1969). Ratios less than 1 suggest nonhuman sources (e.g., cattle). Ratios of 3 or greater suggest a predominance of human contamination.

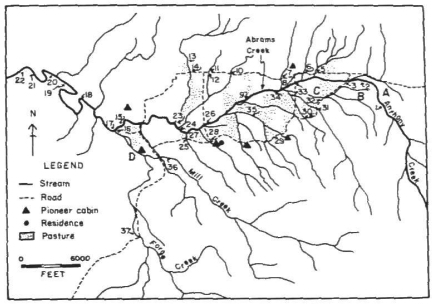

FIG. 2. *Location of the study area in the Great Smoky Mountains National Park, showing sample stations and cultural developments in Cades Cove.*

RESULTS

Main Creek

The numbers of total coliform, fecal coliform, and fecal streptococcus bacteria were variable along the main creek from the headwaters to the base station (22) on each sampling date (Fig. 3). This variability also occurred between sample periods.

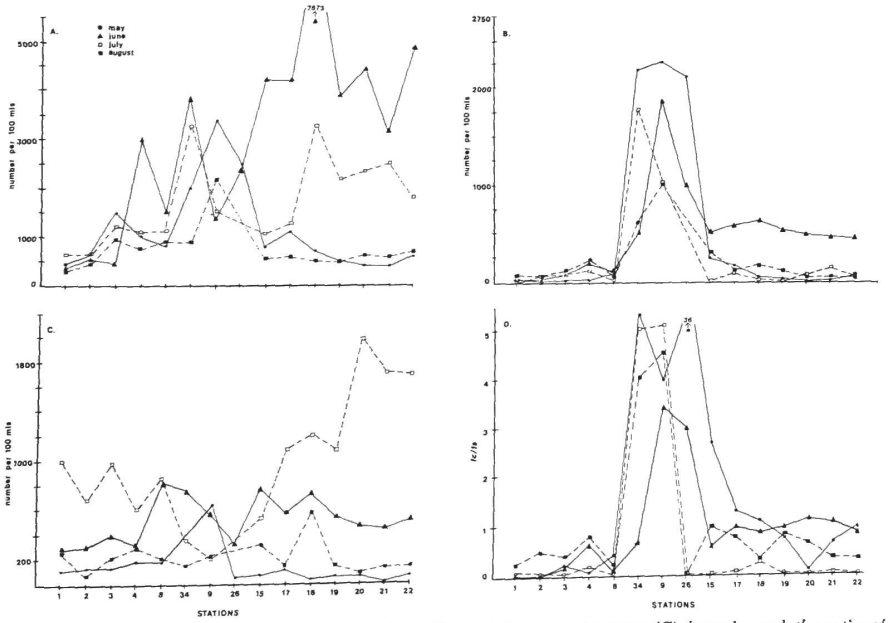

FIG. 3. *Numbers of total coliform (A), fecal coliform (B), and fecal streptococcus (C) bacteria, and the ratio of fecal coliform to fecal streptococcus bacteria (D) at sample stations located on Abrams Creek in May, June, July, and August, 1977.*

The numbers of total coliforms increased, in general, once the stream entered the cove (station 3). With the exception of the high counts at stations 4 and 15 in June, the highest counts typically were found at stations 34, 9, and 26. In May and August, the numbers of these bacteria at stations downstream from the cove were reduced, frequently to levels comparable to those of the uppermost stations (1 and 2). But in June and July, the numbers either increased or remained at levels comparable to the highest numbers found in the cove.

The lowest numbers of fecal coliforms were generally found at stations 1 to 8 and from stations 15 to 22. The highest numbers of this type of bacteria were found at stations 34, 9, and 26. The highest counts occurred in May. In June, the numbers of bacteria increased at stations 15 to 22 as compared to counts at these stations in other months.

In May, the numbers of fecal streptococcus were less than 200 per 100 milliliters from the headwater stations to station 22, except for a count of about 625 at station 9. The counts in June were typically greater than those found in May, particularly in the cove and stations downstream from the cove. In July, the counts generally decreased from station 1 to station 9 and then increased at the downstream stations. In August, the counts were similar to those found in May, except the highest count, about 600, occurred at station 18. The ratio of fecal coliforms/fecal streptococcus for all sample periods was conspicuously above 3 at stations 34, 9, and 26. At other stations the ratios were less than 1.5.

Tributaries

The numbers of total coliforms, fecal coliforms, and fecal streptococcus bacteria in the tributaries varied greatly, often without apparent explanation (Figs. 4

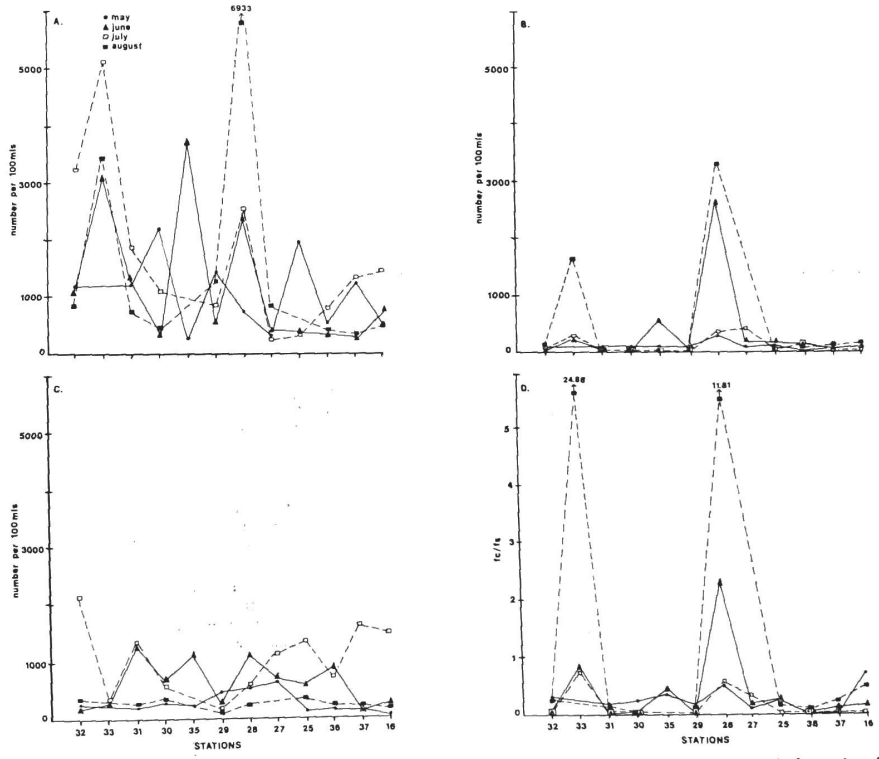

FIG. 4. *Numbers of total coliform (A), fecal coliform (B), and fecal streptococcus (C) bacteria, and the ratio of fecal coliform to fecal streptococcus bacteria (D) at sample stations on tributary streams of Abrams Creek draining the south side of Cades Cove in May, June, July, and August 1977.*

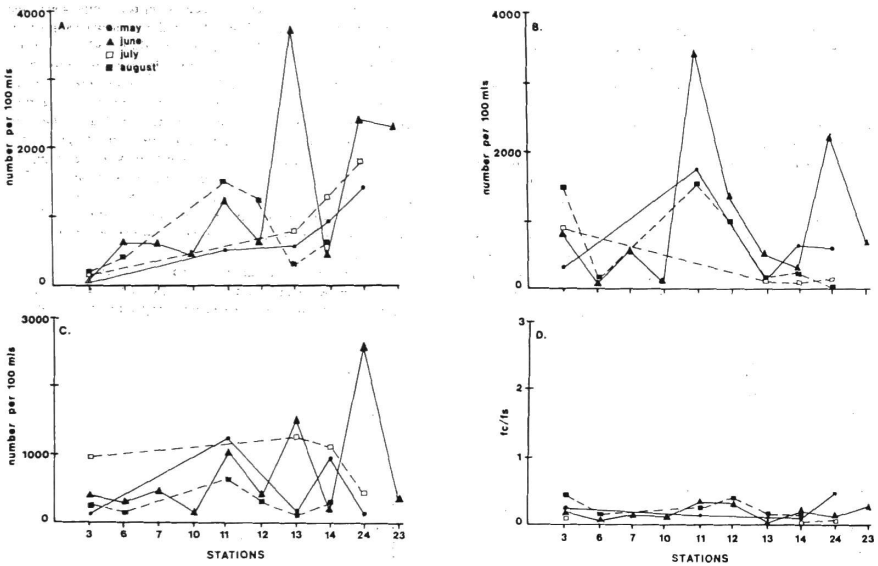

FIG. 5. *Numbers of total coliform (A), fecal coliform (B), and fecal streptococcus (C) bacteria, and the ratio of fecal coliform to fecal streptococcus bacteria (D) at sample stations on tributary streams of Abrams Creek draining the north side of Cades Cove in May, June, July, and August 1977. Missing data indicates that the stream was dry at those sample stations.*

and 5). Nonetheless, tributaries along the south side of Abrams Creek typically had more of these bacteria than did north side streams, this being particularly true for total coliforms and fecal coliforms.

The fecal coliform/fecal streptococcus ratios were nearly always less than 1 in the tributaries. Stations 33 and 28 had ratios greater than 5 in August, however.

Discussion

The purpose of this investigation was to estimate the numbers of three types of bacteria in Abrams Creek in the Great Smoky Mountains National Park. Water samples were collected monthly from May to August at 37 stations. The numbers of bacteria were variable between stations and sampling periods.

One of the major contributions to the variation of bacterial counts undoubtedly originated from intermittent point source contamination by mammals in the Abrams Creek watershed. The obvious difficulty of interpreting such introductions was that they occurred inconsistently. These introductions resulted in high counts on some sampling dates and not on others at particular stations.

Much of the bacterial contamination along certain portions of Abrams Creek probably originated directly or indirectly from the large numbers of visitors in the cove (Table 1). It is our view that the high ratios of fecal coliform to fecal streptococcus bacteria at stations 34, 9, and 26 may have originated from underground seepage from the sewage lagoon (which receives sewage from toilet facilities at the east end of the cove) and contamination from the numerous visitors we observed near the stream at the road just upstream from station 34. Subterranean drainage from the lagoon possibly enters the creek after surfacing at springs located just upstream from station 34. Overflow from the lagoon occurs infrequently, but during such periods the effluent is chlorinated and contains no live bacteria of the types studied in the present work (W. Williams, Park Sanitarian, Great Smoky Mountains National Park, personal communication).

TABLE 1. *Numbers of campers, picnickers, and visitors at Cable Mill in Cades Cove from May through August 1977. Data from public use records compiled by the National Park Service, Great Smoky Mountains National Park.*

Type of Visitor	May	June	July	August
Camper	11,123	19,779	22,988	23,171
Picnicker	9,104	42,008	43,992	29,468
Cable Mill	43,663	41,462	91,126	100,887

Tributary streams along the south side of Cades Cove generally had higher bacteria counts than did north side streams. This was probably influenced by the greater contact which south side streams had with the pastures. Furthermore, the low ratios of fecal coliforms to fecal streptococcus bacteria at nearly all stations on the tributaries suggested that these bacteria originated mainly from nonhuman sources. The abundant cattle, deer, European wild boar, field mice, and ground hogs may be major sources of the bacteria.

The Environmental Protection Agency (1975) established specific criteria for determining if waters are suitable for primary (swimming) or secondary (boating and fishing) contact uses on the basis of numbers of total coliforms and fecal coliforms in the water (Table 2). Primary contact waters have greater constraints than do secondary contact waters. Two standards have been established for each coliform type and contact use, these being the mean numbers of bacteria per 100 milliliters of sample water (representing the Log-mean of at least 10 samples taken over a 30-day period) and the maximum permissible peak count in any sample (Table 2).

The samples collected in the present work were obviously not suitable for the calculation of mean bacteria counts; however, the data represented peak counts. The percentage of samples for the four sample periods, which exceeded the maximum permissible level of total coliforms for primary contact waters, ranged from 6.7 to 40.5; the greatest percentages occurred in June and July (Table 3). These results, plus the fact that the percentage of counts above the desired mean of 1,000 were 62.2 and 78.6 in June and July, respectively, suggested that the water quality of Abrams Creek was not suitable for primary contact use, at least not in June and July. The fecal coliform data also supported this conclusion (Table 4), as do the results presented by Silsbee et al. (1976). Silsbee et al. also showed, however, that such water quality conditions were not typical of other flowing waters in the park (Table 5).

TABLE 2. *Numbers of campers, picnickers, and visitors peak counts of total coliform bacteria and fecal coliform bacteria for primary and secondary contact waters. Criteria established by the U.S. Environmental Protection Agency (1975).*

	Total Coliforms		Fecal Coliforms	
Contact use	Mean Counts	Maximum Peak Counts	Mean Counts	Maximum Peak Counts
Primary	1,000	2,400	200	1,000
Secondary	5,000	10,000	1,000	5,000

TABLE 3. *Ranges of total coliform counts and the percentages of the counts containing more than 1,000 and 2,400 bacteria in water samples from Abrams Creek (and tributaries), May through August 1977.*

		Frequency of occurrence of bacteria counts per 100 milliliters				Percent of samples containing more than	Percent of samples containing more than
Month	No. of samples	<1,000	1,000-2,400	2,400-5,000	>5,000	1,000 bacteria	2,400 bacteria
May	30	17	11	2	0	43.3	6.7
June	37	14	8	14	1	62.2	40.5
July	28	6	15	6	1	78.6	25.0
August	29	22	5	1	1	24.1	6.9

TABLE 4. *Ranges of fecal coliform counts and the percentages of the counts containing more than 200 and 1,000 bacteria in water samples from Abrams Creek (and tributaries), May through August 1977.*

		Frequency of occurrence of bacteria counts per 100 milliliters				Percent of samples containing more than	Percent of samples containing more than
Month	No. of samples	<200	200-1,000	1,000-5,000	>5,000	200 bacteria	1,000 bacteria
May	30	25	2	3	0	16.7	10.0
June	37	21	13	3	0	43.2	8.11
July	28	23	3	2	0	17.9	7.1
August	29	23	3	3	0	20.7	10.3

TABLE 5. *Ranges of fecal coliform counts in flowing waters (except Abrams Creek) in the Great Smoky Mountains National Park in June, July, and August 1976. Data from Silsbee et al. (1976).*

		Frequency of occurrence of bacteria counts per 100 milliliters			
Month	No. of samples	<200	200-1,000	1,000-5,000	>5,000
June	40	38	0	0	2
July	33	33	0	0	0
August	31	31	0	0	0

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