USGS
science for a changing world

Prepared in cooperation with the Minnesota-Wisconsin Boundary Area Commission and the National Park Service

# Fecal Coliform and *Escherichia coli* Bacteria in the St. Croix National Scenic Riverway, Summer 1999

Water-Resources Investigations Report 00–4214

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
U.S. Geological Survey

# Fecal Coliform and *Escherichia coli* Bacteria in the St. Croix National Scenic Riverway, Summer 1999

Sharon E. Kroening

Water-Resources Investigations Report 00–4214

Prepared in cooperation with the Minnesota-Wisconsin Boundary Area Commission and the National Park Service

**U.S. Department of the Interior**
Bruce Babbitt, Secretary

**U.S. Geological Survey**
Charles G. Groat, Director



Mounds View, Minnesota, 1999

For additional information write to:
District Chief
U.S. Geological Survey, WRD
2280 Woodale Drive
Mounds View MN 55112

Copies of this report can be purchased from:
U.S. Geological Survey
Branch of Information Services
Box 25286
Federal Center
Denver CO 80225

For more information on the USGS in Minnesota, you may connect to the Minnesota District home page at
http://mn.water.usgs.gov
For more information on all USGS reports and products (including maps,
images, and computerized data), call 1-888-ASK-USGS

Water-Resources Investigations Report 00–4214

## CONTENTS



## ILLUSTRATIONS



## TABLES



## CONVERSION FACTORS, AND ABBREVIATED WATER-QUALITY UNITS

| Multiply inch-pound unit | By | To obtain metric unit |
|---|---|---|
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second |
| degrees Fahrenheit (°F) | °C = (°F - 32)/1.8 | degrees Celsius (°C) |

Concentrations of fecal coliform and *E. coli* are given in colonies per 100 milliliters

# Fecal Coliform and *Escherichia coli* Bacteria in the St. Croix National Scenic Riverway, Summer 1999

**by Sharon E. Kroening**

## ABSTRACT

Fecal coliform and *Escherichia coli* (*E. coli*) concentrations were determined in the St. Croix National Scenic Riverway to assess whether pathogenic organisms pose a potential problem for recreational use. Samples were collected from May through September 1999 at 22 locations on the St. Croix and Namekagon Rivers. No concentrations exceeded water-quality criteria or standards set by the U.S. Environmental Protection Agency or the states of Minnesota and Wisconsin. Maximum fecal coliform and *E. coli* concentrations were measured in the St. Croix River at St. Croix Falls, Wisconsin. Median fecal coliform and *E. coli* concentrations were greater in the St. Croix River near Woodland Corner, Wisconsin, and at Marine on St. Croix, Minnesota than at other locations sampled.There were no consistent short-term variations in fecal coliform or *E. coli* concentrations during the summer period or any significant relations between concentrations and stream discharge, based on these results.

## INTRODUCTION

The St. Croix National Scenic Riverway (NSR) was established in 1968 under the National Wild and Scenic Rivers Act (Holmberg and others, 1997). The Upper St. Croix NSR consists of the St. Croix River from Gordon Dam to St. Croix Falls, Wisconsin, and also includes the entire Namekagon River (fig. 1). The portion of the St. Croix River south of St. Croix Falls, Wisconsin to the confluence with the Mississippi River was added to the system in 1972 as the Lower St. Croix NSR. Along the St. Croix NSR, the National Park Service administers a corridor approximately one-quarter to one-half mile wide. There are greater than 15 major tributaries to the St. Croix and Namekagon Rivers.

Most recreational use within the St. Croix NSR involves contact recreation with river water, such as boating, canoeing, and swimming. Water contaminated with pathogenic organisms may transmit diseases or may cause infections of the skin, eyes, ears, nose, and throat. Indicator bacteria groups that reflect the potential presence of pathogens in the water generally are used because the numbers of pathogenic organisms generally are very small and difficult to isolate and identify. Potential sources of pathogens in water include wastewater effluents, combined sewer overflows, runoff from urban land, animal waste, and municipal waste sludges disposed of on land or in water (Thomann and Mueller, 1987). The U.S. Environmental Protection Agency (USEPA) uses *Escherichia coli* (*E. coli*) as the indicator bacteria of water quality for contact recreation. The states of Minnesota and Wisconsin use fecal coliform as the indicator bacteria of water quality for contact recreation. The USEPA criteria for *E. coli* in freshwater is a geometric mean (based on at least 5 samples per month) of 126 colonies per 100 milliliters (col/100 mL) of water or an unacceptably high value for a single sample based on the level of recreational use (U.S. Environmental Protection Agency, 1986) (table 1). The Minnesota and Wisconsin State standards for fecal coliform in freshwater both are a geometric mean (based on at least 5 samples per month) of 200 col/100mL and the concentration shall not exceed 400 col/100 mL in more than 10 percent of the samples collected in any month (Minnesota Rules, 1999; Wisconsin Register, 1998). The Minnesota State standard is only applicable from April 1 to October 31, and the Wisconsin State standard is applicable throughout the year.

The U.S. Geological Survey (USGS) conducted a one-year (1999) study cooperatively with the Minnesota-Wisconsin Boundary Area Commission to characterize bacteria concentrations in the St. Croix NSR. The objectives of this study were to provide a detailed reconnaissance of bacteria concentrations in the St. Croix and Namekagon Rivers during the summer when recreational use of the St. Croix NSR is greatest, and to identify reaches of the St. Croix and Namekagon Rivers where pathogenic organisms may limit use of these rivers for recreational purposes.

This report presents the results of the study. Differences in bacteria concentrations were compared among sites, and concentrations were related to Federal and State water-quality standards. At selected sites, bacteria concentrations were related to stream discharge. The scope of this report is limited to data collected by the USGS in 1999.

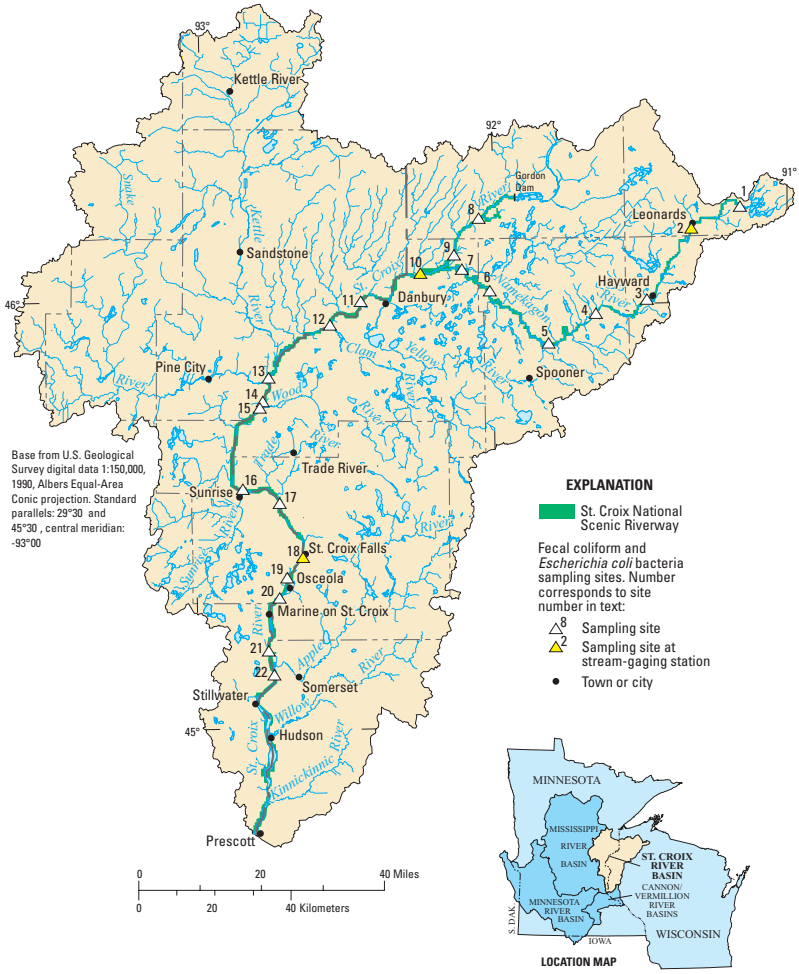


**Figure 1.** Location of the St. Croix River Basin, the St. Croix National Scenic Riverway, select towns and cities, and sampling sites.

Table 1. Single sample criteria for *E. coli* concentrations in freshwater set by the U.S. Environmental Protection Agency (1986)

[col/100 mL, colonies per 100 milliliter]

| Designated beach area | Moderate full body contact recreation | Lightly used full body contact recreation | Infrequently used full body contact recreation |
|---|---|---|---|
| 235 col/100 mL | 298 col/100 mL | 406 col/100mL | 576 col/100 mL |

## Study Design

This study was designed to provide a detailed reconnaissance of fecal coliform and *E. coli* concentrations in the St. Croix NSR during the period when most recreational use occurs and to identify reaches where pathogenic organisms pose a potential problem for recreational use. Water samples for the analysis of fecal coliform and *E. coli* were collected at 22 locations on the St. Croix and Namekagon Rivers from May through September of 1999 (fig. 1). Seven sites were located on the Namekagon River—the remainder were located on the St. Croix River. Sites were located downstream of major tributaries and towns or cities. Most sites were sampled monthly during June through August. Three of the 22 sites (sites 2, 10, and 18; fig. 1) were located at existing USGS stream-gaging stations. These three sites were sampled more frequently and included sampling during May and September.

The quality of the data collected in this study was assessed by quantifying bias and variability. Bias and variability affect the interpretation of water-quality data. Bias is the systematic error inherent in a method and may be either positive or negative. Positive bias may result from the introduction of contaminants into the sample during the sample processing procedures, laboratory analysis, or due to inadequately cleaned sample-collection or analytical equipment. Variability is the random error in independent measures of the same quantity. In water-quality data, variability results from errors inherent in sample-collection, sample-processing, and laboratory analytical procedures.

Contamination bias in the water-quality data was assessed by collecting 14 field blank samples. A blank is a water sample that is intended to be free of the analytes of interest. Growth of bacteria colonies on a field blank sample would indicate the sample-collection and(or) processing equipment was not sterile, and the actual number of bacteria in the water sample was less than what was determined.

Variability in the bacteria concentration data was assessed by collecting 15 concurrent replicate fecal coliform samples, and 11 concurrent replicate *E. coli* samples. Concurrent replicate samples are two or more samples collected at the same location at the same time. As a result, the water in each of the replicate samples is essentially identical in composition. These replicate samples were used to statistically quantify the variability introduced as a result of sample collection, handling, and analysis procedures.

## Sampling and analysis methods

Samples were collected and analyzed according to published USGS techniques (Britton and Greeson, 1987; Myers and Wilde, 1997). Grab samples were collected using a sterilized, narrow-mouth borosilicate glass bottle by wading or from a canoe. Field blank samples were prepared by pouring water intended to be free of bacteria (saline or phosphate buffer water) through all of the sample collection and processing equipment as if an actual environmental sample was being processed. Samples were held on ice and processed within 6 hours.

The membrane filtration method was used to identify and enumerate fecal coliform and *E. coli* bacteria. In the membrane filtration method, bacteria are cultured on selective media after filtration. In this method, fecal coliform bacteria are defined as organisms that produce blue colonies within about 24 hours when incubated at 44.5° Celsius on m-FC medium (nutrient medium for fecal coliform bacteria growth). *E. coli* colonies are defined as yellow or yellow-brown colonies that remain so when placed on a filter pad saturated with urea substrate broth for 15 minutes after incubation for 2 hours at 35° C and for about 24 hours at 44.5° C on m-TEC medium (nutrient medium for *E. coli* bacteria growth).

## HYDROLOGIC CONDITIONS

Stream discharges were normal to above average during the study period. Monthly mean stream discharges for water year 1999 were classified and compared to the last 30 water years (1969 through 1999) at the St. Croix River near Danbury and St. Croix Falls, Wisconsin (sites 10 and 18, fig. 1). A water year is the 12-month period from October 1 through September 30. The water year is designated by the calendar year in which it ends. There was not a sufficient period of record available to classify stream discharges at the Namekagon River at Leonards, Wisconsin (site 2, fig. 1). Monthly mean stream discharges were classified as normal if the monthly mean discharges for 1999 were within the 25th to 75th percentiles of the respective monthly mean stream discharges for the last 30 water years, and were

classified as above average if the monthly mean discharge for 1999 was greater than the 75th percentile. At the St. Croix River near Danbury, Wisconsin (site 10), the monthly mean stream discharges for May, June, and September 1999 were normal, and the monthly mean discharges for July and August 1999 were above average. At this site, the monthly mean discharge for August 1999 was the greatest recorded in the last 30 water years. At the St. Croix River at St. Croix Falls, Wisconsin (site 18), the monthly mean stream discharges for May, June, July, and September 1999 were normal, and the monthly mean discharge for August 1999 was above average.

## BACTERIA IN THE ST. CROIX NATIONAL SCENIC RIVERWAY

A total of 99 samples were analyzed to determine fecal coliform concentrations, and 79 samples were analyzed to determine *E. coli* concentrations (table 2). Variability in bacteria concentrations due to sampling and analysis procedures was quantified by averaging the standard deviations between each set of environmental and replicate samples. Results showed the average variability in fecal coliform and *E. coli* concentrations due to sampling and analysis procedures was about 3 col/100 mL. No field blank samples had any fecal coliform or *E. coli* colony growth, which indicated results were unbiased and procedures to clean and disinfect both the sampling and laboratory equipment were adequate.

Minimum, maximum, mean, and median fecal coliform and *E. coli* concentrations were greater in the St. Croix River than in the Namekagon River (table 3). Fecal coliform colonies were too numerous to count on the membrane filters prepared to determine concentrations in the St. Croix River at County Road T near Dairyland, Wisconsin, on July 6, 1999. A concentration of greater than 80 col/100 mL was assumed based on the maximum ideal count for fecal coliform bacteria (Myers and Wilde, 1997). To calculate descriptive statistics, the concentration at this site. was assumed to be 80 col/100 mL. Median *E. coli* concentrations were determined to be significantly greater at the 0.05 significance level (p=0.036) in the

Table 2. Descriptive statistics for fecal coliform and *E. coli* concentrations in the St. Croix National Scenic Riverway, 1999, by site

[Sites are shown in downstream order; N, number of samples; Min, minimum; Max, maximum; all concentrations in colonies per 100 milliliters; >, greater than]

| Site number (fig. 1) | Site name | Fecal coliform | | | | *E. coli* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | Median | Min | Max | N | Median | Min | Max |
| 1 | Namekagon River near Cable, Wisc. | 4 | 6.5 | 3 | 23 | 3 | 8 | 5 | 15 |
| 2 | Namekagon River at Leonards, Wisc. | 8 | 25 | 5 | 49 | 7 | 20 | 5 | 47 |
| 3 | Namekagon River near Hayward, Wisc. | 4 | 10.5 | 3 | 15 | 3 | 15 | 5 | 17 |
| 4 | Namekagon River near Springbrook, Wisc. | 4 | 12.5 | 4 | 22 | 3 | 16 | 11 | 20 |
| 5 | Namekagon River at Trego, Wisc. | 4 | 23.5 | 23 | 25 | 3 | 28 | 26 | 30 |
| 6 | Namekagon River below McKenzie Creek near Trego, Wisc. | 4 | 12.5 | 7 | 14 | 3 | 7 | 5 | 15 |
| 7 | Namekagon River near Woodland Corner, Wisc. | 4 | 18.5 | 16 | 24 | 3 | 19 | 14 | 28 |
| 8 | St. Croix River at CRD T near Dairyland Wisc. | 4 | 17.5 | 10 | 80 | 3 | 21 | 18 | 80 |
| 9 | St. Croix River near Woodland Corner, Wisc. | 4 | 29 | 11 | 92 | 3 | 39 | 34 | 72 |
| 10 | St. Croix River near Danbury, Wisc. | 8 | 19.5 | 14 | 34 | 7 | 22 | 15 | 32 |
| 11 | St. Croix River at State Highway 77 near Danbury, Wisc. | 4 | 24 | 17 | 37 | 3 | 25 | 22 | 29 |
| 12 | St. Croix River below Clam River near Danbury, Wisc. | 4 | 21.5 | 20 | 27 | 3 | 24 | 21 | 30 |
| 13 | St. Croix River above Snake River near Grantsburg, Wisc. | 4 | 18 | 8 | 23 | 3 | 17 | 16 | 21 |
| 14 | St. Croix River at Hwy 70 near Grantsburg, Wisc. | 4 | 12 | 8 | 17 | 3 | 16 | 13 | 17 |
| 15 | St. Croix River below Wood River near Grantsburg, Wisc. | 4 | 25.5 | 21 | 59 | 3 | 21 | 18 | 39 |
| 16 | St. Croix River below Sunrise River near Sunrise, Minn. | 4 | 14.5 | 9 | 48 | 2 | 36.5 | 10 | 63 |
| 17 | St. Croix River at Nevers Dam site near Wolf Creek, Wisc. | 4 | 14 | 12 | 18 | 3 | 18 | 9 | 27 |
| 18 | St. Croix River at St. Croix Falls, Wisc. | 9 | 19 | 9 | 95 | 9 | 21 | 2 | 97 |
| 19 | St. Croix River at Franconia, Minn. | 4 | 25 | 14 | 27 | 3 | 14 | 8 | 25 |
| 20 | St. Croix River below Osceola, Wisc. | 4 | 21 | 7 | 23 | 3 | 13 | 12 | 21 |
| 21 | St. Croix River at Marine on St. Croix, Minn. | 3 | 31 | 22 | 33 | 3 | 27 | 27 | 33 |
| 22 | St. Croix River below Apple River near Stillwater, Minn. | 3 | 20 | 19 | 40 | 3 | 20 | 18 | 33 |

Table 3. Descriptive statistics of fecal coliform and *E. coli.* concentrations in the Namekagon and St. Croix Rivers, 1999.

[All concentrations in colonies per 100 milliliters]

| | Fecal coliform | | *E. coli* | |
|---|---|---|---|---|
| | Namekagon River | St. Croix River | Namekagon River | St. Croix River |
| Number of samples | 32 | 67 | 25 | 54 |
| Minimum | 3 | 7 | 5 | 2 |
| Maximum | 49 | 95 | 47 | 97 |
| Median | 17 | 21 | 16 | 21 |
| Mean | 17 | 25 | 18 | 27 |

St. Croix River than in the Namekagon River by a Wilcoxon rank-sum test (Helsel and Hirsch, 1992). Median fecal coliform concentrations were determined not to be significantly different (p=0.053) between the St. Croix River and the Namekagon River.

No fecal coliform or *E. coli* concentrations exceeded the state or Federal water-quality criteria or standards for contact recreation at any of the sites (tables 1-3). There were not enough samples collected per month to rigidly compare concentrations with the stricter state or Federal water-quality criteria or standards, which are based on at least 5 samples per month. However, none of the bacteria concentrations measured exceeded these stricter criteria.

In the Namekagon River, the two largest median fecal coliform and *E. coli* concentrations were greatest at Leonards and Trego, Wisconsin (sites 2 and 5, table 3, figs. 2 and 3). The maximum fecal coliform and *E. coli* concentrations in the Namekagon River were measured at Leonards, Wisconsin (site 2, table 3).

Maximum fecal coliform and *E. coli* concentrations were measured in the St. Croix River at St. Croix Falls, Wisconsin. Median fecal coliform and E.coli concentrations were greater in the St. Croix River near Woodland Corner, Wisconsin, and at Marine on St. Croix, Minnesota compared to other locations sampled. There were no consistent short-term variations in fecal coliform or *E. coli* concentrations during the summer period or any significant relations between concentrations and stream discharge, based on these results.

In the St. Croix River, median fecal coliform concentrations were greatest near Woodland Corner, Wisconsin; below the Wood River near Grantsburg, Wisconsin; and at Franconia and Marine on St. Croix, Minnesota (sites 9, 15, 19, and 21; table 3; fig. 2). The maximum fecal coliform concentrations were measured near Woodland Corner and at St. Croix Falls, Wisconsin (sites 9 and 18, table 3). Median *E. coli* concentrations in the St. Croix River were greatest near Woodland Corner, Wisconsin; at State Highway 77 near Danbury, Wisconsin; below the Sunrise River near Sunrise, Minnesota; and at Marine on St. Croix, Minnesota (sites 9, 11, 16, and 21; table 3; fig. 3). The maximum *E. coli* concentrations in the St. Croix River were measured at County Road T near Dairyland, Wisconsin; near Woodland Corner, Wisconsin; and at St. Croix Falls, Wisconsin (sites 8, 9, and 18; table 3).

There were no consistent short-term variations in fecal coliform or *E. coli* concentrations during the summer period, based on these results. Additional sampling through time my better identify any systematic seasonal variations.

Relations between fecal coliform and *E. coli* concentrations and stream discharge were examined at the Namekagon River at Leonards, Wisconsin; St. Croix River near Danbury, Wisconsin; and the St. Croix River at St. Croix Falls, Wisconsin (sites 2, 10, and 18; fig. 1). Relations were quantified using Kendall's tau correlation coefficients (Helsel and Hirsch, 1992). Correlation coefficients measure the strength of association between two variables, such as whether one variable generally increases as the second variable increases. Kendall's tau correlation coefficients were not significant at the 0.05 significance level (table 4).

Table 4. Kendall's tau correlation coefficients between stream discharge and bacteria concentrations at selected sites in the St. Croix National Scenic Riverway, 1999.

[Sites are shown in downstream order]

| Site name | Fecal coliform | | | *E. Coli* | | |
|---|---|---|---|---|---|---|
| | Correlation coefficient | p-value | Number of observations | Correlation coefficient | p-value | Number of observations |
| Namekagon River at Leonards, Wisc. | 0.036 | 1.000 | 8 | -0.238 | 0.281 | 7 |
| St. Croix River near Danbury, Wisc. | .370 | .138 | 8 | .143 | .386 | 7 |
| St. Croix River at St. Croix Falls, Wisc. | .423 | .075 | 9 | -.056 | .460 | 9 |

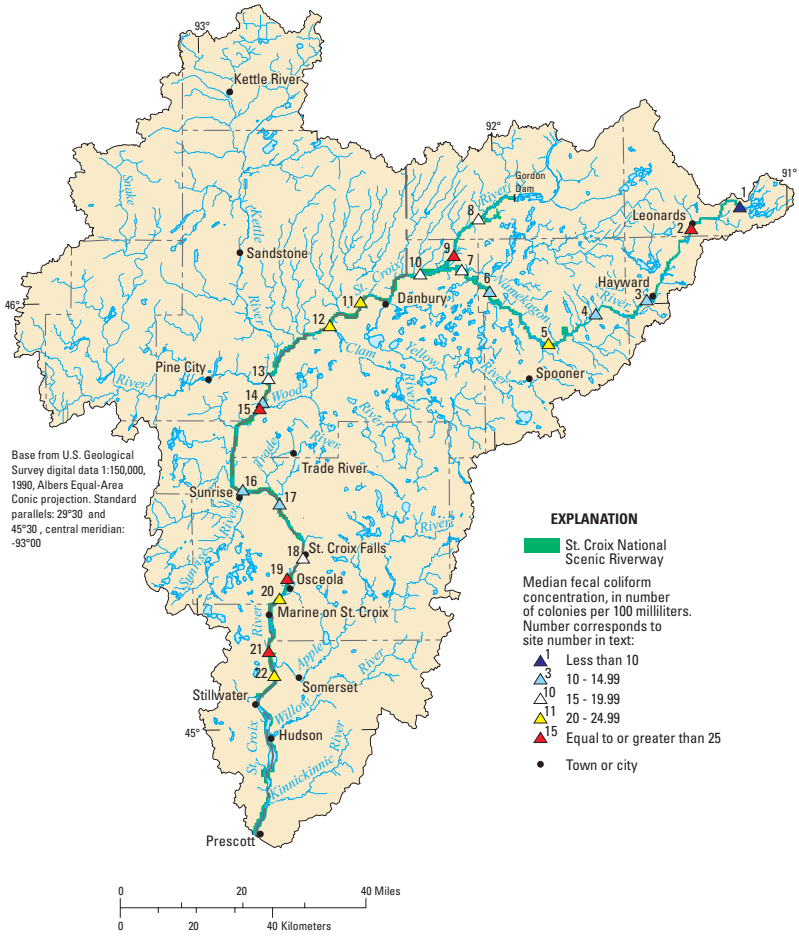


**Figure 2.** Median fecal coliform bacteria concentrations at sampling sites on the St. Croix National Scenic Riverway, 1999.

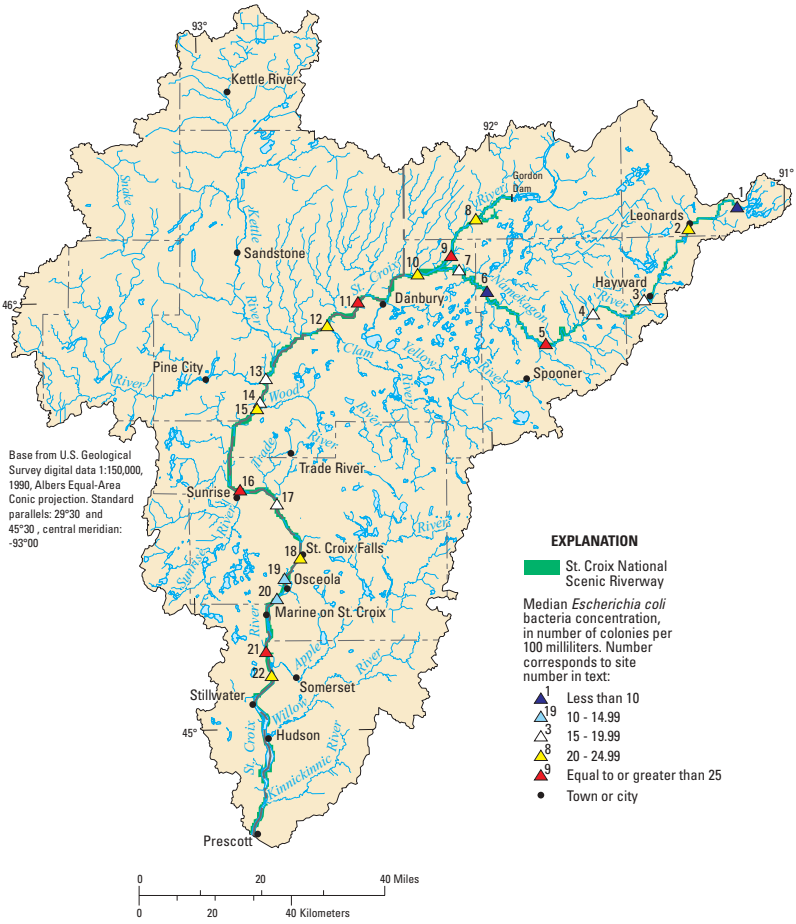


**Figure 3.** Median *Escherichia coli* bacteria concentrations at sampling sites on the St. Croix National Scenic Riverway, 1999.

## SUMMARY AND CONCLUSIONS

Results from this study indicated there were no exceedances of state or Federal water-quality criteria or standards for fecal coliform or *E. coli* bacteria in the St. Croix NSR during summer 1999. The summer period represents the time of year when recreational use of the St. Croix and Namekagon Rivers is the greatest. However, comparisons with water-quality criteria and standards could not be rigidly made because less than five samples per month were collected at each site.

Maximum fecal coliform and *E. coli* concentrations were measured in the St. Croix River at St. Croix Falls, Wisconsin. Median fecal coliform and *E.coli* concentrations were greater in the St. Croix River near Woodland Corner, Wisconsin, and at Marine on St. Croix, Minnesota compared to other locations sampled. There were no consistent short-term variations in fecal coliform or *E. coli* concentrations during the summer period or any significant relations between concentrations and stream discharge, based on these results.

Samples analyzed during this study were collected during a period with normal to above-average stream discharges. In situations where the primary source of bacteria is a point source, such as a wastewater treatment facility, bacteria concentrations in a stream would be expected to be greater during low-flow periods as a result of less dilution.

Bacteria concentrations in the St. Croix NSR also may change over time as a result of additional point sources or changes in land use and land cover. The St. Croix NSR is managed by the National Park Service and the states of Minnesota and Wisconsin with a goal to prevent any degradation of the water quality. Trend analyses can be used to assess whether water quality has improved, degraded, or remained the same. Trend assessments are enhanced when bacteria concentration data are collected at regular intervals, such as monthly or quarterly, to indicate consideration of seasonal variations in concentrations. Data collection that includes determination of stream discharge also is desirable so that relations between bacteria concentration and stream discharge can be distinguished from temporal trends.

## REFERENCES


Britton, L.J., and Greeson, P.E. (eds.), 1987, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigation, chap. A4, 363 p.

Helsel, D.L., and Hirsch, R.M., 1992, Statistical methods in water resources: Studies in Environmental Science, Elsevier, v. 49, 529 p.

Holmberg, K.L., Perry, Jim, Ferrin, R.S., and Sharrow, D.L., 1997, Water resources management plan--St. Croix National Scenic Riverway, Minnesota and Wisconsin: National Park Service, St. Croix Falls, Wisconsin, 155 p.

Myers, D.N., and Wilde, F.D. (eds.), 1997, National field manual for the collection of water-quality data, biological indicators: U.S. Geological Survey Techniques of Water-Resources Investigations, book 7, chap. A7, 38 p.

Minnesota Rules, 1999, Chapter 7050.0222, subpart 2.

Thomann, R.B., and Mueller, J.A., 1987, Principals of surface water quality modeling and control: New York, Harper and Row Publishers, 644 p.

U.S. Environmental Protection Agency, 1986, Quality criteria for water 1986: U.S. Environmental Protection Agency, Office of Water Regulations and Standards, 440/5-86-001.

Wisconsin Register, 1998, No. 506, Chapter NR 102, subpart 4.