EVALUATING WATER QUALITY SAMPLING SCHEDULES USING FECAL COLIFORM CONCENTRATIONS IN SABINO CREEK

by

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ABSTRACT

Sabino Canyon Recreation Area, adjacent to Tucson, and a major water-based recreation complex within the Santa Catalina Mountains, Coronado National Forest, receives intensive recreational use. This natural water resource area with primary water contact activities was monitored for fecal coliform in accordance with U.S. Forest Service Regulation (FSM 2542.2). As part of a larger study, this report discusses the relationships between time, day, and location of sampling with fecal coliform bacterial concentrations in Sabino Creek. Analysis of Variance shows that fecal coliform concentrations were higher: 1) on Sunday than Wednesday, 2) at 4:00 PM than 8:00 AM or 12:00 Noon, and 3) in the lower section of the four miles of the study area. This research provides the U.S. Forest Service with baseline water quality data and a benchmark from which to continue an efficient water quality monitoring program.

INTRODUCTION

Sabino Canyon Recreation Area, which is part of the Coronado National Forest, is located immediately adjacent to the metropolitan area of Tucson. Visitor use in excess of 600,000 visitors per year made this water based recreation area an ideal site to test differences in fecal coliform concentrations.

Twenty-one sites on Sabino Creek were sampled for fecal coliform from July 1974 through June 1975. Fecal coliform bacteria were cultured on M-FC broth with all field and laboratory procedures following those described in Standard Methods for the Analysis of Water and Waste Water (AWWA, 1971).

Research was designed to determine optimum, productive periods to monitor fecal coliform in Sabino Canyon Recreation area. The objectives of the study were to determine:

1) seasonal variations in fecal coliform concentrations
2) time of day variations in fecal coliform concentrations
3) day of the week variations in fecal coliform concentrations
4) location variations in fecal coliform concentrations.

BACKGROUND INFORMATION

Fecal coliform bacteria, a subgroup of the total coliform population, have a direct correlation with fecal contamination of water bodies from warmblooded animals (Geldreich, 1966; AWWA, 1971; Mahloch, 1974). Research by Smith and Twedt (1971) supports the use of fecal coliform due to the isolation of Salmonella when fecal coliform levels were between 100 and 200 organisms per 100 ML of sample. Fecal coliform should be used as a baseline indicator for evaluating the suitability of recreation waters (Geldreich, 1970). Reconfirmation of earlier work, Smith, Twedt and Flanigan (1973) found fecal coliform beneficial as an indicator of recreational water quality.

Federal regulation (Forest Service Manual 2542-2) requires the United States Forest Service to sample water bodies for fecal coliform when in-water recreation activity occurs. The Federal Water Pollution Control Administration (Now E.P.A.) suggests that a minimum of five samples per 30-day period should be required when applying recreational water quality standards (Millipore, 1973). Therefore, five sampling periods per month are critical in order to ascertain the suitability of a water body for recreation.

Primary contact standard for water based recreation areas states "fecal coliform content - shall not exceed a geometric mean of 200/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml" (FWPCA, 1968). Sample dates should be chosen carefully so that periods of expected high fecal coliform concentration are selected. Often sample dates are chosen without regard to critical periods.

METHOD

EXPERIMENT MODEL

The statical model was developed as follows:

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1) The 21 sample locations were grouped into three sample locations (S-1, S-2, and S-3) on the basis of proximity and similarity of the site, and by the natural geographic divisions within the canyon.

2) Samples were collected twice weekly on Sunday and Wednesday which provides each week a sample during relative high and low visitor use periods.

3) Time of sample collection varied each week utilizing three rotating sample hours (8 AM, 12 Noon and 4 PM).

This model was designed so that each sub-population would be sampled within a three week period (Table 1). Analysis of variance was employed to determine significant difference among the sub-populations within each three week period.

Table 1. Sample schedule of the eighteen sub-populations within the statistical model. Seventeen three-week periods were obtained through the course of the study. Data was collected from July, 1974 through June, 1975.

	Sub-population	Day	Location	Time
	1	Wednesday	S-1	8 AM
	2	Wednesday	S-2	8 AM
First	3	Wednesday	S-3	8 AM
Week	4	Sunday	S-1	8 AM
	5	Sunday	S-2	8 AM
	6	Sunday	S-3	8 AM
	7	Wednesday	S-1	12 Noon
	8	Wednesday	S-2	12 Noon
Second	9	Wednesday	S-3	12 Noon
Week	10	Sunday	S-1	12 Noon
	11	Sunday	S-2	12 Noon
	12	Sunday	S-3	12 Noon
	13	Wednesday	S-1	04 PM
	14	Wednesday	S-2	04 PM
Third	15	Wednesday	S-3	04 PM
Week	16	Sunday	S-1	04 PM
	17	Sunday	S-2	04 PM
	18	Sunday	S-3	04 PM

ANALYSIS OF VARIANCE

Steel and Torie (1960) state "The valid application of tests of significance in the analysis of variance requires that the scale of measurement should be one for which the linear additive models holds." With biological data such as bacteria counts, which exhibit a wide range of positive intergers, a logarithmic transformation of the data conforms to the linear additive model. For data with values from zero to 10, log (X + 1) must be used (Steel and Torrie, 1960).

Fecal coliform data for the analysis of variance was transformed as follows: log (fecal coliform + 1). Results of the anlaysis of variance are presented as the transformed data because Steel and Torrie (1960) warn that changing analysis of variance results back to the original scale of measurement is not proper.

All data analyses in this study were conducted through the use of computer programs in the Statistical Package for the Social Sciences (Nie, Bent and Hull, 1970; Nie et al, 1975), and through programs developed by the National Educational Resources, Inc. (1972).

RESULTS

Results of this study are focused on nine of the three week periods which were determined to be biologically important with regard to Primary Recreation Contact Standards. Significant difference for the analysis of variance was set at the five percent level.

TIME OF SAMPLE

As previously explained, times of sampling were 8 AM, 12 Noon, and 4 PM. Based on the analysis of variance, seven of the nine three week periods were significant with time as the treatment. Results are presented in Table 2. For the significant F-values, the least significant difference was used to determine the important factor among the three values. Analysis of variance indicates that mean fecal coliform values from five of the seven three week periods were significantly higher with 4 PM as the sample time period. Although 8 AM and 12 noon time periods had significant mean values, most were co-significant with the 4 PM time period. Wildlife early morning watering or intensive

recreation may account for high mean values at 8 AM and 12 noon. Accumulation of in-water and associated land based recreation use through the day would account for the high mean values at the 4 PM sample period.

Table 2. Results of the analysis of variance with mean (log(fecal coliform + 1)) fecal coliform concentrations as determined by the treatment time for nine three week sample periods. Underlined mean values are significant by the Least Significant Difference Test.

Three Week Sample Period	F-value / Significance	08 AM	12 Noon	04 PM
07/03/74 to 07/21/74	3.38 / .047	2.12	1.09	1.46
07/24/74 to 08/11/74	13.96 / .001	1.03	1.36	1.40
08/14/74 to 09/01/74	2.29 / .105	1.11	0.97	1.11
09/04/74 to 09/22/74	8.51 / .001	1.85	1.32	1.69
09/25/74 to 10/13/74	26.65 / .001	1.79	1.39	1.30
10/16/74 to 11/03/74	37.66 / .001	1.02	0.67	1.17
04/23/75 to 05/11/75	24.18 / .001	0.20	0.56	0.83
05/14/75 to 06/01/75	7.48 / .001	0.54	0.87	1.05
06/04/75 to 06/22/75	0.03 / .999	0.94	0.94	1.09

DAY OF SAMPLE

Two sample days (Sunday and Wednesday) represent the relative high and low recreation use within Sabino Canyon Recreation Area. Based on the analysis of variance, six of the nine three week periods were significant with day as the treatment. Results are Presented in Table 3. Analyses show that mean fecal coliform data were significantly higher on Sunday than on Wednesday. On weekends and holidays, USFS personnel would have to close the recreation area to cars by mid-day to reduce recreation pressure but this problem did not occur on weekdays. Analyses of fecal coliform data reflect the visitor use pattern for Sunday and Wednesday.

LOCATION OF SAMPLE

Based on the analysis of variance, eight of the nine three week periods were significant with location as the treatment. Results are presented in Table 4. For the significant F-values, the least significant difference was used to determine the important value among the three values. Analyses show that mean fecal coliform data were significantly higher at sample location S-3, which is Lower Sabino. Higher mean fecal coliform samples from Lower Sabino than Upper Sabino can be explained in three ways: 1) Upper Sabino was closed to cars while Lower Sabino was surrounded by parking for cars, thus visitors had easy access to Lower Sabino; 2) Lower Sabino is an attractive swimming area due to the beach effect created by Sabino Lake Dam; 3) Accumulation of upstream fecal contamination would flow into Lower Sabino from Upper Sabino.

Table 3. Results of the analysis of variance with mean (log (fecal coliform + 1)) fecal coliform concentrations as determined by the treatment day for nine three week sample periods. Underline mean values are significant by the analysis of variance.

Three Week Sample Period	F-value Significance	Sunday	Wednesday
07/03/74 to 07/21/74	0.43 .999	1.41	1.71
07/24/74 to 08/11/74	7.21 .008	1.37	1.17
08/14/74 to 09/01/74	4.56 .033	1.15	0.98
09/04/74 to 09/22/74	15.19 .001	1.80	1.43
09/25/74 to 10/13/74	77.08 .001	1.76	1.23
10/16/74 to 11/03/74	119.58 .001	0.69	1.22
04/23/75 to 05/11/75	10.65 .001	0.64	0.42
04/14/75 to 06/01/75	3.36 .066	0.92	0.72
06/04/75 to 06/22/75	0.72 .999	1.09	0.89

Table 4. Results of the analysis of variance with mean (log (fecal coliform + 1)) fecal coliform concentrations as determined by the treatment location for nine three week sample periods. Underlined mean values are significant by the Least Significant Difference Test.

Three Week Sample Period	F-value Significance	*S-1*	*S-2*	*S-3*
07/03/74 to 07/21/74	0.64 .999	1.40	no data	1.72
07/24/74 to 08/11/74	15.15 .001	1.02	1.26	1.51
08/14/74 to 09/01/74	26.87 .001	0.89	0.75	1.54
09/04/74 to 09/22/74	9.38 .001	1.41	1.50	1.94
09/25/74 to 10/13/74	7.57 .001	1.34	1.48	1.66
10/16/74 to 11/03/74	21.49 .001	0.84	0.83	1.19
04/23/75 to 05/11/75	83.63 .001	0.21	0.22	1.17
05/14/75 to 06/01/75	39.58 .001	0.44	0.51	1.52
06/04/75 to 06/22/75	29.11 .001	0.41	0.87	1.69

CONCLUSION

Seasonal data show that Sabino Creek receives varying degrees of fecal contamination, that were at times in excess of state and federal primary contact recreation water quality standards. Analysis of variance demonstrates that Sunday (weekend) fecal coliform samples were significantly higher than Wednesday (weekday); 4 PM fecal coliform concentrations were significantly higher than 8 AM or 12 Noon. Consequently, examination of water quality parameters in Sabino Creek for the primary contact standard would best be determined on warm weather weekends and holidays during the late afternoon time period.

Under the present visitor use walk-in policy for Sabino Canyon Recreation Area, Lower Sabino (S-3) with motorized public access had significantly higher fecal coliform concentrations than Upper (S-1) and Middle (S-2) Sabino where motorized public access was prohibited. Changes in the visitor use policy (motor-motorless) with a redistribution of visitors within the recreation area will effect water quality. Therefore, the Forest Service must consider the natural constraints of Sabino Creek and recognize potential water quality problems when planning recreation user patterns and facility development within Sabino Canyon Recreation Area.

Data suggest an apparent association of intensive in-water recreational activity with significantly higher fecal coliform concentrations. Results and study design provide the Forest Service with an efficient period to sample for fecal coliform concentrations and to monitor visitor activity to assist in the determination of water quality carrying capacity for Sabino Creek.

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