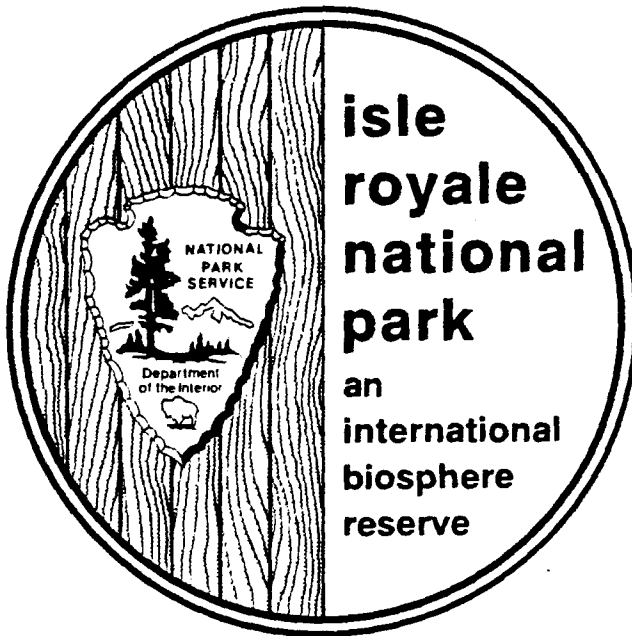


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BACTERIAL WATER SAMPLING
PROGRAM 1984-85

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Executive Summary

In 1984 and 1985, water samples were collected at 18 different sites on Isle Royale to determine the levels of several indicator species of bacteria. These bacterial groups indicate the presence and abundance of pathogenic bacteria in the aquatic environment. Pathogenic bacteria are of interest because of their potential to cause disease in humans. The waters sampled were in or adjacent to campgrounds where visitors draw water for drinking and bathing purposes.

Samples were analyzed for total coliform, fecal coliform and fecal streptococcus bacteria groups. The coliform bacteria are present in warm-blooded animals as well as in vegetation and soils. Most fecal streptococcus bacteria, however, are unique to fecal matter. Fecal coliform to fecal streptococcus (FC:FS) ratios are an indication of the source of pathogenic bacteria in water. A ratio of 0.7:1 or less indicates a non-human source of bacteria, while a ratio of 4:1 indicates a human source.

The waters tested on Isle Royale normally showed ratios of less than 0.7:1, with some notable exceptions. Benson Creek samples, both years, exhibited high levels of bacteria routinely throughout the season. Chickenbone West, Benson Creek, Moskey Basin, and McCargoe Cove all showed high FC:FS ratios at some time during the season, clear indications of human fecal contamination.

Lake Superior control samples exhibited very low levels of bacteria, as should be expected. However, Rock Harbor sample sites (Three Mile, Rock Harbor channel) had relatively high levels of bacteria in comparison. This is an indication that human activities may be increasing bacteria and/or nutrient levels in these areas. The activities include those associated with the campgrounds and Rock Harbor marina.

It is clear that many of the natural waters around Isle Royale used as drinking water sources do not meet either the EPA or State of Michigan standards for safe drinking water. However, visitors are not led to believe that waters are safe to drink without pretreating. The park brochure clearly states the dangers of drinking untreated water; methods of treatment are explained.

Management considerations include: 1) assessing the location and potential of outhouses for contamination of nearby water sources; 2) continue the study looking more intensely at those areas that have had high levels of bacteria and reassess those areas where changes were made (outhouses moved) to determine if bacteria have decreased; and 3) evaluate bacteria levels in other areas.

I. Introduction

In 1984 and 1985, water samples were collected at various locations around Isle Royale. Samples were used to determine the level and type of bacteria present in these waters. All campgrounds sampled are equipped with shallow pit toilets located ten to several hundred meters from the nearest water source. There has been some concern whether effluent from these pit toilets have sufficient time to filter through the soil before reaching nearby water sources used by visitors for drinking water. In response to these concerns, a bacterial water quality monitoring program was initiated in 1984.

Objectives of the bacterial water quality monitoring program were:

- 1) Determine the suitability of various water sources for human consumption (strictly from a bacteriological standpoint)
- 2) Determine if existing toilet facilities are contributing pathogenic bacteria to the waters in the park
- 3) Use these data to develop standards for pit toilet placement in backcountry areas of the park

To achieve these goals, water samples from 18 different sites were collected over a two-year period.

Some bacteria are pathogenic and may cause disease in humans who ingest these microorganisms. To test for this type of bacteria is difficult, time consuming and infrequently done. Instead, most microbiological testing of water is done to find indicator organisms such as coliform and streptococcus bacteria, rather than pathogens. These indicator organisms are not necessarily pathogenic, but are present in water when bacterial pathogens from fecal contamination are present. They survive longer in water than pathogens, disappear following the disappearance of pathogens, and the density of these bacteria is directly related to the quantity of fecal pollution. Analysis of water samples from Isle Royale campgrounds was primarily focused on total coliform (TC), fecal coliform (FC) and fecal streptococcus (FS) bacterial groups.

In 1984, separate samples were analyzed to determine the levels of *Klebsiella* and *Aeromonas*. These strains of bacteria are opportunistic pathogens and respond to increased levels of nutrients in aquatic systems. These genera were not specifically analyzed for in 1985.

The coliform bacteria are of interest because they are known to be present in the intestines of warm-blooded animals in large numbers. They are also found on plants and in the soil in smaller numbers. Most fecal streptococcus, however, are only present in animal intestines although some strains are able to

survive on vegetation (Geldreich, 1976). By determining if these bacterial groups are present and in what quantity, the sanitary quality of the water is known. Fecal coliform to fecal streptococcus ratios indicate whether human or other warm-blooded animal wastes are the major contributors to water contamination. Human feces contain a fecal coliform to fecal streptococcus ratio of 4:1, while other animals have ratios of less than 0.7:1 (Geldreich, 1970).

The campground/dock/residence areas where samples were collected were chosen for:

- 1) easy access for collection purposes;
- 2) their potential as drinking water sources for visitors; and
- 3) the potential of a drinking water source for human contamination.

Sample sites were as follows:

(1984)	Moskey Basin	-- site 4 and dock
	Three Mile	-- dock
	Mott Island	-- dock, near sewage storage tank
	Benson Creek	-- three locations (one upstream, and two downstream from pit toilets)
	Rock Harbor	-- mouth of stream running near sewage treatment plant
	Caribou Island	-- near bridge
	Control	-- open water of Lake Superior, south of Mott
(1985)	Malone Bay Campground	-- near shelter 2
	Malone Bay	-- dock
	Chippewa Harbor	-- dock
	Benson Creek	-- bridge, near outlet
	Hatchet Lake	-- below steps in campground
	Todd Harbor	-- dock
	McCargoe Cove	-- dock
	Chickenbone West	-- near site 3
	Belle Isle	-- dock
	Raspberry Island	-- mid-channel
	Control	-- open water of Lake Superior, south of Mott

II. Methods

Water samples were collected in pre-sterilized whirl pak bags by Resource Management personnel (Janis Meldrum, Bob Nobles, Mike Bencic) and Park Rangers (Elen Maurer, Russ Wilson). A separate 125 ml sample was collected at each sample site for determination of pH and specific conductance. Methods used for sample collection, preservation, pH, conductivity, and analysis were obtained from Standard Methods for the Examination of Water and

Wastewater, 15th and 16th editions (American Public Health Association, 1980 and 1985).

Samples were collected weekly in 1984 and bi-weekly in 1985 on Tuesdays. The following day, samples were sent via the NPS Ranger III across Lake Superior to Dr. Susan Bagley, Department of Biology, Michigan Technological University, for analysis. The maximum time period between sample collection and filtering did not exceed the 30-hour period specified by the American Public Health Association (1980). Samples were kept in an iced cooler from the time of collection until they were processed in the lab. Samples were analyzed using the membrane filter technique.

All data collected during the study is kept in the Isle Royale National Park Resource Management files.

III. Results and Discussion

Interpretation of bacterial data is extremely difficult because the sources of the bacterial groups cannot be determined with any certainty. All three groups identified are present in the feces of warm-blooded animals, thus their presence does not necessarily indicate human fecal contamination. As mentioned previously, TC bacteria occur in vegetation and soils as well as feces. Some strains of FS are also present in the environment outside of animal intestines. Fecal coliform are more restricted to intestinal tracts and probably are not present in the environment as the other two groups are (Geldreich, 1978).

However, with warm temperatures and an abundant nutrient supply, FC have been known to multiply in aquatic environments (Geldreich, 1978). In the Great Smoky Mountains National Park, Hendricks and Morrison (1967) observed growth of FC bacteria in sediments of clear mountain streams. Soil and leaf litter are also favorable environments for the growth of enteric intestinal bacteria.

Most of the data interpretation was derived from Dr. Susan T. Bagley's Investigator's Annual Reports submitted to the park in 1984 and 1985. Those documents can be found in Appendix A of this report.

A. Results of 1984 Bacterial Analysis

In general, variation in FC levels at each sample site appear to be associated with water temperature. The lowest bacterial levels were found in May when water temperatures were between 2 and 10°C, while the highest bacterial densities were observed in August and September when water temperatures increased to 13-16°C. Hendricks and Morrison (1967), McSwain and Swank (1977) and Geldreich (1978) observed increased growth and multiplication of bacteria in soils and stream sediments under warmer

conditions. In the Great Smoky Mountains, Silsbee and Larson (1981) found a strong correlation between water temperature and bacterial densities suggesting that temperature is a major factor regulating bacterial growth and survival.

Some of the highest bacterial levels observed over the sampling period occurred in the Benson Creek sample sites. These high levels are not attributed to human fecal contamination. Although some of the TC levels were over 3000/100ml (Benson Creek 1), FC were normally >1 to 20/100ml. These data indicate that the TC detected in these waters was derived primarily from vegetation, animals and land runoff rather than human fecal contamination.

However, FC to FS ratios for Benson Creek 3 in May exceeded 4:1, a clear indication of human fecal contamination. *Klebsiella* and *Aeromonas* were also at high densities on that date, indicating an increase in nutrient levels, which may have been due to leaching from outhouses upstream.

Moskey Basin also had one instance where ratios indicated the presence of human fecal contamination. On several other sampling dates, ratios fell into a "grey" area between 0.7:1 and 4:1. An alternative site at Moskey Basin, sampled at the same time, had lower levels of both FC and TC than the original site adjacent to the campground. These data indicate that there is a localized, but consistent, input of TC and FC at this site. Black ducks (*Anas rubripes*) were frequently observed at this location by sample collectors. Coliform bacteria levels in this localized area may have been negatively influenced by these animals.

Caribou Island, Mott Island, and Three Mile each had one week where ratios fell into the "grey" area. These data give no conclusive evidence as to the origin of the contamination. However, human contamination is suspect in these high use areas.

Relatively high levels of TC and FC were observed in all samples from Rock Harbor itself, which is not typical of Lake Superior waters, based on the control sample from this study and previous studies (IJC, 1977). Some of this bacteria may be due to human-related activities in the Rock Harbor area (campgrounds and marina). More sampling should be done in this area to fully characterize the nature and extent of these organisms.

The relatively high levels of TC found in Rock Harbor, Moskey Basin, and Benson Creek are of concern because many of the TC organisms are opportunistic human pathogens. It is possible that visitors could ingest the organisms if they do not treat drinking water properly, or from washing dishes in untreated water.

B. Results of 1985 Bacterial Analysis

As in the 1984 sample year, Lake Superior control samples had essentially no TC or FC bacteria in them. In 1985, FS averaged 16/100ml. Belle Isle and Raspberry Island normally had TC, FC, and FS levels close to the Lake Superior control. With some exceptions, both Malone Bay and McCargoe Cove samples had indicator values close to Lake Superior control samples as well.

Lake Superior control samples, in two instances, had FC:FS ratios of 2.0 (August 20 and September 3). This indicates that some FS may routinely occur in the open lake. The source of this bacteria would have to be from land runoff.

On September 3, all samples had FC:FS ratios between 0.7:1 and 4:1. Climatological data in park files indicate a heavy, long period of rain on that date. Surface runoff from land most likely caused the elevated levels of bacteria in the samples.

As during the 1984 sampling year, Benson Creek had high levels of TC (<1200/100ml), FC and FS throughout the 1985 season. Similar trends were observed at Chickenbone West, although bacterial levels were much lower than those found in Benson Creek. It is possible that higher water temperatures aided in the survival and persistence of indicator organisms in the Benson Creek and Chickenbone West samples. A similar trend was observed in 1984 at Benson Creek.

On several occasions, FC:FS ratios indicated human or a mixture of human/non-human contamination at Chickenbone West, possibly indicating a source of persistent contamination of human fecal origin. An alternate sample site chosen at Chickenbone Lake for comparison showed some TC and FC contamination, but not from human sources.

Fecal coliform and fecal streptococcus were routinely detected in many of the sampling sites, although FC levels were normally low. FC:FS ratios were usually extremely low, indicating that contamination was generally from non-human sources. At various times throughout the summer, Chickenbone West, McCargoe Cove, and Chippewa Harbor ratios showed a mixture of human and non-human contamination.

More detailed analysis was conducted occasionally through the summer to determine the types of coliform bacteria present in samples. From all sample sites, TC were found to be primarily a mixture of *Escherichia coli*, *Klebsiella*, and *Enterobacter*, with some *Citrobacter*. The September 3 samples tested for *E. coli* showed an increase from previous weeks samples. A majority of the FC were also *E. coli*.

E. coli normally does not occur from non-human sources and does not survive well once introduced into the environment as do other genera of coliforms. Thus, these results are of particular

interest. Routine observations of E. coli as FC would indicate a constant source of these organisms from human fecal contamination. However, with the limited number of samples taken during this study, it is difficult to make any concrete statements as to their origin. More intensive sampling must be done to fully assess the situation (Bagley, 1985).

The State of Michigan Safe Drinking Water Act 399 (1976) and the Environmental Protection Agency National Interim Primary Drinking Water Regulation (EPA, 1976) set the allowable limits of coliform organisms in potable water supplies. Potable water supplies should most frequently indicate no coliform colonies in 100 ml sample volumes. However, one to three coliform colonies per 100 ml sample are permissible provided the arithmetic mean does not exceed one coliform colony per 100 ml sample.

Clearly, the majority of the waters tested over the two-year period do not meet these standards. However, visitors are informed of the potential hazards of drinking water from these sources and are instructed as to how to treat the water.

IV. Management Considerations

Bacterial diseases have not been a problem at Isle Royale. However, it is clear that the waters in and around the campgrounds on Isle Royale do not meet the standards for safe drinking water. The two-year study has shown that the majority of the bacteria present in these waters is not of human origin. Nothing can be done about the naturally occurring bacteria flowing into these waters. However, the park should encourage visitors to treat drinking water to eliminate the pathogenic bacteria that may be present in them.

In response to the results of the 1984 portion of this study, park managers added a section to the brochure "Drinking Water - Special Notice" on intestinal bacteria (Appendix B1). Filters recommended for removing hydatid tapeworm are not sufficient to remove bacteria. This fact is made clear in the brochure.

Although human contamination does not appear to be a significant problem at Isle Royale, it should also be communicated to visitors that improper disposal of garbage and human waste may add to the contamination of water sources. Additionally, improper disposal of garbage and poor sanitation practices lure fox, squirrels, mice, and other animals to these areas increasing the probability of contamination.

A stronger message was added to the "Drinking Water" brochure in 1987, taking these considerations into account (Appendix B2). One of the best popular articles on the subject of field water treatment is attached to this paper as Appendix C.

Non-human sources of bacteria cannot be controlled, but in areas where human fecal contamination is evident, the park must take steps to reduce or eliminate the source of the problem. In those areas where human fecal contamination is evident, placement of outhouses will be evaluated. Pit toilets may be the primary source of contamination in some areas and should be moved if they could potentially be a problem.

Recommendations for placement of these structures is dependent on soil type, slope and depth of seasonal high water table. General standards for selection of a suitable site include:

1) PERMEABILITY -- The rate of water movement through the soil indicates how quickly bacteria and nutrients will reach a water source, if at all. A percolation test can be done following the procedures given by the U.S. Department of Agriculture (see Appendix D). In absence of this information, minimal recommended distances between water sources and outhouses are as follows:

Soil Texture -----	Minimum Distance -----
Loam (including sandy loam, silty loam and clay loam)	100 ft.
Sand (including sand, loamy sand)	200 ft.
Clay (including clay, loamy clay, silty clay)	100 ft.

(Adapted from USDA, 1978 and 1961)

2) GROUNDWATER LEVELS -- Some soils have groundwater levels within a foot or a few feet of the surface throughout the year. Others have high groundwater levels during certain seasons, usually winter and early spring. Still others have high groundwater levels following periods of prolonged rainfall. None of these conditions provide adequate drainage for pit toilets.

Soil mottling (i.e., soil with spots of varying colors, normally reddish or grey in this area) is an indication of the depth of the seasonal high water table. If a hole is dug below this level, the hole will fill with water for part of the year and will facilitate transport of pathogenic organisms through the soil. Digging into the mottled layer should be avoided. If it is not possible to avoid the mottled horizons, the distance the outhouse is placed from the nearest water source should be increased. The shallower the mottled horizon, the farther the outhouse should be placed from the water. If at all possible, the water table should be a minimum of four feet from the ground surface. Use of a soil auger before the hole is dug will indicate the depth to the water table before the hole is dug.

3) ROCK FORMATIONS OR OTHER IMPERVIOUS LAYERS should be at least 18 inches below the bottom of the outhouse pit.

4) SLOPE should be less than ten percent. This can be determined by use of a clinometer.

A soil survey is scheduled to be completed for Isle Royale in 1987-1989. Preliminary information on depth of water table and other soil characteristics of potential outhouse sites will be available then prior to actual digging.

This study analyzed bacteria levels at only a few sites around the Island, and for only a limited amount of time. Nonetheless, there is enough information now available to indicate potential problem areas, and existing outhouse locations should be examined (i.e., Benson Creek, Chickenbone Lake, Moskey Basin, and McCargoe Cove). If and when outhouses are relocated to better sites, followup sampling should be initiated to determine whether bacteria levels have declined. Waters in the Benson Creek/Daisy Farm area are of particular concern due to the possible removal of the potable water treatment system in 1987 or future years.

A number of sites around the Island should be looked at in future years for the presence of pathogenic bacteria. Both Washington Creek and Island Mine have slow-moving, shallow water courses where visitors obtain their drinking water. Both have the potential for high bacteria levels. Siskiwit Bay campground has an outhouse close to the shore in a sandy soil, which may be conducive to fast leaching of bacteria and nutrients into the lake, near where visitors obtain their drinking water.

In 1984 and 1985, initial temperature, pH, and conductivity readings on water samples were done by park staff in situ or in the resource management lab at Mott Island. Bacterial analysis was performed in Houghton by microbiologists at Michigan Tech at no charge to the park. Transportation of samples was done as quickly as possible, but samples were normally filtered very close to the 30-hour maximum time limit. If samples could have been filtered within the six-hour optimal time limit recommended in Standard Methods (American Public Health Association, 1985), we may have seen lower bacterial levels.

In order to become self-reliant for bacterial analysis, incubators and other related microbiology supplies were purchased in 1985. Resource management staff can now, if necessary, perform all needed bacterial analysis in the park. It should be recognized, however, that accurate bacterial analysis is time consuming and requires experience, and using this equipment for followup studies may not be cost effective except on an emergency basis. Isle Royale maintenance staff operate a high-quality state-certified water quality laboratory at Rock Harbor. If resource management and maintenance can cooperate on future bacterial studies in the park, high-quality, reputable results should be possible at reasonable cost.

V. Conclusion

Many of the natural waters on Isle Royale used as drinking water sources are known to have levels of indicator bacteria higher than state or federal standards allow for potable water sources. However, visitors are informed of the potential dangers of drinking untreated waters in the park and are advised as to the methods for treatment.

The occurrence of non-human bacteria in the aquatic ecosystem cannot be eliminated. Where it is obvious that human fecal contamination is present, park managers need to determine the source of the bacteria and take measures to eliminate or reduce their presence near water sources.

A followup study should be initiated to run samples from locations not sampled in 1984 and 1985 and to determine the success of management actions taken to mitigate the problem.

Bacterial analysis can be more easily accomplished and in a shorter time period if completed on Isle Royale. More remote sites can also be sampled if analysis is done in the park.

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