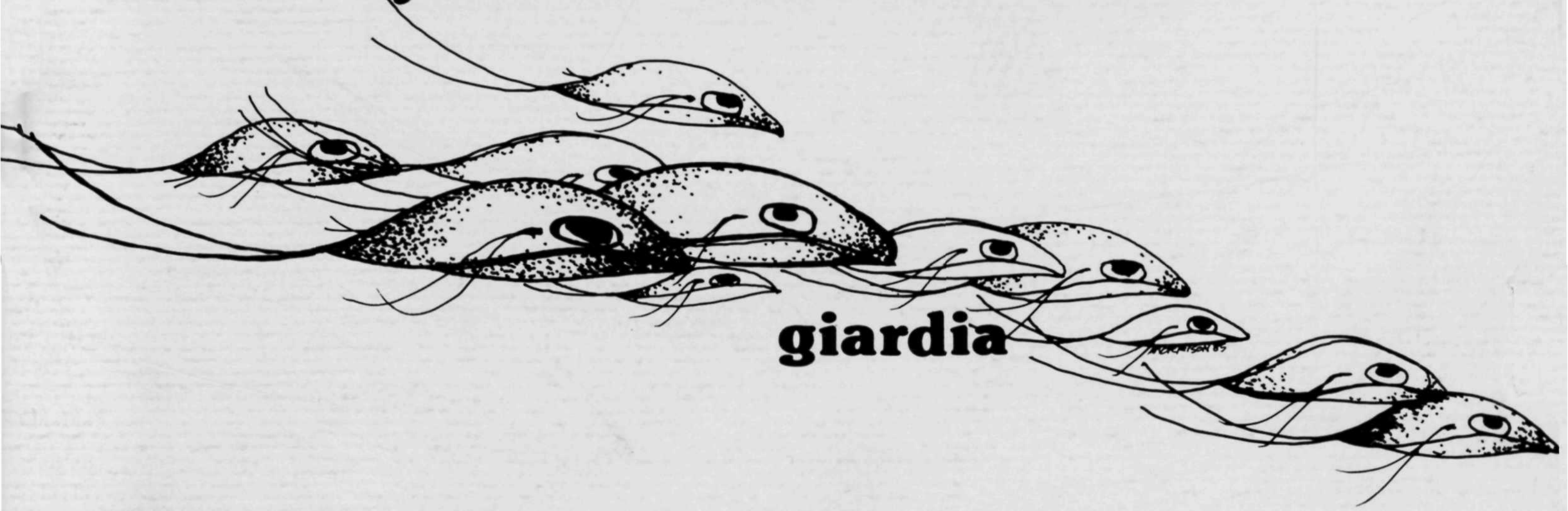
Field Survey of <u>Giardia</u> in Streams and Wildlife of the Glacier Gorge and Loch Vale Basins, Rocky Mountain National Park



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FIELD SURVEY OF *GIARDIA* IN STREAMS AND WILDLIFE OF THE GLACIER GORGE AND LOCH VALE BASINS, ROCKY MOUNTAIN NATIONAL PARK

Natural Resources Report Series 85-3

Prepared by

Water Resources Division
National Park Service

in cooperation with

Rocky Mountain National Park

and the

Colorado State University
Department of Pathology
Department of Microbiology and Environmental Health
and
Department of Recreation Resources and Landscape Architecture

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ABSTRACT

Two popular, high-elevation watersheds in Rocky Mountain National Park, the Glacier Gorge and Loch Vale basins, were surveyed in the summer of 1984 for *Giardia* and indicator bacteria. Stream water was pumped through a filtering mechanism designed for use in the study and was analyzed for *Giardia* cysts. Water samples were collected and analyzed for fecal coliforms, total coliforms, and fecal streptococci. Hikers were interviewed to determine patterns of water use, water purification methods used in the backcountry, and any prevalence of gastrointestinal illness.

Bacterial counts were low overall, with fecal coliforms being mostly under 10 colonies per 100 ml. *Giardia* was found at elevations up to 3365 m (11,040 feet) in concentrations of between 3 and 11 cysts per 1000 ℓ in 7 of the 35 stream pumpings done during August, September, and October. Thirty-six scat samples from the typical high-country fauna (marmots, pikas, deer, elk, bears, coyotes, mountain sheep, and snowshoe hares) were collected, and all were negative for *Giardia*.

Interviews of 556 hikers showed that 13.7 percent of all hikers drank water directly from the streams without treating it in any way. This 13.7 percent of recreationists drinking raw water containing an average of 9 *Giardia* cysts per 1000 ℓ theoretically have a 2 percent chance of ingesting a cyst for every 2 ℓ of raw water they consume in the high country.

Since all wildlife scat analyzed were negative for *Giardia*, and because the three highest concentrations of *Giardia* cysts occurred in samples taken from stream sites located below camping and bivouac areas, the possibility exists that the *Giardia* that is present is brought in by the estimated 9,800 recreationists using the area each year. However, further research would be needed to definitively confirm whether the *Giardia* found in the study area is of human or animal origin.

PROJECT PERSONNEL

This cooperative study between the National Park Service (NPS) and Colorado State University (CSU) combined the efforts of the many individuals listed below.

The study design and the project operation were coordinated by the NPS Water Resources Division. Field data collection and laboratory bacteriological isolations were carried out by CSU research assistants in conjunction with the Division. The CSU Department of Pathology conducted analyses of the water filters and wildlife scat and advised on the project in general. Department of Microbiology personnel assisted with the project by providing training and quality control assistance with field laboratory operations, and the staff of the Department of Recreation Resources and Landscape Architecture designed, carried out, and analyzed the hiker survey.

The following is a list of project personnel, grouped by affiliation:

Rocky Mountain National Park

Dave Stevens, Research Biologist: park liaison, project design.

Rob Porter, Water Systems Operator: park liaison, project assistance.

Water Resources Division

Sam Kunkle, Hydrologist: project coordinator; project design, operation, and interpretation.

Mark Flora, Hydrologist: project design, operation, and interpretation.

Jerry Grondin, CSU Graduate Research Assistant: field sampling and analysis coordinator.

Tom Ricketts, CSU Undergraduate Research Assistant: field data collection, graphics conceptualization.

Karen Short, CSU Graduate Research Assistant: field sampling and analysis.

Juliette Wilson, Research Associate: manuscript preparation and editing, field data collection.

CSU Department of Recreation Resources and Landscape Architecture

Robert Aukerman, Professor: technical advisor on field interview design and implementation, interpretation of survey results and recreation impacts.

Nancy Cowdin, CSU Graduate Research Assistant: field interview coordinator, field interview design and implementation, interpretation of survey results and recreation impacts, field sampling and analysis.

CSU Department of Pathology

Charles Hibler, Professor: technical advisor on *Giardia* sampling methodology.

Greg Hibler, Student Assistant: sample analysis.

Don Monzingo, Graduate Student: sample analysis.

Dianne Swabby, Student Assistant: sample analysis.

John Wegrzyn, Graduate Student: sample analysis.

CSU Department of Microbiology and Environmental Health

Kirke Martin, Senior Research Associate: technical advisor on bacteriological analysis.

This project was funded primarily by the National Park Service with important contributions of personal services, analyses and materials by the CSU Department of Pathology and Department of Microbiology and Environmental Health.

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INTRODUCTION

Background

Giardia—the protozoan parasite found in many of our surface waters today—presents a widespread risk for recreationists, residents of mountain municipalities, and others in mountain, forest, and other backcountry areas. Especially in the Rocky Mountains, Pacific Northwest, and Northeast, the cool conditions are favorable to the survival of viable Giardia cysts in water (Craun 1979; Meyer and Jarroll 1980). This parasite causes a gastrointestinal illness, giardiasis, that in some individuals can be debilitating and long-lasting if not identified and treated. People visiting or living in the mountains, forests, and parks of these regions run the risk of contracting a case of giardiasis by drinking raw or insufficiently treated water. In recent years, Giardia has become a particular concern of backcountry recreationists in national parks and forests in the western United States and Canada; it has been identified in Olympic National Park (Starr 1981), Sequoia and Yosemite National Parks (Suk 1983), and the Bridger-Teton Wilderness Area (Johnston 1978), among others. For the past six years, giardiasis has been the most frequently reported waterborne disease in the United States (Centers for Disease Control, 1984).

Giardia can be expected in waters where poor sanitation practices by humans visiting or working in backcountry areas introduce human fecal wastes into a watercourse. As few as ten cysts can be infective (Rendtorff 1954), and since individuals clinically or asymptomatically infected can shed millions of Giardia cysts each day, contamination of a stream is not difficult. In cold water (0-10°C), Giardia cysts have been shown to survive for at least two months and possibly can survive four to five months (Meyer and Jarroll 1980; Hibler 1982).

Infection occurs when cysts are ingested, excyst into their trophozoite form, attach to the host's intestinal wall, and reproduce to great numbers. Symptoms generally appear from 6 to 21 days after ingestion of the cysts and can include diarrhea, abdominal cramps, fatigue, and weight loss. In severe cases these can lead to malabsorption and steatorrhea (Wolfe 1984). Many persons have asymptomatic or very mild infections of Giardia and spontaneously cure (Meyer and Jarroll 1980; Rendtorff 1975). Studies have shown that previous exposure without treatment also can provide some immunity or resistance; however, the person may still be a carrier.

Wildlife and domestic animal species also serve as potential carriers of Giardia, a point of particular concern in wildland watersheds. Giardia cysts have been isolated in beaver, muskrats, dogs, coyotes, cattle, domestic sheep, moose, and other animals (Hibler 1982). Water-based animals such as beaver and muskrats are of greatest concern since their water-dwelling habits help transmit the cysts.

The particular "type" of Giardia investigated in this study was G. duodenalis, of which the human strain, G. lamblia, is one. Questions still remain among investigators as to the number of species that exist and their differential infectivity to certain hosts. Cross-transmission

studies should help to answer these questions and clarify the differences. In the interim, it is probably wise to err on the side of caution and assume that cysts of the duodenalis type are infective to humans. So far, we know that 1) *Giardia* cysts from humans, dogs, cats, and beaver are not host specific; 2) human source *Giardia* cysts will infect dogs, laboratory rats, and beaver; 3) beaver source *Giardia* cysts will infect dogs; and 4) dog or cat cysts will cross-infect between these species (Davies and Hibler 1979; Davies et al. 1981). Cysts from these sources are all of the duodenalis type.

Colorado's mountain streams and lakes are susceptible to *Giardia* contamination because of three important factors that coincide in the Colorado Rockies:

1. Large numbers of hikers, backpackers, fishermen, skiers, and other recreationists visit this area, and one-tenth of them are likely to be *Giardia* carriers who may be shedding cysts (Hibler, personal communication, 1984).

2. Cold mountain waters favor the survival and transmission of the *Giardia* protozoans, particularly in zones where beaver or muskrats serve as *Giardia* reservoir hosts (Hibler 1982).

3. Water supplies in mountain communities are not always adequately treated to kill *Giardia* cysts since *Giardia* are relatively resistant to chlorination (Craun 1984; Alsaker 1982).

With this combination of factors, it is not surprising that Colorado has experienced numerous *Giardia* outbreaks (Wright et al. 1977; Hibler 1982; Craun 1984). Recent research and case study reports indicate that infected beaver ponds above water supplies of mountain resort areas may have been the sources of *Giardia* in those water supplies (Dykes et al. 1980; Hibler 1982; Monzingo 1985). One beaver feces can contain millions of cysts (Monzingo, personal communication, 1984), and as we have said, as few as ten *Giardia* cysts can infect a person (Rendtorff 1954); therefore, in the event of inadequate treatment (by, say, a malfunctioning water filtration system), many people who drink municipal water are likely to contract giardiasis. This has been the case at several Colorado resort towns during the last two decades, including Aspen Highlands, Vail, and Estes Park (Istre et al. 1982; Craun 1984).

In recognition of the potential hazard of water contamination in the backcountry, the administrators of Rocky Mountain National Park in Estes Park, Colorado, requested that the NPS Water Resources Division (WRD) investigate the presence and impacts of *Giardia* in high-elevation streams in the park. To this end, a project was designed to investigate the following:

1. the impact of several thousand recreationists on stream water quality (defined using three bacterial indicator organisms) in two representative high elevation watersheds;

2. the presence or absence of *Giardia* in these two watersheds as well as in the mammals living there; and

3. the impact, if any, on backcountry users who ingest water from streams and lakes in these watersheds.

For this investigation we deliberately selected heavily used watersheds under the assumption that, if *Giardia* is in fact associated with human impact, the effects would be most evident in areas of intensive use.

An important aspect of this study was to field-test an automatic storm-water sampler developed by WRD staff and to develop and field-test a portable system (one that can be carried in a backpack) for isolating *Giardia* from stream water.

The Study Area

Rocky Mountain National Park is an area of granitic peaks, alpine tundra, coniferous forests, mountain meadows, and cold, clear lakes and streams. Its high elevation backcountry areas are a favorite of outdoor enthusiasts, and each year these areas are used extensively by backpackers, rock climbers, day hikers, and other recreationists, particularly during the warmer months of July, August, and September. In order to survey levels of *Giardia* present in areas of such heavy visitor use, we selected for study two characteristic high-elevation watershed basins that are popular with backcountry recreationists. The two contiguous basins, Glacier Gorge and Loch Vale, lie in the south-central portion of the park (Fig. 1) and were easily accessible to project personnel in Estes Park and Fort Collins.

At the head of the two study basins lies the Continental Divide, which at over 3962 m (13,000 ft) forms the southwestern boundary of the study area. In more level areas on and below the Divide lies the tundra, consisting of lichens, low grasses and flowering plants, and small shrubs. Timberline, at about 3282-3353 m (10,800-11,000 ft), is marked by the presence of krummholz, the low-growing trees dwarfed by severe environmental conditions. Below this elevation the slopes and valleys are covered with forests of spruce (*Picea engelmanii*), lodgepole pine (*Pinus contorta*), and subalpine fir (*Abies lasiocarpa*). Isolated stands of aspen (*Populus tremuloides*) can also be found, especially near meadows and other openings. Mammalian wildlife present at various elevations in the area includes bears, elk, deer, bighorn sheep, cougars, bobcats, and coyotes; smaller mammals such as pine martens, snowshoe hares, marmots, and pikas; and various small rodents.

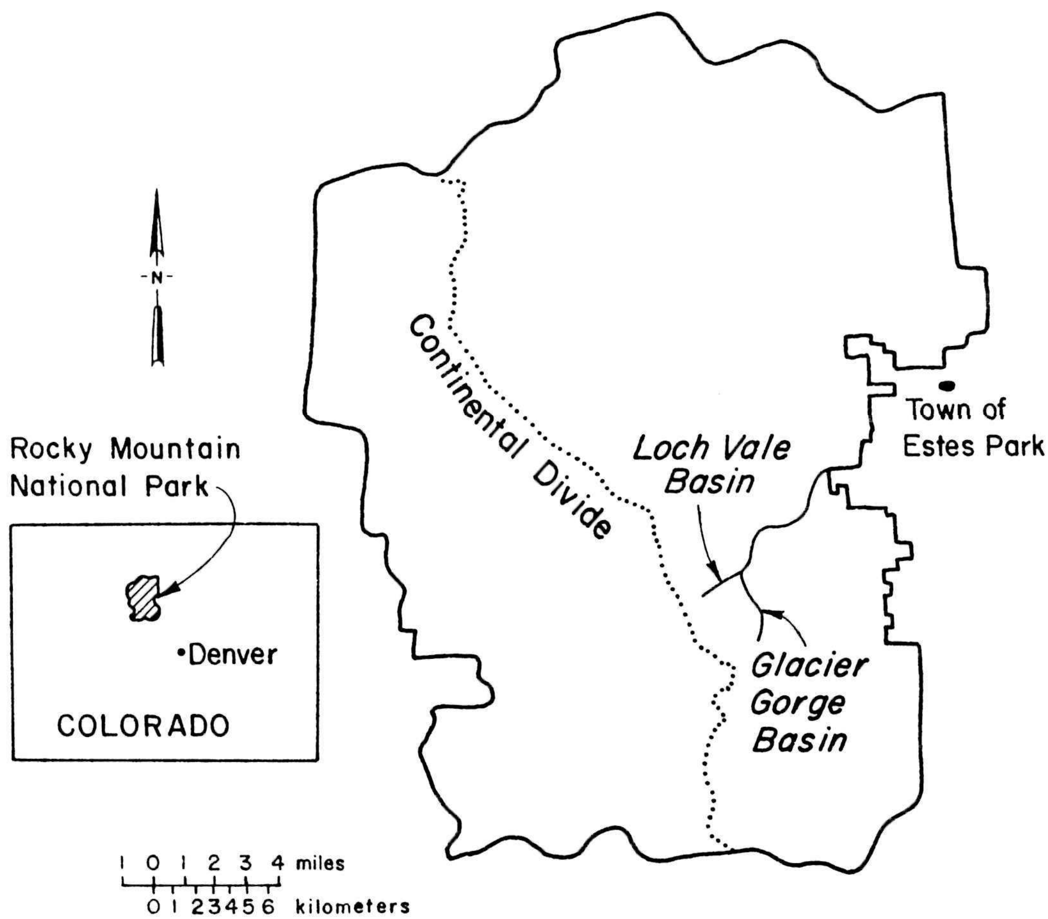


Fig. 1. Rocky Mountain National Park, showing relative location of the study area and the park's location in Colorado (inset).

METHODS AND PROCEDURES

Bacterial Analysis

Five sampling locations were chosen within the study area: Sky Pond and Andrews Creek Campground in the Loch Vale basin, and Green Lake, Black Lake, and Glacier Gorge Campground in the Glacier Gorge basin (Fig. 2). The Sky Pond and Green Lake areas, situated at the higher elevations of the two basins, attract rock climbers who bivouac overnight. Backpackers stay at Andrews Creek and Glacier Gorge campgrounds in the lower elevations of the basins, and Black Lake, at an intermediate elevation, is frequented by day hikers and fishermen. It was in these areas of heaviest use that the potential for contamination—of water by humans and of humans by water—seemed greatest.

To evaluate potential visitor impact on a given area, we established ten bacteria sampling sites representing five "paired" sites, with one site above (upstream) and one below (downstream) the five areas being tested (Table 1 and Fig. 3). Data from the upstream and downstream sites were then compared to evaluate local impacts of visitor use on the areas in question. To investigate the temporal nature of visitor impacts, samples were generally collected on Thursday or Friday and again on Monday, so that bacterial levels before and after the weekend might be compared. (On a few occasions, severe weather intervened and forced a day's variation in schedule.) Finally, field personnel collecting the samples also made notes of human and animal activity or disturbances to aid in later interpretation of the water quality data.

Table 1. Sampling site codes and descriptions.

Site	Terrain	Elevation m	Elevation ft
Loch Vale Basin			
ASP - Above Sky Pond	Tundra	3328	10,920
BSP - Below Sky Pond	Tundra	3316	10,880
AAC - Above Andrews Creek Campground	Forested	3213	10,540
BAC - Below Andrews Creek Campground	Forested	3158	10,360
Glacier Gorge Basin			
ABG - Above Bivouac at Green Lake	Tundra	3523	11,560
BBG - Below Bivouac at Green Lake	Tundra	3365	11,040
ABL - Above Black Lake	Timberline	3231	10,600
BBL - Below Black Lake	Timberline	3222	10,570
AGC - Above Glacier Gorge Campground	Forested	3097	10,160
BGC - Below Glacier Gorge Campground	Forested	3069	10,070

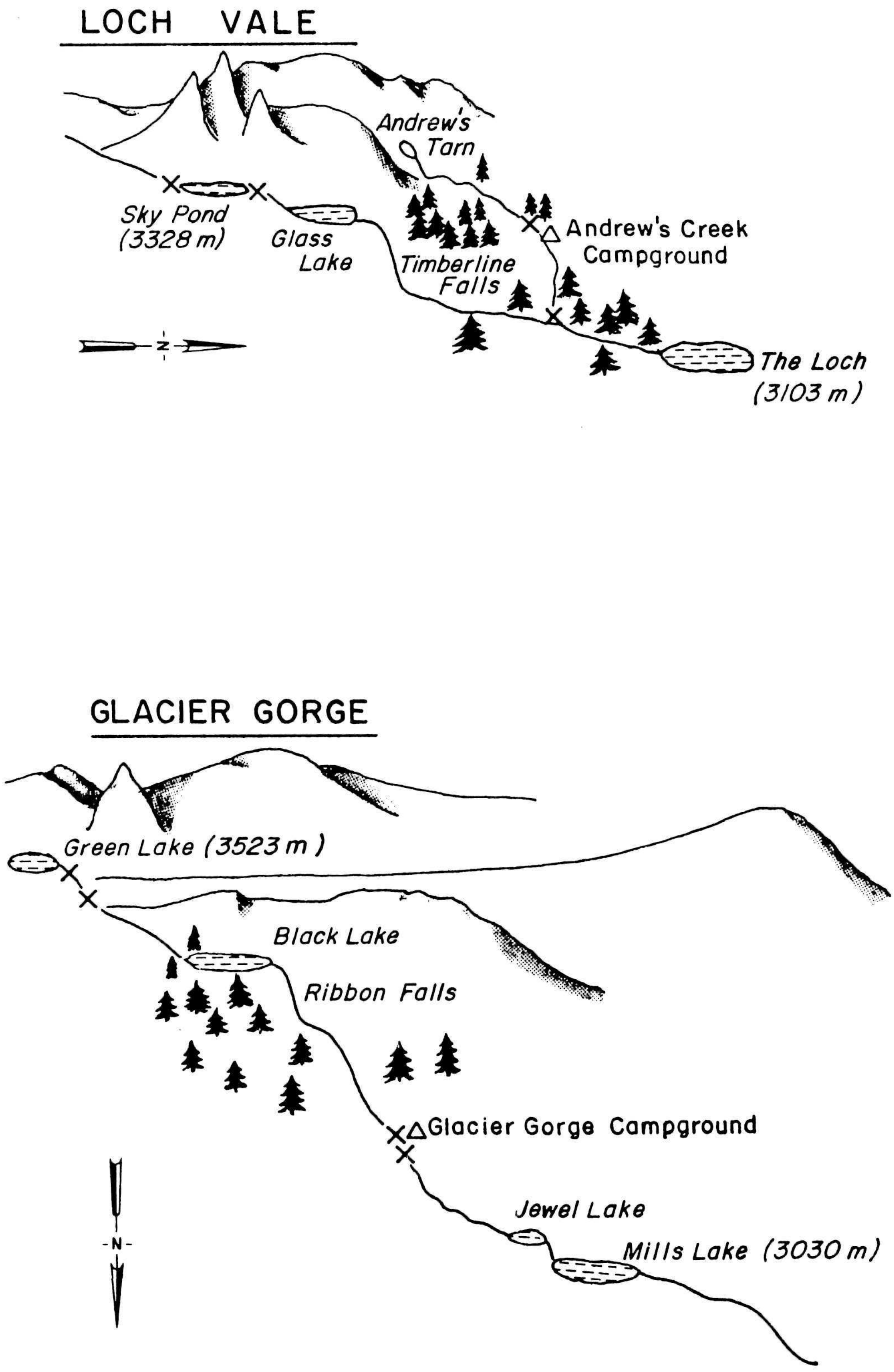


Fig. 2. Topographic views of the Loch Vale and Glacier Gorge basins, Rocky Mountain National Park. X denotes Giardia sampling sites. (Not drawn to scale.)

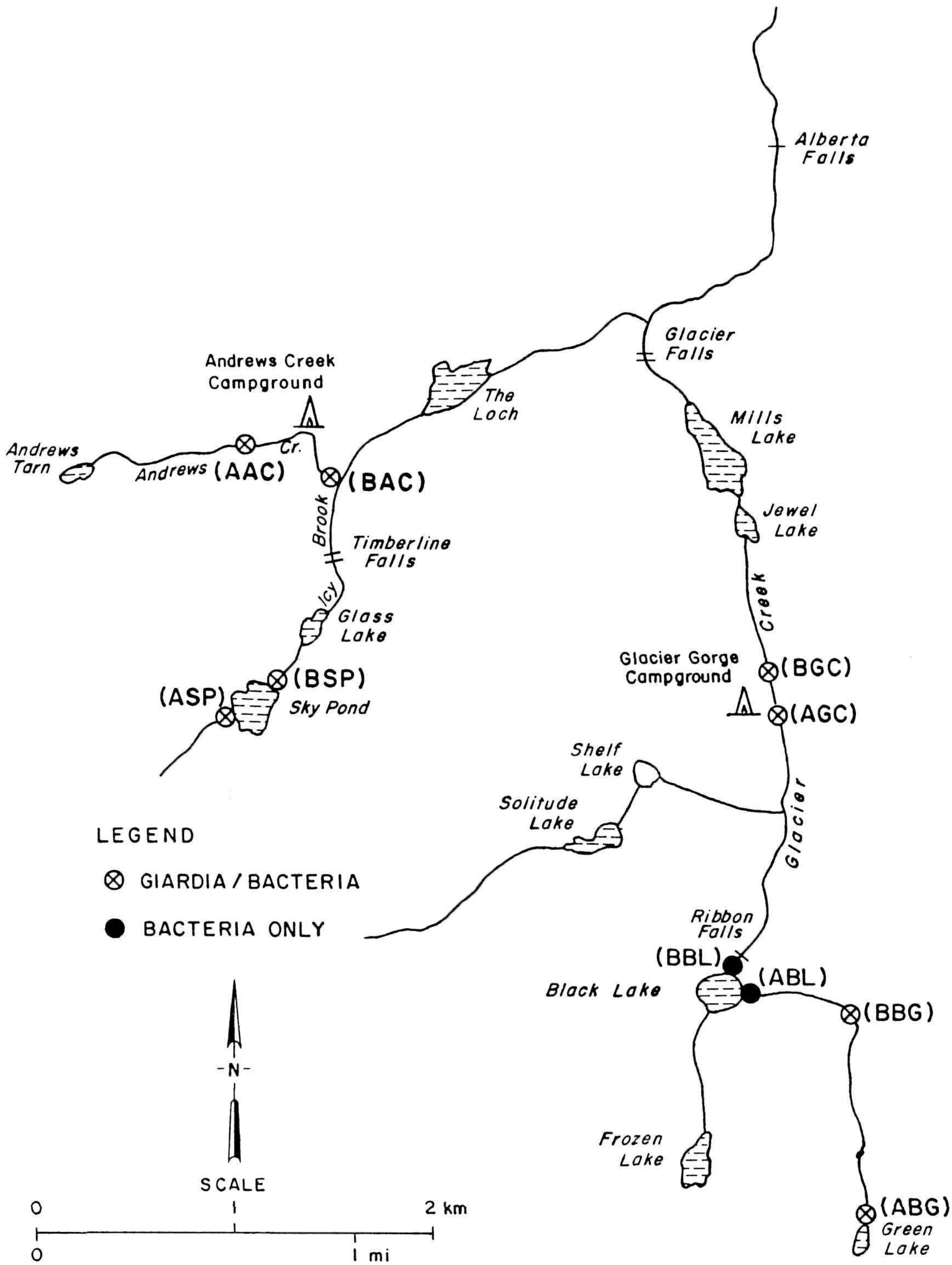


Fig. 3. Giardia and bacteria sampling sites in the Loch Vale and Glacier Gorge basins, Rocky Mountain National Park.

To determine the existence and extent of bacterial contamination, water samples were collected using two different techniques. Hand-collected ("grab") samples were taken twice a week at each of the five sites using sterilized 500 ml polyethylene bottles. In addition, we constructed an automatic storm-water sampling device (Fig. 4) of our own design for placement at two of the five sites, Sky Pond and Andrews Creek Campground. This "storm sampler" collected water in sterilized polyethylene bottles whenever rainstorm runoff raised normal water levels in streams where the samplers were placed. (The storm sampler works on the principle in which rising water fills a bottle. Appendix B contains design and construction information.) In this way we hoped to determine whether surface flushing of meadows or other land forms generates higher bacteria counts in the streams, as other research in the area has shown (Kunkle and Meiman 1968).

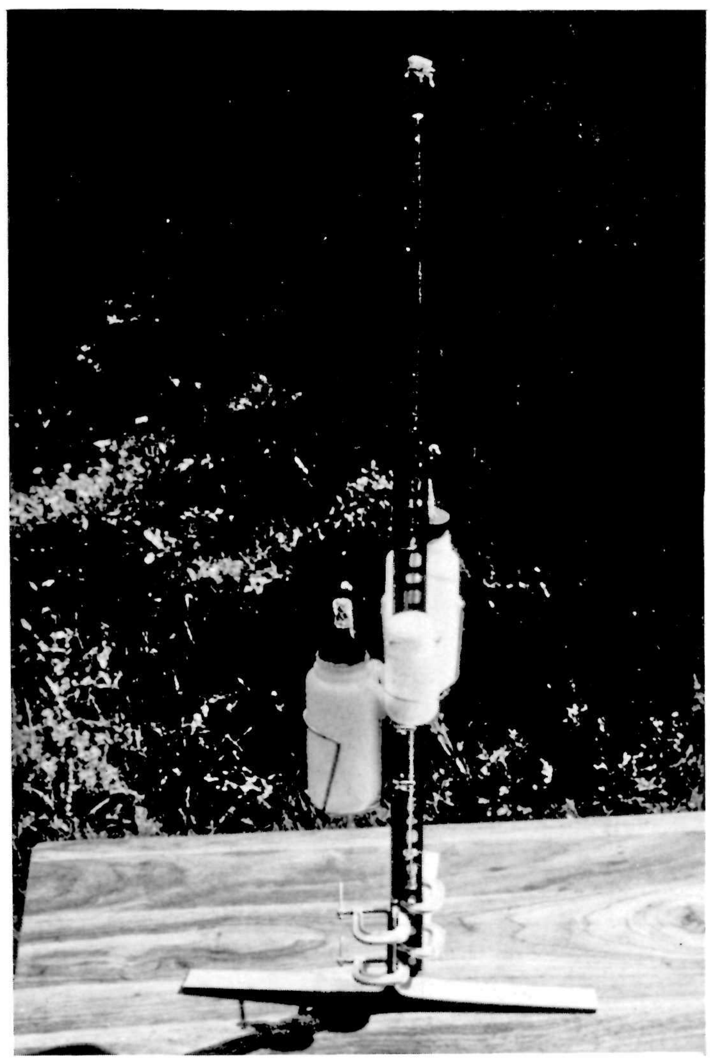


Fig. 4. Automatic storm-water sampler.

All water samples collected were protected from sunlight and heat, which destroy bacteria, and were backpacked to the trailhead. They were then transported to the field laboratory (about a half-hour drive) where they were analyzed the same day or refrigerated overnight for analysis the following morning.

Water samples were analyzed for fecal coliform bacteria (FC), total coliform bacteria (TC), and fecal streptococci (FS) using the Standard Methods (American Public Health Association 1980) membrane filter procedure approved by the Environmental Protection Agency. Confirmations of total coliforms were made using Hach Company's prepared-media lauryl tryptose broth and brilliant green lactose broth. Sample bottles were autoclaved and laboratory equipment was sterilized by ultraviolet radiation. Turbidity and conductivity measurements were taken for each sample using a Hach 21-A turbidimeter and a Beckman conductivity bridge with a YSI cell (cell constant = 1.0).

Stream Discharge Data

Stream discharge was measured in the two study basins. In the Glacier Gorge basin, just below Ribbon Falls, a temporary staff gauge was installed for measuring stream depth at a stable, straight cross-section of the stream (Fig. 5). The cross-section was calibrated using Price standard and pygmy current meters, and a rating curve was developed so that our staff gauge readings could be expressed as discharge

Fig. 5. Current metering site in the Glacier Gorge basin. J. Grondin takes readings.

units (cubic feet per second, or cfs) (Fig. 6). A gauging facility operated in Icy Creek for an acid precipitation research project provided stream flow data for the Loch Vale basin (Fig. 7). The discharge data help indicate the amount of dilution water available in a stream and show the general seasonal changes in stream flow.

Giardia Analysis: Stream Water

Sampling for *Giardia* in stream water was conducted at eight of the ten bacteria-sampling sites, again using "paired" sites at four areas of potential impact (Figs. 2 and 3). Each basin was sampled on five different occasions, twice each during August and September and once in early October. The sampling for *Giardia* was timed to coincide with periods of peak recreational use (mid- to late summer) and increased wildlife activity (early fall).

To isolate *Giardia* cysts, approximately 760 ℓ (200 gallons) of stream water were pumped through a 1.0 micron wound polypropylene filter (Fig. 8). The sampling system incorporated a small 0.75 amp bilge pump, a plastic water metering device attached to the filter housing, a gel-cell battery, and a length of plastic tubing (Fig. 9). A styrofoam collar around the pump kept the water intake approximately 5 cm below the surface and away from the stream bed (we assumed that in these

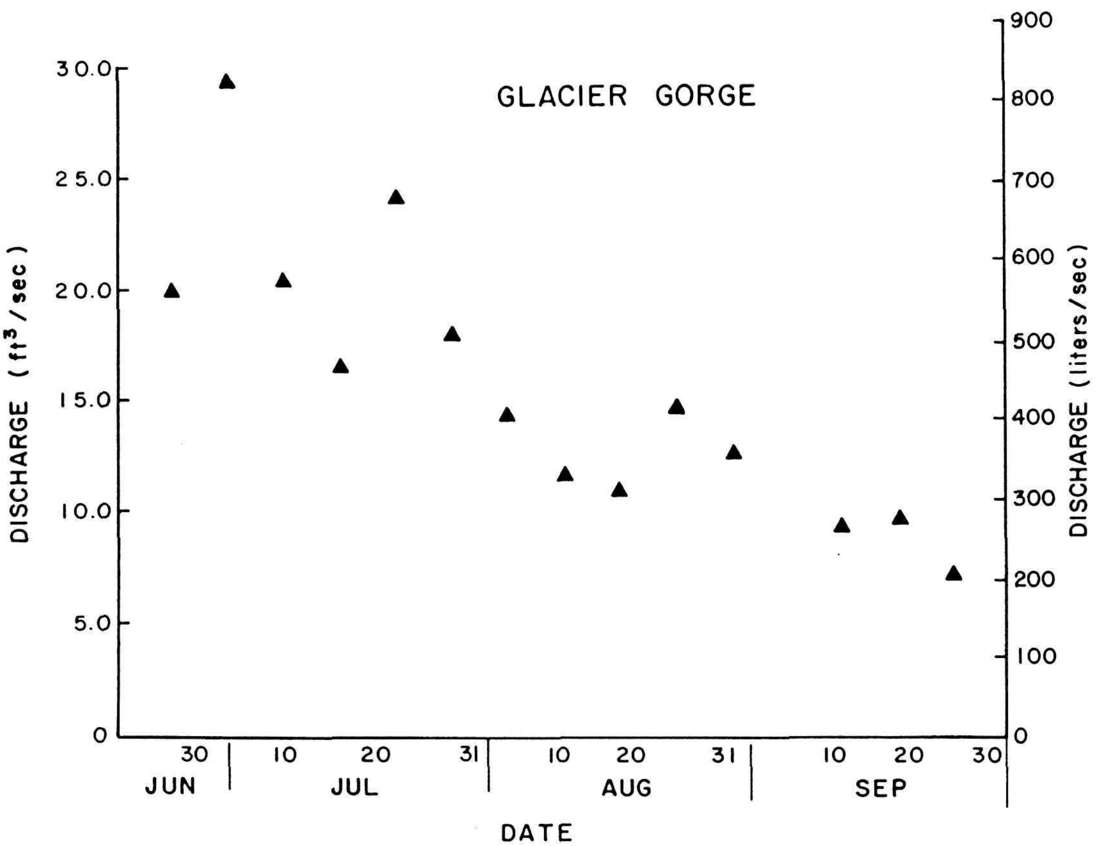


Fig 6. Stream discharge measurements for Glacier Creek in the Glacier Gorge basin, June-September 1984.

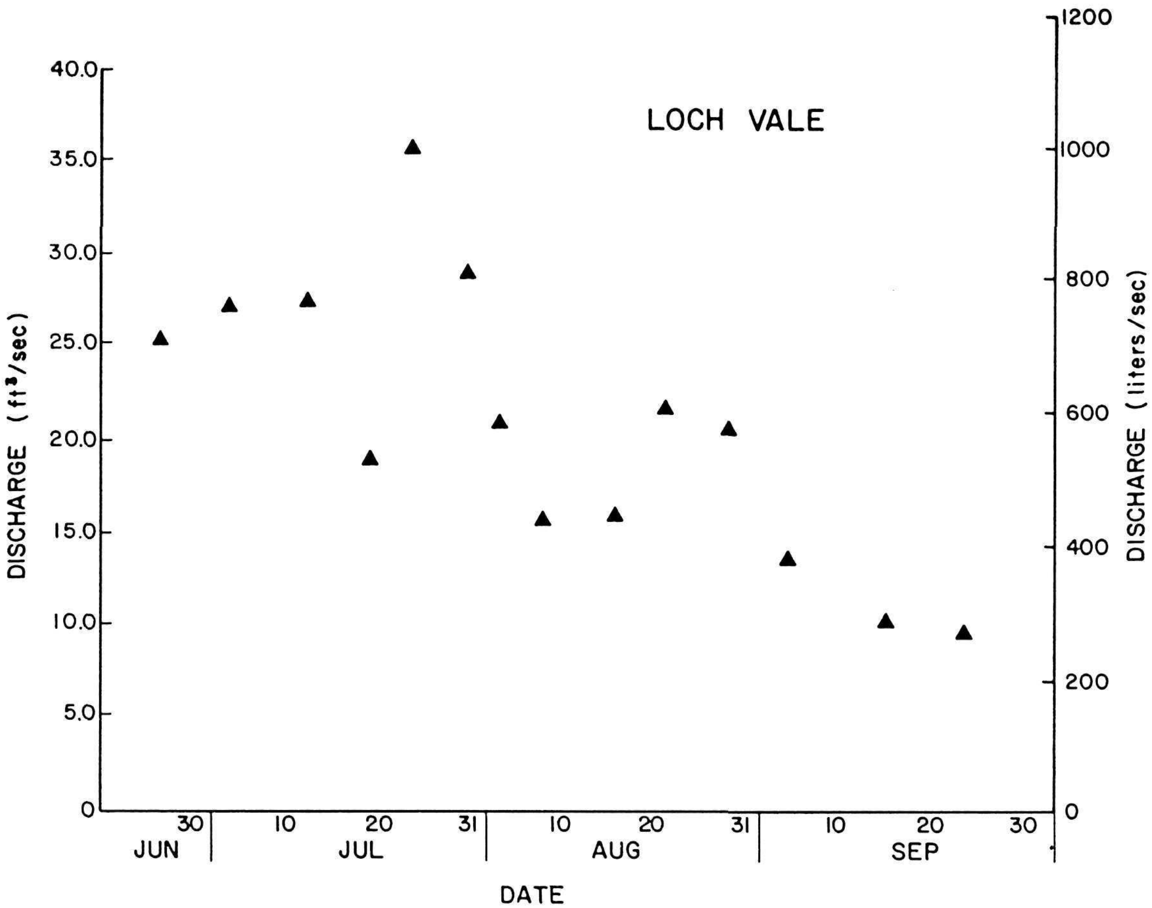


Fig. 7. Stream discharge measurements for Icy Creek in the Loch Vale basin, June-September 1984.

fast-flowing waters, any Giardia cysts present would be mixed throughout). (Details on materials and construction are provided in Appendix A.) In all, 35 pumpings were conducted.

Once the pumping at each site was completed, spent filters were kept cool, moist, and protected from sunlight and were backpacked to the trailhead, transported on ice to the CSU Pathology Laboratory in Fort Collins, and refrigerated upon arrival. Within 48 hours the filters were washed and the washings left to settle overnight. The following morning the water was decanted, and the sediments were centrifuged to concentrate any cysts present into a pellet (Fig. 10). Concentrated pellets were then prepared for microscopic analysis by laboratory personnel. (Infectivity was assumed based on morphology.)

The laboratory analysis for Giardia used by the CSU Department of Pathology is a modification of the zinc sulfate technique. Each fecal sample was placed in a 50 ml paper cup, wetted with distilled water (less than 10°C or 50°F), and stirred to form a fecal suspension. The solution was strained through surgical gauze held over the mouth of the cup into a 15 ml centrifuge tube to remove organic material from the feces. Then, the sample was centrifuged at 1500 rpm (970 G) for five minutes to concentrate the suspended material at the bottom of the tube into a pellet. After the liquid in the tube was decanted with a

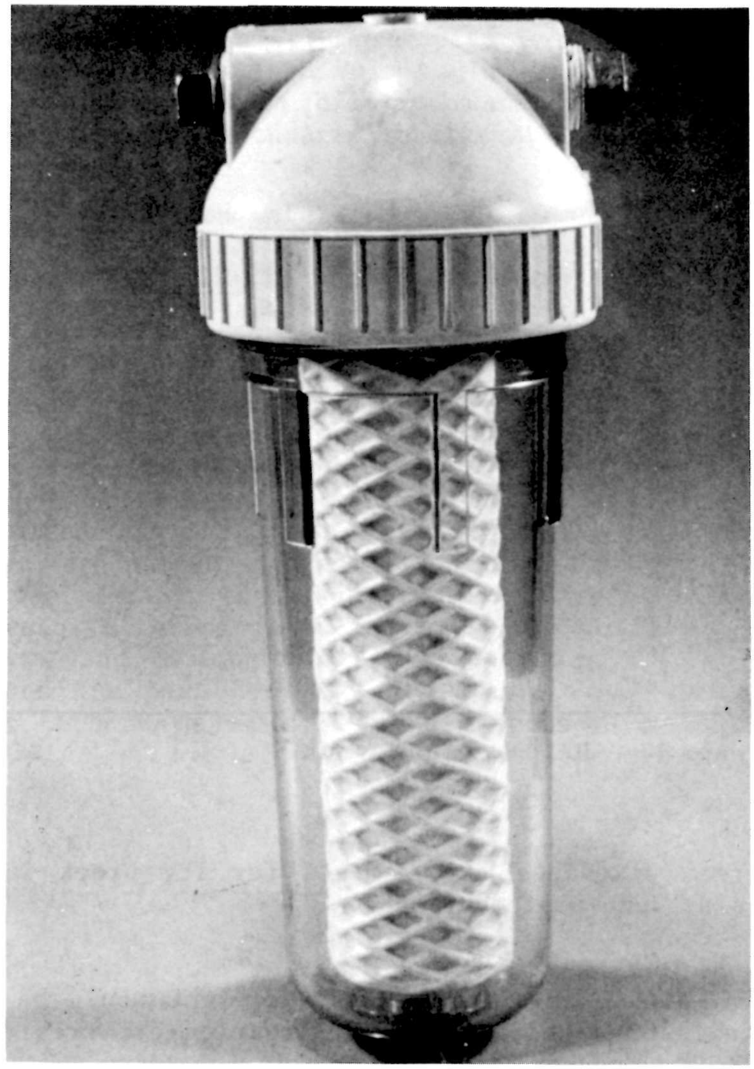
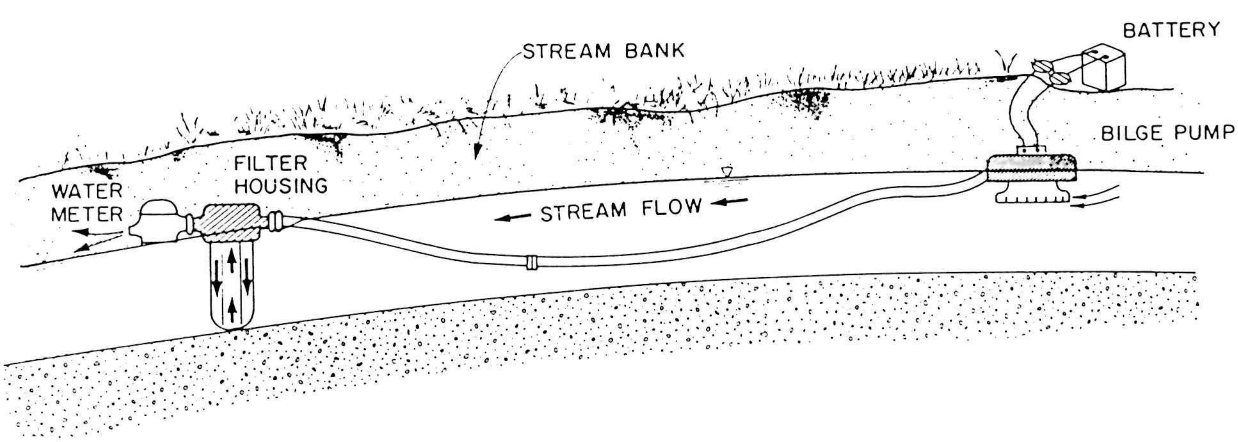


Fig. 8. Wound polypropylene filter (shown inside filter housing) used for isolating *Giardia* cysts from stream water.

suction hose, five drops of Lugol's Iodine was mixed with the pellet to stain any *Giardia* cysts present. Next, zinc sulfate ($ZnSO_4$, specific gravity = 1.18) was added and mixed in. (The specific gravity of the $ZnSO_4$ caused any *Giardia* cysts present to be displaced to the surface.) The tube was returned to the centrifuge, and enough zinc sulfate was added to form a convex meniscus (above the lip of the tube). A microscope cover slip was placed on top and the sample was again centrifuged for five minutes at 1500 rpm (970 G). Finally, the cover slip was removed, placed on a microscope slide, and examined microscopically for *Giardia* cysts. A *Giardia* cyst and trophozoite are illustrated in Figure 11.

A



B

Fig. 9. A) Photograph and B) schematic of the *Giardia* sampling system.

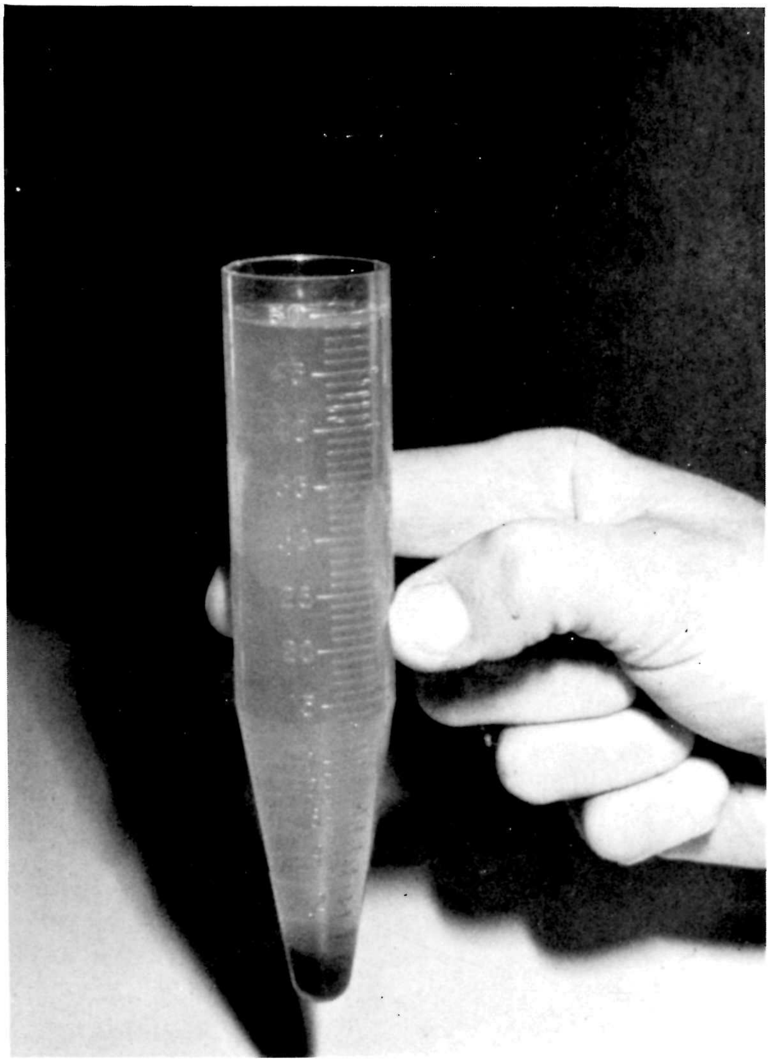


Fig. 10. Centrifuge tube used for isolating Giardia cysts from water filter washings. A pellet of concentrate forms in the bottom of the tube.

Giardia Analysis: Wildlife

Because mammals presumed capable of carrying and spreading Giardia are known to inhabit the sampling areas (especially marmots and pikas, which were observed regularly in the study area), wildlife scat samples also were collected for analysis. Care was taken to collect only those samples that were clearly recent (still moist). The scat samples were picked up using disposable surgical gloves, which were removed from the hand "inside out" and knotted at the top, thereby enclosing the samples. These "containers" were kept cool and transported on ice to the CSU Pathology Laboratory where they were refrigerated and analyzed within 48 hours using the zinc sulfate technique described above.

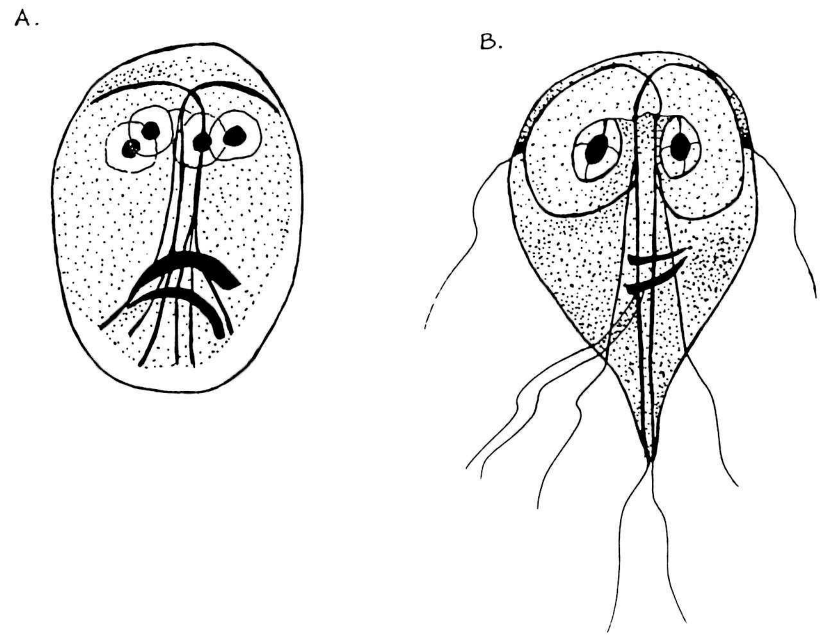


Fig. 11. (A) Giardia cyst and (B) trophozoite. (Adapted from Levine 1961 and Strawn 1979.)

Hiker Survey

As part of the study, CSU personnel interviewed 556 hikers, campers, and bivouac users returning from the Glacier Gorge and Loch Vale basins (Fig. 12). Interviews were conducted from early July through mid-September on various days of the week at different times of day, with most occurring during late July through early September when park visitation was highest. (Interview questionnaires are presented in Appendix D.)

The primary objective of the hiker survey was to determine what proportion of visitors to the two basins had drunk water from natural sources in the basins and whether those doing so later suffered any ill effects. Those who had drunk study-area water were given a follow-up interview by telephone several weeks later. The questions asked were designed to identify those suffering from gastrointestinal symptoms, which would suggest possible infection with Giardia or other waterborne pathogens.

A secondary purpose of the survey was to determine the respondents' knowledge and conceptions of backcountry water use. Questions were designed to provide indications of the respondent's awareness of water-related illnesses, sources of information on water treatment, and the conditions which the individual considered "safe" or "unsafe" regarding water consumption in the backcountry.

Respondents who reported having drunk from streams or lakes in the study area were asked where they drank, whether they first treated the water, and if so, what treatment method was used. In addition, because

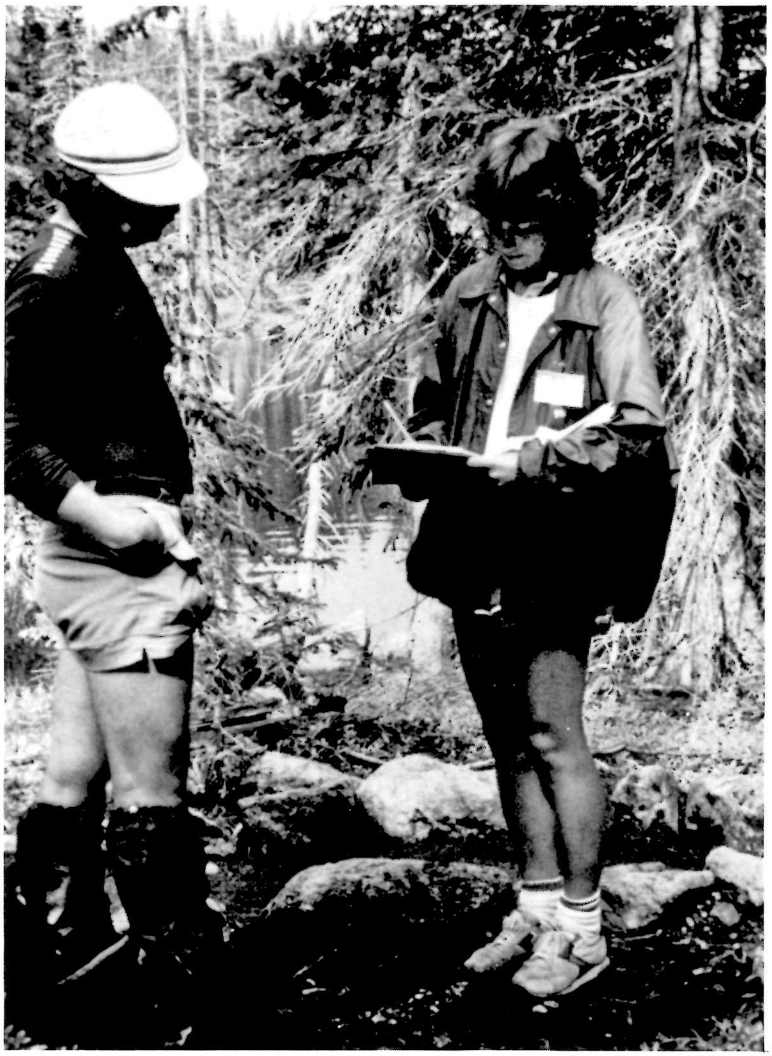


Fig. 12. N. Cowdin interviews a hiker in the Glacier Gorge basin.

individuals previously infected with Giardia can become carriers and recontaminate the environment, questions were asked to determine where and how any human waste had been left in the basins (e.g., proximity to streams, extent to which it was buried, etc.). Special note was made of those respondents who voluntarily reported having had giardiasis or other water-related illnesses. Finally, those participating in the follow-up interviews were asked more specifically about their knowledge of and exposure to Giardia.

RESULTS

Introduction

Natural waters in the Loch Vale and Glacier Gorge basins are of pristine quality and do not appear to be affected to any serious degree by present levels of human or wildlife use or to be causing human health problems of which park officials are aware. Turbidity and conductivity values were low for all grab samples, indicating little sediment or inorganic chemical loading. Mean turbidity was 0.38 NTU with a range of 0.16-7.0 NTU, and the mean conductivity was 8 µmhos/cm with a range of 4-26 µmhos/cm. Water at all sampling sites was fast-moving and therefore assumed to be mixed, although the site below Sky Pond could have been influenced by settling. Our study uncovered no confirmed cases of giardiasis among the recreationists surveyed. Nonetheless, we found *Giardia* in some of the streams and our surveys indicate that some hikers are drinking raw water directly from the streams; therefore, the potential exists for giardiasis among recreationists. In addition, though the waters are very clean, they are not free of contamination, as enteric bacteria appeared in small numbers in nearly every sample.

Bacterial Analysis: Human and Wildlife Impacts

The streams in both basins contained low—mostly near zero—concentrations of the three types of indicator bacteria (Tables 2 and 3). Maximum values of fecal coliforms (FC) never exceeded 24 colonies per 100 ml, and median values were zero for all sites throughout the study period. (As a comparison, fecal coliform standards for recreational

Table 2. Concentrations (in colony-forming units per 100 ml) of fecal coliforms (FC), total coliforms (TC), and fecal streptococci (FS) observed at sampling sites in the Loch Vale basin, June-October 1984.

Site	Type of Bacteria	Number of Samples	Concentration (cfu/100 ml) Minimum	Maximum	Median	Mean
ASP	FC	18	0	1	0	0
	TC	21	0	1	0	0
	FS	21	0	4	0	0
BSP	FC	18	0	1	0	0
	TC	21	0	140	2	26
	FS	21	0	4	0	0
AAC	FC	20	0	24	0	1
	TC	21	0	>200[1]	2	16
	FS	21	0	>200[1]	0	10
BAC	FC	20	0	8	0	1
	TC	21	0	24	2	5
	FS	21	0	5	0	1

[1]Two hundred is the upper statistical counting limit.

Table 3. Concentrations (in colony-forming units per 100 ml) of fecal coliforms (FC), total coliforms (TC), and fecal streptococci (FS) observed at sampling sites in the Glacier Gorge basin, June-October 1984.

Site	Type of Bacteria	Number of Samples	Concentration (cfu/100 ml)			
			Minimum	Maximum	Median	Mean
ABG	FC	17	0	1	0	0
	TC	20	0	22	0	2
	FS	19	0	23	0	1
BBG	FC	19	0	8	0	1
	TC	19	0	100	6	16
	FS	19	0	11	1	2
ABL	FC	20	0	8	0	1
	TC	21	0	60	2	9
	FS	20	0	11	2	2
BBL	FC	20	0	5	0	0
	TC	21	0	109	0	12
	FS	20	0	3	0	1
AGC	FC	19	0	3	0	2
	TC	20	0	45	5	12
	FS	19	0	10	1	2
BGC	FC	20	0	5	0	1
	TC	21	0	91	8	16
	FS	20	0	9	1	1

use water at swimming beaches usually are set at 200 colonies per 100 ml.) Total coliform (TC) maximum values were mostly under 25 but occasionally reached over 200 per 100 ml; even so, median values for all sites were 8 or less per 100 ml. With one exception, maximum values for fecal streptococci (FS) were less than 24 colonies per 100 ml, and median values were 2 or fewer colonies per 100 ml.

Figure 13 illustrates the seasonal trends for total coliform bacteria for two "below" sites (areas of heavy human use) in the Loch Vale basin. As the summer season progressed and water levels declined, concentrations of bacteria increased slightly. The three "below" sites in the Glacier Gorge basin show similar rises in bacterial concentrations (Fig. 14). In Figure 15, data from the "above" and "below" sites at Sky Pond illustrate possible human and/or animal impact in that the bacterial concentrations at the "below" site rise with the advancing summer season.

By sampling above and below impact areas and before and after weekends, we were endeavoring to learn whether waste from campgrounds and bivouac areas appeared to be entering streams, and if so, whether this phenomenon seemed related to more intensive weekend use. T-tests were used to compare data from the "above" sites with data from the "below" sites. Test results showed that total coliforms were in

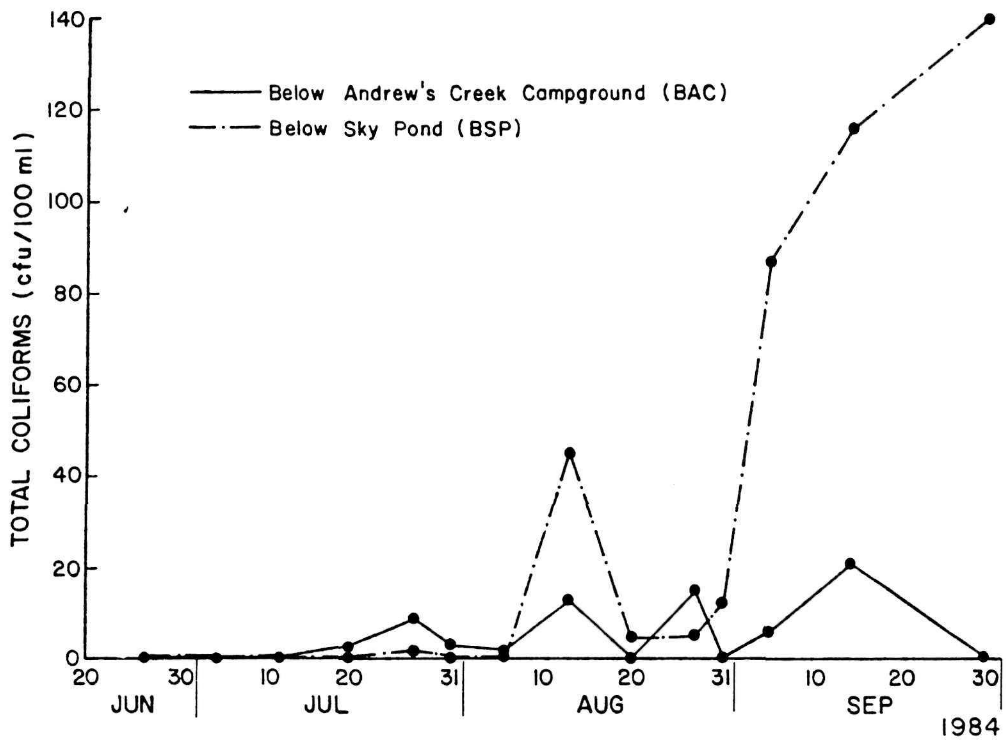


Fig. 13. Total coliform concentrations (in colony-forming units per 100 ml) for the two "below" sites in the Loch Vale basin.

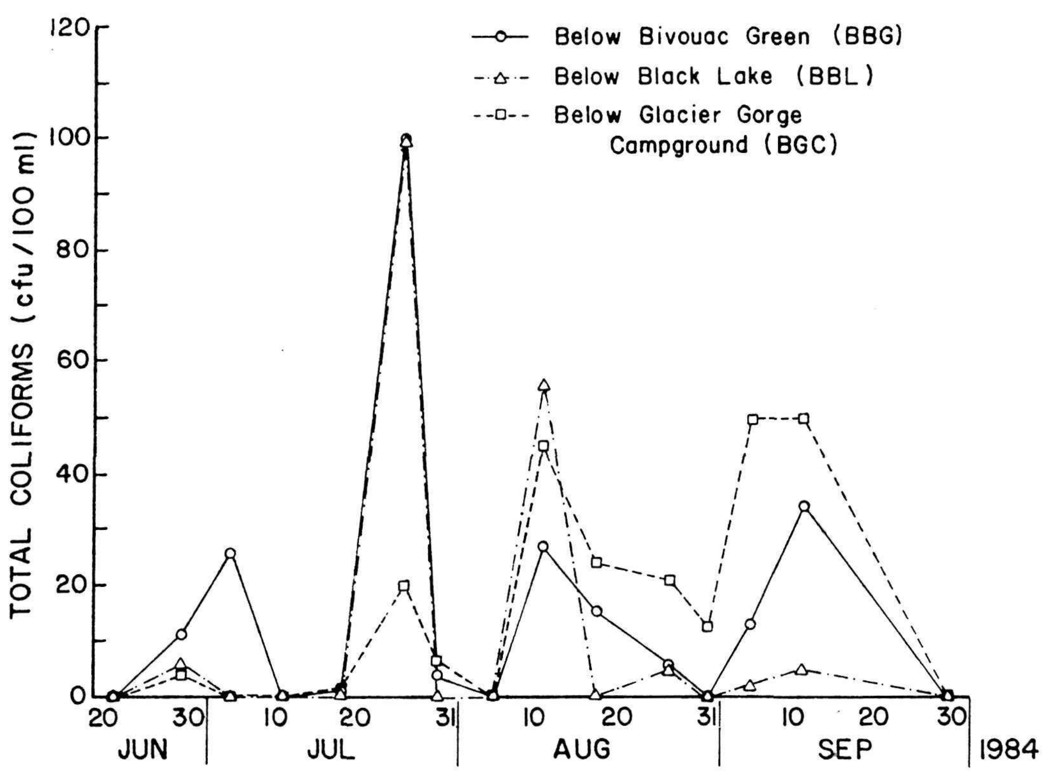


Fig. 14. Total coliform concentrations (in colony-forming units per 100 ml) for the three "below" sites in the Glacier Gorge basin.

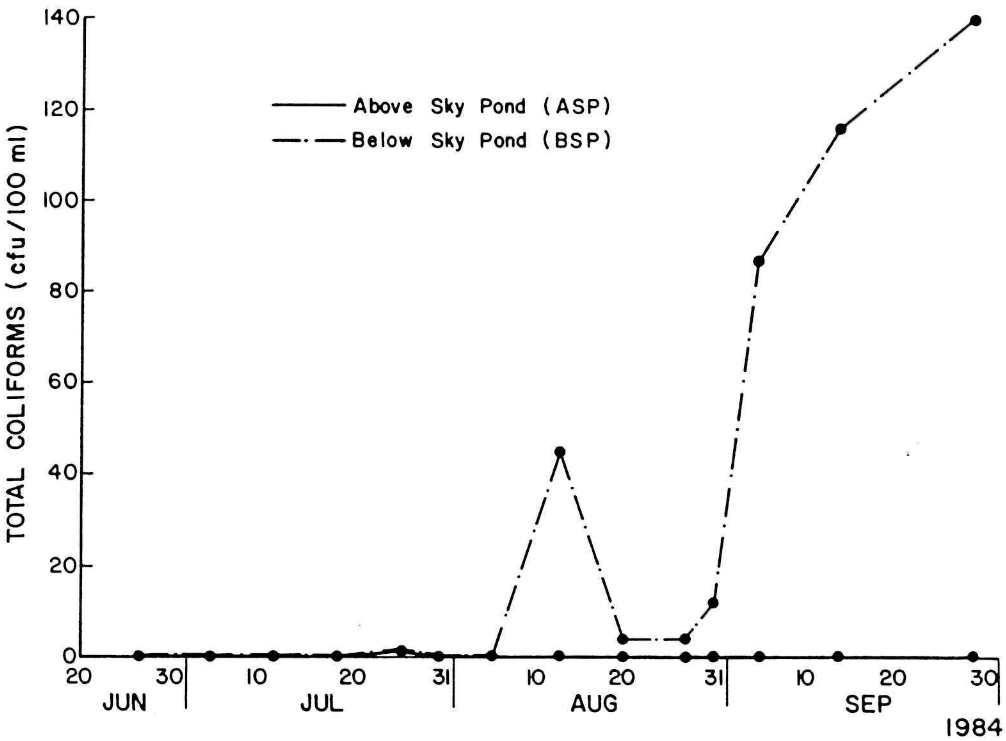


Fig. 15. Total coliform concentrations (in colony-forming units per 100 ml) for the two Sky Pond sites in the Loch Vale basin.

significantly greater concentrations below the two bivouac sites (Green Lake and Sky Pond) than they were above these sites; however, the actual figures were low and on most occasions were zero. The other three paired sites showed no significant differences. In addition, no significant differences in above-below comparisons could be demonstrated for fecal coliforms, the more specific index of human impact, or for fecal streptococci, the index more closely related to wildlife impact, at any of the five paired sites.

We were unable to determine that bacterial counts increased following weekend use. Fecal coliform and fecal streptococcal counts were so low (mostly zero) that differences before and after weekends, where they occurred, were negligible. Total coliform counts were generally higher than the other two indicator bacteria; however, no consistent patterns were discernible. Finally, the number of observations was necessarily halved in order to compare "before" samples to "after" samples; this process rendered the number of observations at each site too small for valid statistical comparisons.

One way to detect human impact is to examine the ratio of FS to FC. In our study, the bacteria concentrations are so low that valid generalizations cannot be made. Even so, it is interesting to note that FS values were about three times higher than FC values at most sites. Despite the low numbers, these differences imply that the contamination

is of animal origin since human waste normally contains higher proportions of FC, while wildlife waste contains higher proportions of FS.

Bacterial Analysis: Storm Runoff

The storm sampler developed for the study effectively collected water from several storms during the study period. In the Loch Vale basin, where the samplers were installed, we were able to obtain 13 suitable storm-water samples. The "macaroni clock," which featured a mostaccioli noodle (a kind of pasta shaped like a short, straight tube with slanted ends) in a separate 250 ml polypropylene bottle attached to the storm sampler, enabled us to distinguish recent samples (less than 18 hours old) from older ones that would be unsuitable for analysis. In prior tests we determined that the noodle behaved as follows: after six hours, the noodle was slightly swollen but still firm; after 12 hours, the noodle was 1½ times its original size and soft; after 18-24 hours, the noodle had swollen to about twice its original size and disintegration had begun; after approximately two days, disintegration was advanced. Thus, if the disintegrating mostaccioli noodle indicated that 18 hours or more had elapsed since the storm occurred, we discarded that sample and reset the sampler for the next storm.

By comparing the concentrations of bacteria in storm-water samples with those found in grab samples taken in the Loch Vale basin, we wished to learn whether any pollutant (bacterial) load was being flushed into the streams during rain storms. Mean bacterial concentrations in the storm runoff samples (Table 4) were slightly higher than the mean concentrations found in the grab samples (Tables 2 and 3), which were taken during non-storm periods. Data points were too few (N=13) to correctly apply a t-test, but the bacterial counts themselves were low enough to indicate that no large pollutant load was being flushed into streams with runoff. Turbidity and conductivity were only slightly higher in storm samples, with a mean turbidity of 4.4 NTU and mean conductivity of 9.0 µmhos/cm.

Giardia Analysis: Human and Wildlife Impacts

Results from all 35 pumpings for Giardia are summarized in Figure 16. (Five additional pumpings were cancelled because of severe weather.) Giardia was present in both basins at six of the sampling sites and in seven of the samples taken, but only in low numbers. The maximum observed was about 4 cysts per 100 gallons or about 9 cysts per 1000 ℓ. This compares with an average of 50-100 cysts per 1000 ℓ and a high of 611 cysts per 1000 ℓ found in lower elevations (under 2900 m or 9500 ft) of the park where beaver ponds are common (Monzingo 1985).

Giardia were slightly more common at the lower elevation, forested sites (3048 m or 10,000 ft) where five Giardia samples were positive, as compared with only two positive samples from the higher elevation (3353 m or 11,000 ft) tundra sites. No seasonal trend for the occurrence of Giardia appeared during the sampling period. There was a

Table 4. Concentrations of bacteria found in storm-water samples (cfu/100 ml).

Collection Date	Site	Bottle Height	Fecal Coliform	Total Coliform	Fecal Streptococcus
21 July	ASP	Low	0	0	0
22 July	AAC	Low	0	0	0
23 July	ASP	High	0	100	27
23 July	ASP	Low	0	4	1
23 July	BSP	Low	0	11	3
23 July	AAC	High	23	80	12
23 July	AAC	Low	29	100	23
23 July	BAC	Low	0	>200[1]	53
30 July	ASP	Low	45	158	8
30 July	AAC	Low	46	2	27
2 August	ASP	Low	1	3	5
19 August	ASP	Low	1	3	5
24 August	ASP	Low	0	9	0
Mean:			11	51	12
Median:			0	6	4

[1]Two hundred is the upper statistical counting limit.

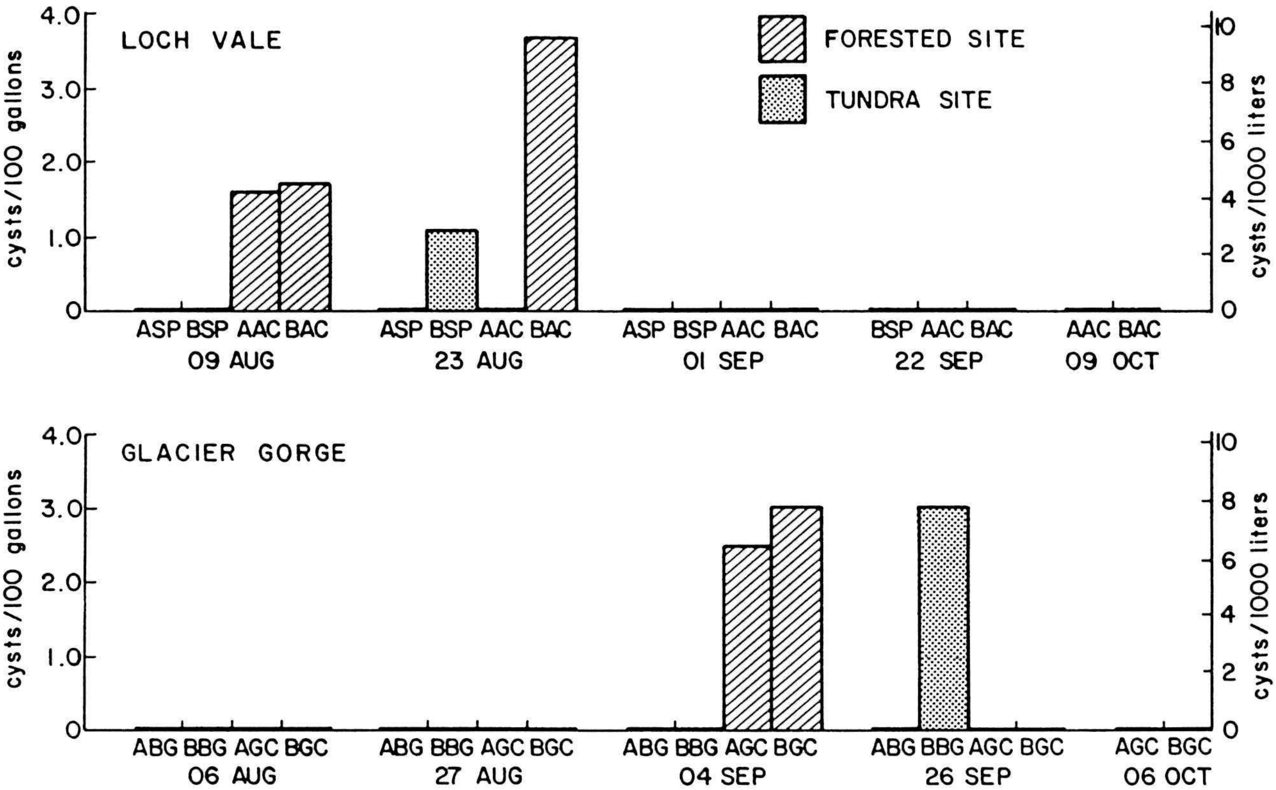


Fig. 16. Giardia cyst concentrations for five sampling periods for sites in the Loch Vale and Glacier Gorge basins.

slight tendency for more Giardia to be found below the campgrounds or bivouac areas (five positive samples) than above (two positive samples).

Tables 5 and 6 list the 36 scat samples gathered for several species of mammals in the two basins during late June to late September. All 36 scat samples were negative for Giardia cysts.

Giardia-Bacterial Relationships

Giardia and bacterial data were graphically compared by site for all values throughout the season, with sampling dates matched as closely as possible. No discernible correlation could be found between bacterial counts or trends and those for Giardia.

Hikers and Water Use Patterns

Based on nearly daily observations of numbers of hikers on the trails, we estimated that a total of 9800 recreationists visited the two

Table 5. Wildlife fecal samples collected in the Loch Vale basin.[1]

Date	Species or Feces Type	Number of Samples	Location
26 June	Marmot (*Marmota flaviventris*)	1	Sky Pond inlet, NW shore (snowfield) (3328 m)
26 June	Pika (*Ochotona princeps*)	2	Sky Pond inlet, NW shore (snowfield) (3328 m)
30 July	Marmot	1	Timberline Falls (3219 m)
30 July	Deer or elk (*Odocoileus hemionus*) or (*Cervus elaphus*)	1	Timberline Falls (3219 m)
16 August	Pika	4	Sky Pond inlet (snowbank) (3328 m)
18 August	Small carnivore	1	Glass Lake (snow-bank) (3292 m)
18 August	Marmot	1	Below Sky Pond outlet (3322 m)
18 August	Small mammal	1	Firetrail (2957 m)
23 August	Elk	1	Above Andrews Creek campground (3213 m)
24 August	Mammal	1	Firetrail (2957 m)
24 August	Marmot	1	Glass Lake (3292 m)
4 September	Elk	1	Above Andrews Creek campground (3213 m)
6 September	Small mammal	1	Firetrail (2957 m)
6 September	Small mammal	1	The Loch (3109 m)
22 September	Small rodent	1	Below Timberline Falls (3170 m)
22 September	Small rodent	1	Below Andrews Creek campground (3158 m)
22 September	Hare (*Lepus americanus*)	1	Below the Loch (switchbacks) (3094 m)

[1]No *Giardia* cysts were found in any scat samples, i.e., all microscopic analyses were negative for *Giardia*.

Table 6. Wildlife fecal samples collected in the Glacier Gorge basin.[1]

Date	Species or Feces Type	Number of Samples	Location
26 June	Pika (*Ochotona princeps*)	1	Green Lake outlet (3511 m)
9 July	Marmot (*Marmota flaviventris*)	1	Black Lake outlet (3222 m)
9 July	Pika	1	Green Lake inlet (snowbank) (3523 m)
23 July	Small rodent	1	Trail intersection for Sky Pond and Black Lake (2987 m)
26 July	Black bear (*Ursus americanus*)	1	Below Black Lake inlet (3225 m)
26 July	Marmot	2	Green Lake outlet (3523 m)
26 July	Black bear	1	Black Lake inlet (3231 m)
30 July	Coyote (*Canis latrans*)	1	Below Green Lake outlet (3499 m)
30 July	Marmot	1	Above Black Lake (3240 m)
23 August	Small mammal	1	Jewel Lake (3036 m)
23 August	Marmot	1	Green Lake outlet (3511 m)
4 September	Small mammal	1	South end of Mills Lake (3036 m)
24 September	Deer (*Odocoileus hemionus*)	1	Below Glacier Gorge Campground (3069 m)
24 September	Marmot	1	Above Glacier Gorge campground (3097 m)

[1]No *Giardia* cysts were found in any scat samples, i.e., all microscopic analyses were negative for *Giardia*.

basins during early to late summer 1984. A breakdown of water use by the 556 individuals we interviewed is presented in Figure 17. In short, we learned the following:

- 94% of the recreationists interviewed were day hikers.
- 80% of the recreationists carried their own supply of drinking water into the backcountry.
- 14% drank untreated stream water.
- 6% drank stream water but first treated it in some manner.
- 91% of the raw water drinkers were day hikers.

Table 7 summarizes the treatment methods used by the 6% who treated their water. Boiling was the most common treatment, at 55 percent, followed by filtration (25 percent) and chemical treatment (20 percent).

Incidence of Giardiasis

The recreationists surveyed were concerned about Giardia contamination, and though many had heard of it, they typically had only limited knowledge. Because of their general interest, the 111 recreationists who drank the natural waters agreed to participate in the follow-up telephone interviews.

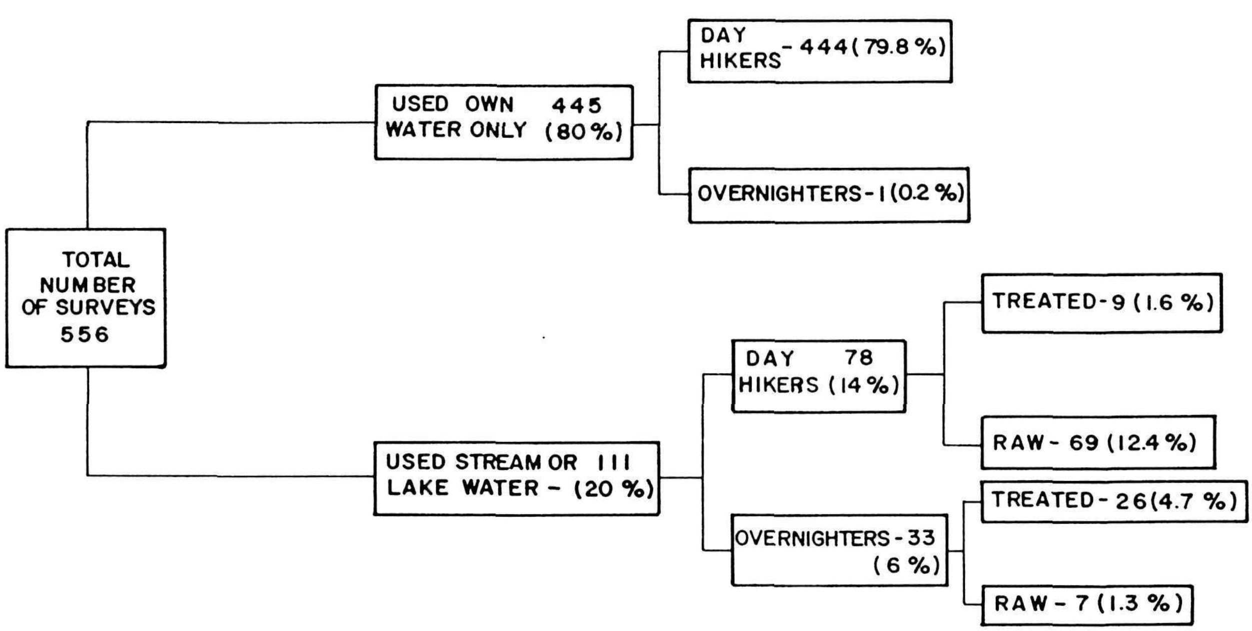


Fig. 17. Water use by day hikers and overnight hikers in the study area, July-September 1984.

Table 7. Summary of water treatment methods used by hikers in the Glacier Gorge and Loch Vale basins, July-September 1984.

Treatment Method			Number of Users	Percent[2] of Total Number Treating Water (N = 35)
Iodine:	Potable Aqua[1]		5	14%
	Coghlan's[1]		2	6%
		Total	7	20%
Filtration:	Aquatech[1]		4	11%
	First-Need[1]		5	14%
		Total	9	25%
Boiling:	10 minutes		2	6%
	5 minutes		5	14%
	2 minutes		2	6%
	1 minute		8	23%
	Unspecified		2	6%
		Total	19	55%

[1]Product trade names.
[2]Percentages are rounded to nearest whole number.

Of the 96 people we actually interviewed by telephone (and by mail for the few we were unable to reach by phone), none had confirmed cases of giardiasis, although four reported they had later experienced some gastrointestinal illnesses. However, no medical diagnoses were made.

DISCUSSION

Introduction

In the Colorado Rockies, localized outbreaks of waterborne giardiasis have been common for over 15 years (Craun 1984; Hibler 1982). Such giardiasis epidemics can be confirmed through clinical testing of patients in conjunction with isolation of *Giardia* cysts from their common water supply.

Problems of giardiasis have been suspected among hikers in remote backcountry areas as well, and isolated case studies of hikers contracting *Giardia* infections are known (Barbour et al. 1976). But actual data on *Giardia* in remote areas is minimal. Therefore, a primary objective in our study was to gather data on *Giardia*, giardiasis, and any bacterial impacts for a popular, high-elevation hiking area in the park and to identify the concentrations and patterns of any *Giardia* found. No *Giardia* data had previously been collected for high-elevation watersheds in Rocky Mountain National Park.

The most important reason for the study, from a park management viewpoint, is to better understand the level of risk of giardiasis among hikers by quantifying 1) the percentage of hikers drinking untreated stream water and 2) concentrations of *Giardia* in park waters, since the two factors combined provide an index of the risk of ingesting cysts. We therefore conducted interviews in addition to the water sampling to obtain the needed data on raw water drinkers.

Finally, we wanted to learn more about the role of high country wildlife in spreading *Giardia*. Our data on this were limited, but certain implications about marmots, pikas, and other mammals at higher elevations could be drawn.

Theoretical Discussion of Epidemiology

Hiker interviews indicated that 13.7 percent of the recreationists drank raw stream water. Based on our data, the chance of ingesting a *Giardia* cyst by drinking raw water in the study area could then be estimated as follows:

- assume a recreationist drinks about 2 ℓ per day;
- water at the most polluted study site contained 9 cysts per 1000 ℓ;
- therefore, 2 ℓ x 9 cysts/1000 ℓ = 0.02 cysts/2 ℓ, which translates to a 1 in 50, or 2 percent, chance of ingesting a cyst by drinking raw water.

By way of comparison, where waters in lower elevation areas exhibit 50-100 cysts per 1000 ℓ, a raw water drinker would run about a 10-20 percent chance of ingesting a cyst.

According to our data, then, the 13.7 percent of recreationists who indicated that they had drunk raw water ran a 2 percent chance of ingesting a Giardia cyst. In addition, some interviewees may not have treated their water adequately to kill Giardia cysts; these individuals also ran a risk, though small, of ingesting cysts. However, we are unable to predict potential numbers of cases of giardiasis with any confidence because of a number of complicating factors. Among these are natural immunity, resistance to infection, and hygiene habits on the part of the individual; infectivity of any ingested cysts to humans (although the duodenalis type cysts identified in our study are presumed to be infective to humans); the number and viability of cysts ingested (since trophozoites reproduce asexually, it does not seem unreasonable that one cyst could infect, although this has not been documented); the effectiveness of any water purification techniques applied to raw water; and sampling error. To complicate matters, many individuals who contract giardiasis remain asymptomatic; in these cases, it is unlikely that they or any investigators would learn of the presence of the disease.

From the hiker survey, we were unable to determine that any of the raw water drinkers actually contracted giardiasis. Though in the follow-up interviews four of the 96 raw water drinkers reported signs of gastrointestinal distress, no medical diagnoses were available to us. Because our water data indicated a 2 percent chance of cyst ingestion, theoretically giardiasis could have accounted for some or all of the illness. However, we could not confirm this clinically, and the illness could have been due to bacteria, viruses, or other sources.

Bacteria were found in water at all study sites. Though they exist in very small concentrations, they pose a risk of bacterial infection to persons drinking untreated surface water. Boiling water for one minute or filtering water will remove Giardia but not all bacteria and viruses, the latter requiring longer boiling (10-15 minutes) or chemical disinfection.

Human Impacts on Water Quality

Most of the Giardia found were in samples taken near campgrounds below timberline, where both humans and wildlife are abundant. By the same token, we found little significant evidence that present patterns of bivouac use at the higher elevation tundra sites (Green Lake and Sky Pond) are contaminating nearby waters. This may be explained by the self-purifying or disinfecting effects of the following factors:

- high radiation (kills bacteria) (Kunkle and Meiman 1968);
- high winds (desiccate wastes, killing cysts) (Jarroll, Hoff, and Meyer 1984);
- freezing and thawing (kills cysts) (Meyer and Jarroll 1980);
- dispersed, relatively small volumes of wastes.

Wildlife may also be responsible for the increased total coliform concentrations, but numbers for Giardia cysts and all three bacterial groups were so low that sources of contamination cannot be specified.

Effects of Wildlife

The limited number of scat samples (36) cannot be considered adequate for making supportable generalizations; however, a few implications can be drawn. Previous research (Johnston 1978; Suk 1983) suggests that marmots can carry Giardia. In view of this, our negative scat samples would imply that these animals are not Giardia carriers at present (at least not to the degree of easy detection), nor does Giardia appear among the other wildlife sampled in the upper reaches of the study basins. By contrast, Monzingo (1985) found Giardia to be endemic in beaver populations in the Hidden Valley and Fall River areas of Rocky Mountain National Park. The water tested in these lower elevation areas (2900 m or 9500 ft) contained up to ten times the concentrations of cysts (611 cysts/1000 ℓ) found in higher elevation streams.

Relationships to Elevation

A slight (but not significant) tendency for bacterial counts as well as Giardia levels to be greater at lower elevations appears in our data, with five of the seven sites positive for Giardia located in the lower forested zone of the study area and only two in the higher tundra zone. Several explanations are possible:

- lower elevations receive heavier human use;
- lower elevation areas are less exposed to wind and radiation, which are detrimental to the survival of bacteria and cysts;
- wildlife is more prevalent in the forested zones and also may be attracted to campground areas;
- though not generally found where aspen and willows are sparse or nonexistent, beaver can occur at these levels; however, we saw none in the study area.

Giardia-Bacterial Relationships

An examination of data for both Giardia and bacteria did not reveal any correlation in numbers or occurrence between the two. Many complicating factors may explain this lack of relationship. First, not all animals carry Giardia, but all excrete coliform bacteria and fecal streptococci (thus, the ubiquitous nature of these groups). Second, it has been shown that sunlight will kill bacteria in just a few hours (Kunkle and Meiman 1968), whereas Giardia cysts can survive in cold water for two months or longer (Meyer and Jarroll 1980; Hibler 1982). Therefore, one could find high numbers of coliforms, for instance, in a stream but no Giardia, and Giardia could be present in the general absence of bacteria.

Lightweight Water Sampling Devices

Remote areas in the park are accessible only by hiking, so we needed to modify existing sampler components to build the backpack-model *Giardia* sampler and a portable storm-water sampler to meet our field sampling needs.

A number of *Giardia* sampling mechanisms have been developed, though all must be considered experimental at this time. An original EPA-developed sampler (Jakubowski and Ericksen 1979; Williams 1981), more suited for water treatment facilities than streams, was modified by Rosgen (Williams 1981) in 1978 for use by the U.S. Forest Service. His model employs a small flume set in a stream which by gravity flow alone can sample several thousand liters. However, the sampling rate is slow and can take an entire day. In their 1983 Lolo National Forest work, Rosquist (1983) and Metzmaker (1983) used this gravity-fed flume for sampling *Giardia* in streams. Its advantages lie in its capability to sample large volumes of water, produce a somewhat time-integrated sample, and operate without a power source.

Monzingo (1985) and others at Colorado State University have used a small bilge pump, filter holder, and water meter driven by an automobile battery. However, a smaller, lighter battery was needed for backpacking. Sorenson, Suk, and others from the U.S. Geological Survey working in Yosemite National Park had successfully used a hand pump as well as a gel-cell battery in their field work (Shulters and Sorenson 1984; Suk 1984). The sampler we constructed was essentially the Monzingo model of pump, filter, and water meter powered by a gel-cell battery similar to that used by Sorenson et al. For the low turbidity waters of our work it was satisfactory and dependable. It consistently pumped about 760 ℓ (200 gal) per hour for five-hour periods of use and sometimes at temperatures under 4.4°C (40°F). The battery could be recharged overnight.

The storm water sampler with its "macaroni clock" worked satisfactorily. The "macaroni clock" provided a good indication of the relative age of the caught water. Basically, its level of sophistication allows one to distinguish only same-day, day-old, and two-day-old water; but for our purposes, this level of distinction sufficed.

Certain modifications might further enhance the effectiveness of the storm-water sampler. For example, in streams where it is possible to drive a pipe into the stream bed, one could simply use the pipe for the sampler frame. (In our case this was not possible.) For extra insurance against contamination by birds, buoyant covers that would float as the water rose could be added to the sampling bottles. We also found bottle height adjustment to be slow in cold waters; a quick-release clamp might be an improvement under such conditions. One improvement on the "macaroni clock" might be a better cover arrangement, such as a flat disc on the bottle cap, to protect the noodle from stray water droplets from stream activity or rain.

RESOURCE MANAGEMENT CONSIDERATIONS AND CONCLUSIONS

The present park management of the two basins appears satisfactory from a water quality viewpoint, since our 1984 bacterial data showed no significant pollution or degradation of streams passing through the two campgrounds or the two bivouac areas. Some *Giardia* contamination is present at low levels in the two study basins, but the source, whether wildlife, humans, or mixed, cannot reliably be determined from our data. The park therefore will need to continue its visitor information and education program on *Giardia* and its effects.

In contrast to beaver and muskrats, in which *Giardia* infections are prevalent (Monzingo 1985; Frost et al. 1980), the marmots, pikas, and other wildlife common at elevations over 2987 m (9800 ft) in our study were not shown to be *Giardia* carriers. From our limited scat sample data, we were unable to establish that wildlife in the basins were carrying *Giardia* at the time of the study.

From a public information consideration, one might conclude that the present park program of brochures, signs (Fig. 18), and newsletter

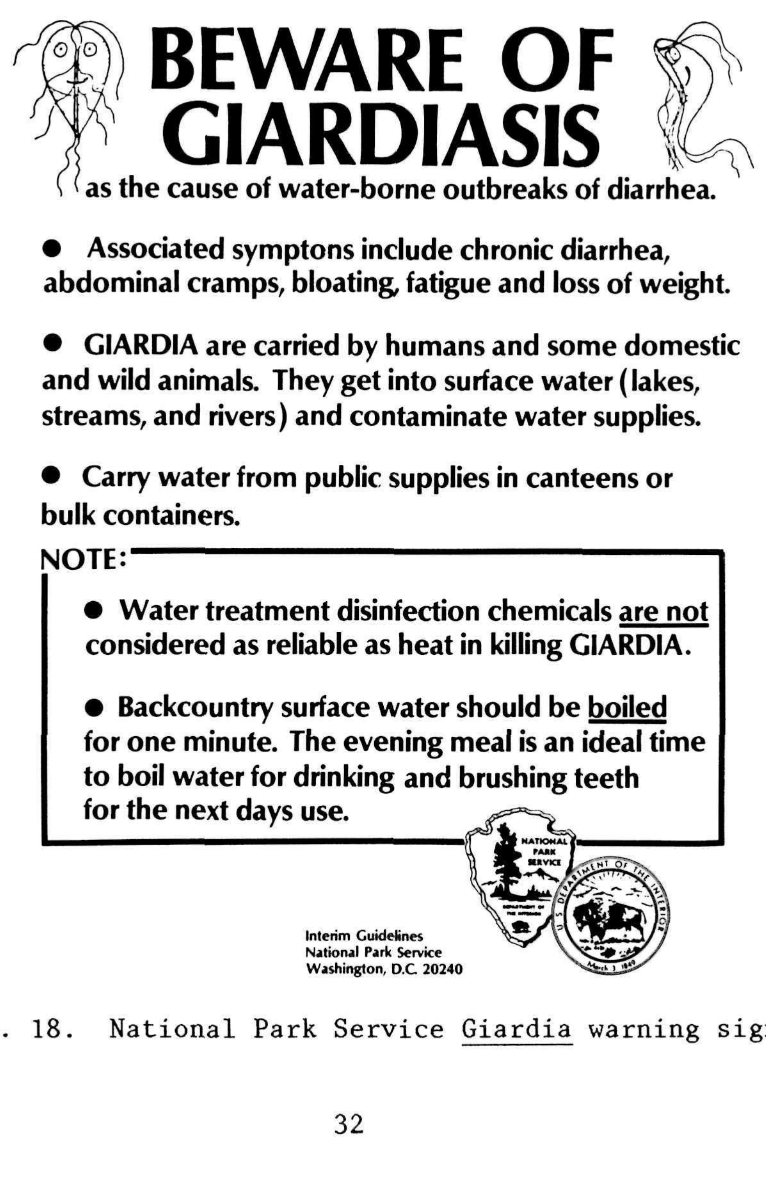


Fig. 18. National Park Service *Giardia* warning sign.

notices is reasonably effective, given that an estimated 86 percent of the visitors to the study area do not drink raw stream water, according to our data. Another interpretation might be that the great majority of hikers are simply well-informed. In view of people's "right" to drink raw water and an inevitable segment of inexperienced hikers who fail to carry adequate water supplies for the day, it should be expected that some recreationists will drink untreated water. However, our interviews revealed high interest by hikers in the specific details of Giardia and giardiasis, e.g., treatment of the illness, whether immunity is possible, and ways of disinfecting water if boiling is not possible. The Park staff may want to distribute additional information on the topic to visitors, possibly using information available from the Water Resources Division in Fort Collins and CSU.

In 1984 we investigated only two basins, albeit popular and fairly representative ones. In 1985, three additional basins experiencing lower recreational impact were examined as a comparison to the present study and Monzingo's 1983-1984 work (Monzingo 1985), which examined high human-use areas and wildlife-impacted areas, respectively. A preliminary look at the findings indicates that little or no Giardia is present in these lesser-used high-elevation watersheds. In other words, watersheds unaffected by beaver or large numbers of recreationists may not naturally be contaminated by Giardia.[1] These findings corroborate results from the present study that indicate inverse relationships between high elevation and low human-impact areas and Giardia. In the future, park personnel may want to continue to monitor selected areas throughout Rocky Mountain National Park to determine if the contamination levels of Giardia follow patterns seen in the Giardia studies completed to date. For example, is the Giardia problem spreading to higher elevations, or is it limited mostly to lower elevation zones inhabited by beaver? Are other animals in other areas infected? Is there a distinct relationship between the abundance of Giardia and elevation? Does this relationship, if it exists, correlate with the degree of recreational use? Are water-use patterns or treatment methods of hikers interviewed in the study area similar to those of hikers using other areas of the park?

It would seem from our findings that continued education of the public is most important. Other possible management actions might include installing additional safe drinking-water supplies at trailheads and parking lots or developing sanitation guidelines for hikers and campers in remote areas that are easy to apply and acceptable to the public. But many questions not addressed by this study remain unanswered. For example, some National Forest managers have had to review the role of dogs and stock animals such as horses as possible Giardia carriers (Metzmaker 1983; Rosquist 1984; Hibler, personal communication, 1984). In the Lolo National Forest in Montana, dogs have been restricted in certain watershed areas above municipal water supplies (Hibler, personal communication, 1985). Although national parks typically have greater restrictions regarding domestic animals, it is

[1]Findings for the 1985 study are being summarized in a follow-up report by Monzingo and Kunkle (in preparation).

possible that many areas near waterways where these animals are allowed are already being affected. (However, once humans or dogs have introduced Giardia into a watershed and its wildlife, the watershed may continue to harbor Giardia, and restricting dogs in an already infected watershed may therefore serve no function.) The Rocky Mountain National Park staff might wish to consider whether such a problem is occurring in areas of the park where dogs or stock animals are allowed. From a more long-term point of view, the following questions might also be relevant:

1. What recreational activities can we allow on watersheds serving as water supplies without risking giardiasis outbreaks?

2. As our knowledge of Giardia transmission expands, how can we modify our wildlife management programs, especially for beaver and muskrats, to help control Giardia and still conserve wildlife?

3. In terms of the legal implications, do land management agencies have any special responsibilities for informing people of Giardia hazards in order to help protect them? Several lawsuits involving Giardia at different mountain resorts are now underway and may yield outcomes of interest to park management.

Watershed managers and rangers need familiarity with Giardia monitoring procedures, which are not well known, especially since data on Giardia is commonly lacking for remote watersheds. Recreationists need balanced, factual information on giardiasis. Various agencies need to share their brochures, pamphlets, and other materials on Giardia. Research also is needed on a number of these questions so that we can learn to recognize and manage Giardia as part and parcel of our management of the water resources of parks, forests, and remote watersheds.

APPENDIX A

PORTABLE *GIARDIA* SAMPLER

APPENDIX A: PORTABLE GIARDIA SAMPLER

The following is a description of the equipment needed to sample water for *Giardia*. The equipment list includes a battery, bilge pump, clear plastic tubing, filter housing, filters, water meter, and a battery charger (Table A-1). A major point to remember in purchasing equipment is that it should be light-weight if intended for backpacking. A total of $350 bought all of our equipment, including a case of 30 polypropylene filters, adequate for 30 samples (filters cost about $8 apiece). The entire system fits into a standard-size frame backpack and weighs approximately 7 kg (16 lbs), excluding the weight of the pack.

Table A-1. Purchase information for *Giardia* sampling equipment.[1]

Item	Obtained from:
gel-filled battery (Gelyte PB6100)	battery specialty shop
bilge pump (360 gallon-per-hour outlet for 0.75 in I.D. hose, 0.75 amp draw @ 12 VDC)	marine supply store
tubing and accessories (clear tubing 3-4 m long x 0.75" I.D., wire connectors, hose couplers)	hardware store
filter housing (Type 1M1, clear plastic)	Eggelhof, Inc. 4050 Globeview Denver, CO 80216
filters (1.0 micron polypropylene, AMF Cuno Microwynd II)	Eggelhof, Inc. 4050 Globeview Denver, CO 80216
water meter (Badger, all-plastic model)	city water and sewer department
battery charger (0.5 amp)	motorcycle shop

[1]This information is provided only as a suggestion and is not an endorsement by NPS or CSU of any particular brand or company.

Battery

The battery is the heaviest part of the sampler. We used two 6-volt gel-filled batteries attached in series. The pair of batteries weighs approximately 4.3 kg (9.5 lbs) and has a charge capacity of 13 hours when used with the 0.75 amp motor of the bilge pump. The

battery cost approximately $40 and was available from a battery specialty company.

Bilge Pump

The plastic, 0.75 amp bilge pump draws water from the stream and pumps it through the plastic tubing and filter. There are many models of pumps available; our pump, rated at 300-360 gal (1135-1360 ℓ) per hour (in still water), was well-suited for the job (ours actually pumped 200 gal [760 ℓ] per hour due to the fast-moving, air-laden water and the resistance produced by pumping through a filter). The pump cost about $20 and was available from a marine supply shop. (Caution: Do not get a pump with a motor too large for the battery to drive!)

Clear Plastic Tubing and Accessories

The polyethylene or plastic tubing should be garden-hose sized and smooth inside to reduce friction during pumping and to allow easy flushing of the system. Clear tubing also enables the user to check the tube visually for blockage. The tubing should be about 3-4 m (10-15 ft) long with an inner diameter that will fit the pump's outlet (in our case, the inner diameter of the tubing was 0.75 inch). The extra length is helpful in developing a head, which in turn increases the flow rate through the tubing.

Some important accessories include wire for the battery, waterproof electrical tape, hose couplers (preferably plastic), and male and female plugs, which altogether can be purchased for about $20.

Filters

The type of filter used was a 1.0 micron, wound polypropylene filter that can be used only once. (It is important that the filter have a porosity rating of 1.0 micron, so that *Giardia* cysts are captured and do not slip through.) Filters were purchased from Eggelhof, Inc., where a case quantity of 30 cost us about $175.

Filter Housing

The plastic filter housing is used to hold the AMF-Cuno filter, which traps the *Giardia* cysts. We used a filter housing (type 1M1) purchased through Eggelhof, Inc., in Denver, Colorado, at a cost of approximately $50.

Water Meter

The all-plastic water meter attached to the end of the filter housing measures the water flow rate and total number of gallons pumped. The water meter can be obtained from a city water department for about $35.

Battery Charger

We typically used our pump about five hours during a day in the field, including four sample pumpings of an hour each plus rinses between each sample. The motor never slowed its rate for the five hours. Fully charged the motor should run for 13 hours, according to battery specifications. A 0.5 amp trickle charger, costing $18, was used to recharge the battery overnight.

APPENDIX B

AUTOMATIC STORM-WATER SAMPLING DEVICE

APPENDIX B: AUTOMATIC STORM-WATER SAMPLING DEVICE

The automatic storm-water sampling device, or "storm sampler," was developed by the staff of the NPS Water Resources Division for use in remote areas. This inexpensive, simple-to-construct device proved effective in collecting storm runoff samples during the water quality investigations conducted in Rocky Mountain National Park.

The storm sampler operates in the same way as existing suspended sediment samplers, whereby rising stream water resulting from storm runoff causes the sample bottles to fill. Once the bottle is filled, a ping-pong ball inside the bottle floats to the top and seals the opening, which prevents further exchange of water. Tests conducted under laboratory conditions, in which a dye-filled sampler was submerged in water for a 24-hour period, showed that only 1 ml of water from the sample bottle was lost to the outside in that time.

The storm sampler is constructed from steel angle iron, aluminum strips, plastic tubing, hose clamps, polyethylene bottles, rubber stoppers, screen, funnels, bicycle water bottle holders, and ping-pong balls (Fig. B-1). Assembled, the sampler weighs approximately 2.5 kg (5.5 lbs) and is about 1 m (3 ft) in height, but the height can be varied to suit individual needs. Materials cost about $25, and construction requires three to four hours.

The sample bottles are fitted with a rubber stopper, into which a small funnel has been inserted upside down (Fig. B-2). The wide end of the funnel provides a sealing seat for the ping-pong ball in the bottle to press against when water entering the bottle floats the ball to the top. The bottle, thus sealed, allows no more water in or out of the sample bottle. The narrow end of the funnel, through which the water enters, is covered with 1 mm-size screen to keep particulate matter from entering the bottle or clogging the water intake. The screen is cone-shaped to insure against air lock and to allow the bottle to fill freely. Sample bottles were also covered with aluminum foil to protect the contents from direct sunlight, since ultraviolet radiation is bactericidal. By this means the water samples were also kept cool until collected for analysis.

The sample bottles are set above normal stream level but at a height where they would be inundated in the event of storm runoff. More than one bottle may be used, and two or more may be set at different levels on the stand. We used two bottles and set them approximately 10 to 15 cm (4½-6 in) apart in order to accommodate both lower and higher runoff flows. The minimum stream depth needed for the sampler to operate is about 30 cm (1 ft).

Attached along the axis of the sampler stand is a length of hollow plastic tubing which is covered at the base with screen. Inside the tube is some ground cork, which rises with an influx of water and sticks to the side of the tube at the height the water reached during the storm runoff. Thus, it can be estimated how high the stream rose when the storm water sample was collected.

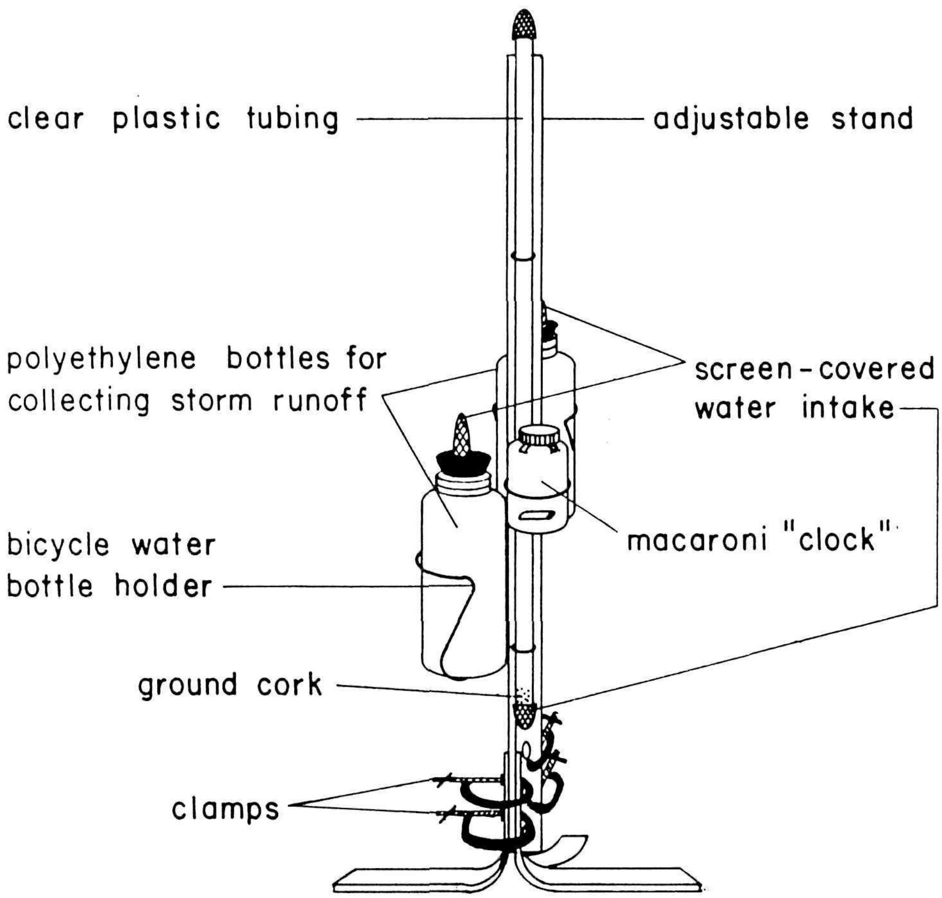


Fig. B-1. Schematic of automatic storm-water sampler.

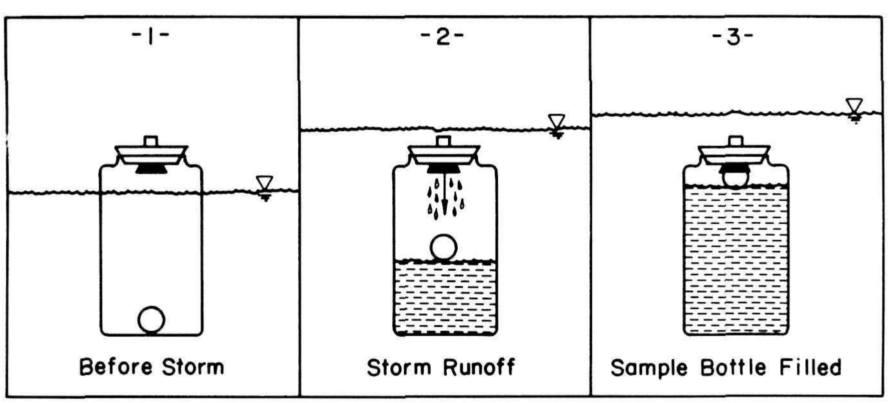


Fig. B-2. Operation schematic.

In order to determine the approximate age of the storm sample, we developed what came to be known as the "macaroni clock," so called because it incorporates a piece of macaroni in a small (250 ml), separate polyethylene bottle also attached to the sampler unit. A piece of mostaccioli about 4 cm in length and 0.7 cm in diameter works well. The bottle that contains the single mostaccioli piece contains small holes in the neck of the jar to take in water during storm runoff at the same time one or more sample bottles are filling. Once wet, the noodle will gradually absorb water and indicate the age of the water sample. In cold (5°C) water, the noodle behaves as follows: after 12 hours, the noodle is swollen and soft. After 18-24 hours, it swells 1½-2X its dry diameter. In 36 hours the noodle appears even more distended, and disintegration is visible at both ends. After 48 hours, disintegration is advanced. In this way, the "clock" enabled field personnel to distinguish day-old storm samples from two-day or older samples. (The timing is important so that bacterial analysis is valid, since old samples are subject to bacteria die-off.) Thus, we could be fairly sure that the samples automatically collected by the storm sampler and retrieved for analysis were from storms that occurred during the previous afternoon and not from old events.

APPENDIX C

WATER PURIFICATION PRINCIPLES AND METHODS

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Boiling

Boiling is a frequently used, generally effective form of water disinfection. Most waterborne pathogens are readily harmed by heat, and a period of boiling will kill them. Since some pathogens require a longer heat exposure to be destroyed, recommendations for boiling time vary. In addition, boiling times must be increased at higher elevations where water boils at a lower temperature (Table C-1). *Giardia* cysts, for example, are destroyed after one minute of boiling at sea level; at 3050 m (10,000 ft) or higher, it may take 5-10 minutes of boiling to destroy the cysts as well as bacteria and viruses. Some specialists recommend boiling for as long as 15 minutes (Alsaker 1982).

Table C-1. Boiling points of water at various elevations.

Elevation (m)	Elevation (feet)	Boiling Point (°C)	Boiling Point (°F)
Sea level		100	212
500	1641	98.9	210
1000	3281	97.9	208
1500	4922	96.8	206
2000	6562	95.7	204
2500	8203	94.7	202
3000	9843	93.6	200
3500	11,484	92.5	199
4000	13,124	91.4	197

While the often-recommended boiling offers the backcountry user a relatively effective and inexpensive method of water purification, in many cases it is not practical or convenient. Boiling takes time; and in areas where wood fires are not allowed (which is often the case in national forest, park, and wilderness areas), boiling alone uses a significant amount of fuel.

Chemical Treatment

Chemical means of water purification generally involve disinfection with various chlorine or iodine preparations. These chemicals are available in pure form or under such brand names as Halazone (chlorine) and Globaline, Coughlan's, and Potable-Aqua (tetraglycine hydroperiodide). Even household chlorine bleach can be used. But in treating water this way, several factors must be considered. First, both chlorine and iodine are more effective in clear water, at warmer temperatures, and with increased contact times. Therefore, the number of required drops or tablets of disinfectant per liter varies with the temperature and clarity of the water. While chemical treatments are usually adequate for the elimination of most bacteria and viruses, chemicals have a less dependable effect on *Giardia*; therefore, extra

contact time is essential. A minimum of 30 minutes of purification time is recommended; however, in order to improve the effectiveness of the treatment as well as the taste of the water, some suggest allowing the chemical to work for an hour or more (State of New Mexico 1983; Centers for Disease Control n.d.) or even overnight (Knotts 1983). It is important that turbid water be allowed to settle prior to treatment, as suspended matter in water will hinder purification effects of the disinfectant. Some specialists have found that the use of a coagulant will expedite the settling process (Tunnicliff and Brickler 1984).

Iodine is more effective in killing *Giardia* than chlorine over wider temperature and pH ranges. One writer (Manley 1983) recommends keeping a saturated solution of iodine on hand by pouring more than the required amount of iodine crystals (0.29 g per 100 cc of water) into a bottle and filling it with 100 cc of water. Once the solution is saturated, the excess crystals will remain on the bottom, and the mixture can be spooned a tablespoonful at a time into containers of water to be purified. If that water is warmed to 20°C, a tablespoonful of the iodine solution per liter will kill *Giardia* cysts (Manley 1983). However, the use of pure iodine crystals presents some risk of poisoning, and care should be taken *not* to ingest any of the crystals, which are toxic, or to ingest highly concentrated iodine solutions. Normally, this is not a practical concern since high concentrations of iodine make the water extremely unpalatable.

For safety and convenience, the commercial preparations may be a better choice. Commercially distributed tablets of the compound tetraglycine hydroperiodide (TGHP) contain a premeasured dose of iodine (8 ppm) and are generally stable. Chlorine preparations in tablet form are less stable and become less effective upon exposure to heat and air, so that old Halazone tablets, for example, should not be used (Knotts 1983).

Mechanical Filters

Commercially available mechanical filters exhibit varying degrees of effectiveness in the removal of *Giardia*. In a study by Hibler (1984), seven filters for tap water purification were tested in the laboratory. Four of these were found to be 100 percent effective, but the other three ranged from as low as 66.4 percent to 97.6 percent effective. Backpacking filters may vary similarly in their effectiveness. Therefore, in choosing a filter, several important factors should be considered. To effectively filter out *Giardia* and other microorganisms, the filter should have a pore size of 2.0 microns or less. Such a size counters the pliability of *Giardia* cysts, a characteristic that allows them to squeeze through apertures somewhat smaller than their actual size. To also remove bacteria and smaller pathogens, one filter system that uses a 0.4 micron filter induces electrical charges in the filter that attract and hold particles smaller than 0.4 microns (Knotts 1983). When the turbidity is high, filters can become clogged and rendered ineffective. Turbid water should be allowed to "settle" or be treated with a coagulant before filtering.

Filtering units are relatively expensive, ranging from about $40.00 to over $170. Even so, frequent users of the backcountry might find that a well-designed, effective filter is worth its price. Better quality filters have a provision for backwashing the filter; or, if needed, replacement filters are usually available.

Alternatives

A combination of water treatment methods might provide a viable alternative for many backcountry users. It has been shown, for example, that at a temperature of 20°C (68°F), iodine successfully destroys *Giardia* cysts (Manley 1983). This means that by boiling only one-fifth of the desired volume of water (one-fourth the volume at high altitudes) and then mixing it with the remaining cold water, the temperature of the cold water would be raised to 20°C (Manley 1983). This would significantly reduce the amount of fuel needed for boiling. The amount of saturated iodine solution (prepared by putting crystals in water) needed per liter of 20°C water is about one tablespoon (15 cc). Or, commercial preparations of iodine or chlorine can be used according to directions. In the warmer water, these disinfectants will act with increased effectiveness and eliminate the need for extended boiling.

There are other options to boiling which can elevate the water temperature to an appropriate level. A canteen or plastic water container placed in the sunlight for a length of time would raise the temperature significantly; or, chemically treated water can be placed in a sleeping bag overnight (Knotts 1983). This would warm the water as well as provide for a longer contact time with the chemical. In short, any technique that raises the water temperature and increases chemical contact time is likely also to increase the purifying effectiveness of disinfectant chemicals.

Conclusions

Much has been said about water purification in the backcountry, but documentation on the effectiveness of the various treatment methods is limited. There appears to be a need for comprehensive information which is research-based, and claims made by manufacturers of water purification products should be supported by independent research. In the meantime, we suggest the following reading material for those wishing to know more about *Giardia* and water purification in the backcountry:

1. Centers for Disease Control. n.d. *Giardia lamblia* information paper. Available from Department of Health and Human Services, CDC, Atlanta, GA 30333.

2. Erlandsen, S., and E. Meyer. 1984. *Giardia* and giardiasis. New York: Plenum Press. 407 p.

3. Knotts, D. M. 1983. Purifying water in the wild. Sierra 68(4):57-59.

4. Manley, H. An easy preventative for "backpacker's disease." Backpacker 11(2):95.

5. State of New Mexico Health and Environment Department. 1981. Water disinfection for campers and backpackers. Brochure issued by Health Services and Environmental Improvement Divisions, P.O. Box 968, Santa Fe, NM 87504-0968.

APPENDIX D

DEPARTMENT OF RECREATION RESOURCES HIKER SURVEY QUESTIONNAIRES

ON SITE INTERVIEW ____________

Date________________

Interviewer__________

Hello. As a part of a research project being conducted by Colorado State University examining water quality and the recreationist we are asking for assistance from backcountry users such as yourself. The target area of the study is the Glacier Gorge and Loch Vale areas in Rocky Mountain National Park. Would you be willing to take just a few minutes to answer a few brief questions?

1. Did you camp, bivouac, or day hike in this area?

   a. camp   b. bivouac   c. dayhike (if c., go to number 3)

2. Where did you camp or bivouac?

   a. Glacier Gorge campsite
   b. Andrews Creek campsite
   c. Sky Pond
   d. Green Lake area
   e. Blue Lake area
   f. Frozen Lake area
   g. other______________________________

3. Did you drink water from a natural source anywhere in this area on this trip?

   a. yes   b. no (if no, go to number 10)

4. Using this map, could you show as specifically as possible the area(s) from which you took water for drinking? (Have him/her mark the location on the map. Then use the transparency to determine the zone for each mark.)

5. Did you purify the water taken from any of the locations mentioned above?

   a. yes   b. no (if no, go to number 7)

6. What method of purification did you use? (For each site named in #4, indicate the zone and the method used.)

	Site Identification by Zone #			
	#	#	#	#
Method				
chlorine				
Halazone				
iodine				
boiling				
filtration				
(type of filter_______________)				
other				
(describe "other" ____________)				

7. Referring again to the area(s) where you drank water, what animals were seen and how many were seen at each site. (List the zone identification and numbers for each.)

	Site Identification by Zone #						
	#	#	#	#	#	#	#
Animals							
a. squirrels							
b. pica							
c. chipmunk							
d. deer							
e. elk							
f. marmot							
g. beaver							
h. other							

(describe "other"____)

8. Would you be willing to give us your name, address and phone number so that I could contact you in a few weeks with some brief follow-up questions?

   a. yes b. no (if no, go to number 11)

9. Name____

   Address____

   Zip Code__________Area Code________Phone Number______________

   (go to number 11)

10. Why didn't you drink the water? (Indicate all that apply.)

   a. "I packed in all of my own water." (Ask "why?"______________)
   b. "I heard that you could get sick from the water."
   c. "I have heard about *Giardia*."
   d. "I know someone who has had *Giardia*."
   e. "I have had *Giardia*."
   f. "A Park Ranger warned me against drinking the water."
   g. "____
   ____(list other)

11. There is no proven right or wrong way to dispose of human fecal material. Although I realize that this is a delicate subject, we need to examine relationships between human waste disposal and water quality. In order to help to determine the best ways it is necessary to ask you a few personal questions. Would you please show me on the map where you deposited fecal waste? (List zone number)

   a.__________ c.__________

   b.__________ d.__________

12. In which way did you dispose of the waste?

   a. buried in soil
   b. buried under rocks
   c. left exposed to air and sunlight
   d. other ______________________________

13. What age range are you in?

   a. 10-17
   b. 18-24
   c. 25-34
   d. 35-44
   e. 45-54
   f. 55-64
   g. over 65

14. What city and state (or country) are you from?

   City________________State________________Country____________

15. What is the highest level of education you have reached?
   a. grade school
   b. junior high
   c. high school
   d. college
   e. graduate school
   f. PhD or professional school (M.D., Law School, etc.)

16. What is your occupation?

   ____

17. You will be contacted in a few weeks either by phone or by mail. Your input will provide valuable information which will enable backcountry users to have a safer and a more enjoyable experience. Thank you very much for your cooporation. (END)

FOLLOW-UP INTERVIEW

____

Date________________

Interviewer__________

Hello. My name is __________ and I am an official interviewer for Colorado State University. A few weeks ago you were asked some questions while on the Glacier Gorge trail in Rocky Mountain National Park. You mentioned that you would be willing to answer some follow-up questions. The questions should take only a few minutes. This survey is strictly confidential. Do you have time now?

You described an area/some areas from which you drank water from a natural source in the Mills & Black Lakes or Loch Vale areas in the Park.

1. Did you experience any of the following symptoms upon returning from your stay in this area of the Park?

   a. nausea
   b. headache
   c. diarrhea (mild)
   d. diarrhea (severe)
   e. cramps
   f. visible bloating
   g. vomiting
   h. significant weight loss______(pounds)
   i. other______________________________
   j. did not experience any symptoms (if j., go to number 3)

2. How long after your trip did these appear?

   a. within the first week
   b. within the second week
   c. within the third week
   d. other than above________________________(explain)

3. Were other members of your party interviewed?

   a. yes (if yes, go to number 6) b. no

4. To your knowledge, did anyone else in your party drink water from a natural source and then experience any of these symptoms?

   a. yes b. no (if no, go to number 6)

5. Which symptoms were experienced and by how many members other than yourself?

   a. nausea ______
   b. headache______
   c. diarrhea (mild)______
   d. diarrhea (severe)______
   e. cramps______
   f. visible bloating______
   g. vomiting______
   h. significant weight loss______
   i. other____________________
   ____

6. In the past five weeks, did you drink water in its natural state in any area around the country other than mentioned?

   a. yes b. no (if no, go to number 9)

7. Did you purify the water in any way?

   a. yes b. no (if no, go to number 9)

8. What method of purification was used?

a. chlorine
b. halzone
c. iodine
d. boiling_____minutes
e. filtration____(type)
f. other____
____

9. Did you stay in any mountain town during this five week period?

a. yes b. no (if no, go to number 11)

10. Where did you stay?

____

11. Did you drink water (unbottled) outside of the U.S. during this period?

a. yes b. no (if no, go to number 13)

12. Where did you drink water outside the U.S.?

____

13. If you experienced any symptoms upon return from your trip, did you seek medical treatment for these symptoms? (if no symptoms, go to number 16)

a. yes b. no (if no, go to number 15)

14. What was the diagnosis?

a. intestinal virus
b. dysentary
c. giardiasis
d. influenza
e. other____
(go to number 16)

15. Why have you not sought medical treatment?

____

16. Do you always purify water taken from a natural source?

a. yes b. no

17. When you do purify why do you do it?

a. afraid of getting sick
b. water does not look clean
c. have materials needed for purification handy
d. check with ranger to see if purification is necessary
e. have become ill from drinking untreated water
f. know someone who has become ill
g. other____

18. Where did you learn about water purification?

a. club or organization____(name)
b. literature____(name)
c. friend or relative
d. other____

19. When do you not purify the water?

a. when inconvenient
b. when it flows from a glacier
c. when it is above timberline
d. when it comes from a spring
e. when it is flowing very fast
f. when no purification materials
g. I always purify
h. I never purify
i. other ____________________

20. If you were to drink water from a natural source and were unable to purify it, where would you choose?

a. alpine
b. glacial
c. running shallow and exposed to sunlight
d. running very fast and over rocks
e. inlet to lake
f. outlet from lake
g. spring
h. other ____________________

21. What are some reasons why you would avoid drinking water from a natural source in the mountains?

a. wildlife
b. other people (human fecal waste)
c. garbage &/or detergent introduced by others
d. stagnant water
e. water running too slowly
f. bacteria and microorganisms
g. other ____________________

22. Have you ever heard of Giardia?

a. yes b. no (if no, go to number 28)

23. From what source did you hear of Giardia?

a. friend or relative
b. news source (T.V., radio, etc.)
c. literature ____________________ (name)
d. National Park personnel
e. organization ____________________ (name)
f. other ____________________

24. What do you know about Giardia?
a. protozoan
b. microscopic
c. can survive freezing temperatures
d. symptoms can recur
e. multiplies in the intestinal tract
f. "Elk's disease"
g. other ____________________

25. Have you ever been diagnosed as having Giardia?
a. yes __________ (when) b. no (if no, go to number 28)

26. Have you ever been treated for Giardia?
a. yes b. no (if no, go to number 28)

27. What was the treatment?

____

28. Do you ever experience recurring diarrhea?

    a. yes b. no

29. Do you ever experience diarrhea under times of stress?

    a. yes b. no

30. Do you have any questions or comments?

____

____

REFERENCES

Alsaker, D. 1982. Untitled. Opflow (a monthly publication for members of the American Water Works Association) 8(3):1-2.

American Public Health Association. 1980. Standard methods for the examination of water and wastewater. Washington, D.C. 1134 p.

Barbour, A. G., C. R. Nichols, and T. Fukushima. 1976. An outbreak of giardiasis in a group of campers. The Am. J. Trop. Med. Hygiene 25:384-389.

Centers for Disease Control. n.d. _Giardia lamblia_ information paper. (Available from Department of Health and Human Services, CDC, Atlanta, GA 30333.)

Centers for Disease Control. 1984. Water-related disease outbreaks: Annual summary 1983.

Craun, G. F. 1979. Waterborn giardiasis in the United States: A review. Am. J. Public Health 69(8):817-819.

Craun, G. F. 1984. Waterborne outbreaks of giardiasis: Current status, pp. 243-261. _In_ S. L. Erlandsen and E. A. Meyer (eds.), _Giardia and giardiasis: Biology, pathogenesis, and epidemiology. New York: Plenum Press._

Davies, R. B., K. Fukutaki, and C. P. Hibler. 1981. Cross transmission of _Giardia_. Final report to EPA. Health Effects Research Laboratory, Environmental Protection Agency, Research Triangle Park, NC. 23 p.

Davies, R. B., and C. P. Hibler. 1979. Animal reservoirs and cross-transmission of _Giardia_, pp. 104-126. _In_ W. Jakubowski and J. C. Hoff (eds.), _Waterborne transmission of giardiasis_. EPA 600/9-79-001. Environmental Protection Agency, Cincinnati, OH.

Dykes, A. C., D. D. Juranek, R. A. Lorenz, S. Sinclair, W. Jakubowski, and R. Davies. 1980. Municipal waterborne giardiasis: An epidemiologic investigation. Ann. Intern. Med. 92(2):165-170.

Frost, D., B. Plan, and B. Liechty. 1980. _Giardia_ prevalence in commercially trapped mammals. J. Environ. Health 42:245-248.

Hibler, C. 1982. Epizootiology of waterborne giardiasis in Colorado. Project proposal. Dept. of Pathology, Colorado State University, Fort Collins, CO. 18 p.

Hibler, C. 1984. Inactivation and/or destruction of the cysts of _Giardia_ with photozone. Unpublished paper. Dept. of Pathology, Colorado State University, Fort Collins, CO. 12 p.

Hibler, C. P., and C. M. Helmick. n.d. Diagnosis of waterborne giardiasis: State-of-the-art. Unpublished paper. Dept. of Pathology, Colorado State University, Fort Collins, CO.

Istre, G. R., T. S. Dunlop, G. B. Gaspard, and R. S. Hopkins. 1982. Waterborne giardiasis at a mountain resort: Evidence for possible acquired immunity. Unpublished paper. 1 pp. (Available from G. R. Istre, Field Services Division, EPO, Centers for Disease Control, Atlanta, GA 30333.)

Jakubowski, W. 1984. Detection of Giardia cysts in drinking water: State-of-the-art, pp. 263-285. In S. L. Erlandsen and E. A. Meyer (eds.), Giardia and giardiasis: Biology, pathogenesis, and epidemiology. New York: Plenum Press.

Jakubowski, W., and T. H. Ericksen. 1979. Methods for detection of Giardia cysts in water supplies, pp. 193-210. In W. Jakubowski and J. C. Hoff (eds.), Waterborne transmission of giardiasis. EPA 600/9-79-001. Environmental Protection Agency, Cincinnati, OH.

Jarroll, E. L., J. C. Hoff, and E. M. Meyer. 1984. Resistance of cysts to disinfection agents, pp. 311-328. In S. L. Erlandsen and E. A. Meyer (eds.), Giardia and giardiasis: Biology, pathogenesis, and epidemiology. New York: Plenum Press.

Johnston, L. 1978. An investigation of animal hosts for Giardia lamblia in the Bridger Wilderness Area. Unpublished paper. Bridger-Teton National Forest, Moose Head, WY. 18 p.

Knotts, D. M. 1983. Purifying water in the wild. Sierra 68(4):57-59.

Kunkle, S. H., and J. R. Meiman. 1968. Sampling bacteria in a mountain stream. Colorado State University, Hydrology Paper Series No. 28. March 1968. 28 p.

Levine, N. D. 1961. Protozoan parasites of domestic animals and of man. Minneapolis: Burgess Publishing Co. 411 p.

Manley, H. 1983. An easy preventative for "backpacker's disease." Backpacker 11(2):95.

Metzmaker, J. B. 1983. An investigation into the potential for a Giardia lamblia contamination in the Rattlesnake NRAW. M.S. thesis, University of Montana, Missoula. 63 p.

Meyer, E. A., and E. L. Jarroll. 1980. Giardiasis. Am. J. Epidemiol. 111(1):1-12.

Monzingo, D. L. 1985. The prevalence of Giardia in a beaver colony and the resulting environmental contamination. Ph.D. diss., Colorado State Univ., Fort Collins, CO. (In press).

Rendtorff, R. C. 1954. The experimental transmission of human intestinal protozoan parasites. II. Giardia lamblia cysts given in capsules. Am. J. Hygiene 59:209-220.

Rendtorff, R. C. 1975. Giardia in water. Letter to the editor. Ann. Intern. Med. 82(2):280.

Rosquist, A. E., Jr. 1983. A Giardia source investigation in a national forest municipal supply watershed. Unpublished paper. 8 p. (Available from Lolo National Forest, Missoula, MT 59801.)

Rosquist, A. E., Jr. 1984. Lolo National Forest Giardia source investigation in Rattlesnake Creek, July 5-October 31, 1983. Report to District Ranger, U.S. Forest Service, Missoula, MT. 7 February 1984.

Shulters, M. V., and S. K. Sorenson. 1984. Letter to Dick Riegelhuth, Yosemite National Park, California, 11 January 1984.

Starr, R. 1981. Giardiasis confirmed at Olympic NP. Park Science 2(2):10.

State of New Mexico Health and Environment Department. 1981. Water disinfection for campers and backpackers. (Brochure issued by Health Services and Environmental Improvement Divisions, P.O. Box 968, Santa Fe, NM 87504-0968.)

Strawn. 1979. Drawing of Giardia trophozoite. From files of C. Hibler, Colorado State University.

Suk, T. J. 1983. Investigation of animal hosts for Giardia spp. in California's Sierra Nevada mountains. Cooperative Park Studies Unit, University of California, Davis, California. Contribution number CPSU/UCD 187/01. 21 p.

Suk, T. J. 1984. Letter to S. Kunkle, 8 February 1984.

Tunnicliff, B., and S. K. Brickler. 1984. Drinking water treatment and procedures for Colorado River Corridor raft trips, Grand Canyon National Park. School of Renewable Natural Resources, Univ. of Arizona, Tucson. 52 p.

Williams, O. R. 1981. Giardia and the waterborne transmission of giardiasis: A general review. Watershed Systems Development Group Report No. WSDG-TP-00003, USDA Forest Service, Fort Collins, CO. 25 p.

Wolfe, M. S. 1984. Giardiasis: Symptomatology, diagnosis, and treatment, pp. 147-159. In S. L. Erlandsen and E. A. Meyer (eds.), Giardia and giardiasis: Biology, pathogenesis, and epidemiology. New York: Plenum Press.

Wright, R. A., H. C. Spencer, R. E. Brodsky, and T. M. Vernon. 1977. Giardiasis in Colorado: An epidemiologic study. Am. J. Epidemiol. 105(4):330-336.

BIBLIOGRAPHY

Alsaker, D. 1983. Untitled. Opflow (a monthly publication for members of the American Water Works Association) 8(3):1-2.

American Public Health Association. 1980. Standard methods for the examination of water and wastewater. Washington, D.C.

Baker, D. 1985. Giardia! Nat. Wildlife 23(5):19-21.

Barbour, A. G., C. R. Nichols, and T. Fukushima. 1976. An outbreak of giardiasis in a group of campers. The Am. J. Trop. Med. Hygiene 25:384-389.

The beaver may be innocent. High Country News (Paonia, CO), March 25, 1985.

Bellamy, W. D., F. P. Silverman, D. W. Hendricks, and G. S. Logsdon. 1985. Removing Giardia cysts with slow sand filtration. Am. Water Works Assoc. J. 77(2):52-60.

Brady, P. G., and J. C. Wolfe. 1975. Giardia in water. Reply to letter of R. C. Rendtorff. Letter to the editor. Ann. Intern. Med. 82(2):281.

Braidech, T. E., and R. J. Karlin. 1985. Causes of a waterborne giardiasis outbreak. Am. Water Works Assoc. J. 77(2):48-51.

Brandborg, L. L., moderator; R. Owen, R. Fogel, H. Goldberg, J. Garvie, and S. Grossman, discussants; H. Shapiro, R. Ockner, and R. Schmid, participants. 1980. Giardiasis and traveler's diarrhea. Gastroenterology 78:1602-1614.

Buchanan, W. 1983. Troubled waters: Will Giardia take the fun out of wilderness travel? Unpublished paper. 9 p. (Available from William Buchanan, 12 Midhill Dr., Mill Valley, CA 94941.)

Centers for Disease Control. n.d. Giardia lamblia information paper. (Available from Department of Health and Human Services, CDC, Atlanta, GA 30333).

Colorado ski area sued for Giardia outbreak. 1985. Am. Water Works Assoc. Mainstream (February 1985):3.

The Conservation Foundation. 1984. State of the environment: An assessment at mid-decade. Washington, D.C.

Craun, G. F. 1979. Waterborne giardiasis in the United States: A review. Am. J. Public Health 69(8):817-819.

Davies, R. B., K. Fukutaki, and C. P. Hibler. 1981. Cross-transmission of Giardia. Final report to EPA. Health Effects Research Laboratory, Environmental Protection Agency, Research Triangle Park, NC. 23 p.

Davies, R. B., and C. P. Hibler. 1979. Animal reservoirs and cross-transmission of Giardia, pp. 104-126. In W. Jakubowski and J. C. Hoff (eds.), Waterborne transmission of giardiasis. EPA 600/9-79-001. Environmental Protection Agency, Cincinnati, OH.

Dykes, A. C., D. D. Juranek, R. A. Lorenz, S. Sinclair, W. Jakubowski, and R. Davies. 1980. Municipal waterborne giardiasis: An epidemiologic investigation. Ann. Intern. Med. 92(2):165-170.

Erlandsen, S. L., and E. A. Meyer. 1984. Giardia and giardiasis: Biology, pathogenesis and epidemiology. New York: Plenum Press. 407 p.

Filice, F. P. 1952. Studies on the cytology and life history of a Giardia from the laboratory rat. Univ. Cal. Publ. Zool. 57:53-143.

Frost, F., B. Plan, and B. Liechty, 1980. Giardia prevalence in commercially trapped mammals. J. Environ. Health 42(5):245-248.

Frost, F., L. Harter, B. Plan, K. Fukutaki, and B. Holman. 1983. Giardiasis in Washington state. Project summary. Report No. EPA-600/S1-82-016. Environmental Protection Agency, Center for Environmental Research Information, Cincinnati, OH.

Galazka, S. S. 1982. Giardia lamblia: A clinical-epidemiological case report. The J. Fam. Pract. 15(6):1165-1169.

Galbraith, A. F. 1980. Water quality and wildland resource management, pp. 298-310. In Proceedings of the Symposium of Watershed Management, American Society of Civil Engineers, Boise, ID, July 21-23, 1980.

General Ecology, Inc. 1984. Guide to choosing a water filter/purifier for Giardia protection. Technical Memorandum No. 040484. Lionville, PA.

Giardia suits may be tried together. 1984. U.S. Water News (November 1984):16.

Giardiasis. 1982. State of Maryland, Division of Communicable Diseases and Epidemiology Newsletter. June 1982.

Giardiasis in Plumas County. 1979. California Morbidity (weekly report from the Infectious Disease Section, State Dept. of Health Services, CA) No. 46 (Nov. 23, 1979).

Griffith, E. W. 1982. Giardiasis in the Salmon River basin. Unpublished paper. Salmon River Ranger District, Klamath National Forest, Etna, CA. 3 p.

Hach Chemical Co. 1984. Giardiasis. News and Notes for the Analyst 8(3):11.

Hibler, C. 1982. Epizootiology of waterborne giardiasis in Colorado. Project proposal. Dept. of Pathology, Colorado State University, Fort Collins, CO. 18 p.

Hibler, C. 1984. An evaluation of filters in the removal of *Giardia lamblia*. Water Technol. 7(4):34-36.

Hibler, C. 1984. Inactivation and/or destruction of the cysts of *Giardia* with photozone. Unpublished paper. Dept. of Pathology, Colorado State University, Fort Collins, CO. 12 p.

Hibler, C. P., and C. M. Helmick. n.d. Diagnosis of waterborne giardiasis: State-of-the-art. Unpublished paper. Dept. of Pathology, Colorado State University, Fort Collins, CO.

Holman, B., F. Frost, B. Plan, K. Fukutaki, and W. Jakubowski. 1983. Recovery of *Giardia* cysts from water: Centrifugation vs. filtration. Water Res. 17(11):1705-1707.

Istre, G. R., T. S. Dunlop, G. B. Gaspard, and R. S. Hopkins. 1982. Waterborne giardiasis at a mountain resort: Evidence for possible acquired immunity. Unpublished paper. 14 p. (Available from G. R. Istre, Field Services Division, EPO, Centers for Disease Control, Atlanta, GA 30333.)

Jakubowski, W. 1984. Detection of *Giardia* cysts in drinking water: State-of-the-art, pp. 263-285. *In* S. L. Erlandsen and E. A. Meyer (eds.), *Giardia* and giardiasis: Biology, pathogenesis, and epidemiology. New York: Plenum Press.

Jakubowski, W., and J. C. Hoff (eds.). 1979. Waterborne transmission of giardiasis. Proceedings of a symposium sponsored by the Health Effects Research Laboratory and the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio, Sept. 1978. EPA 600/9-79-001. 306 p. (Available from National Technical Information Service, Springfield, VA 22151.)

Jarroll, E. L., J. C. Hoff, and E. M. Meyer. 1984. Resistance of cysts to disinfection agents, pp. 311-328. *In* S. L. Erlandsen and E. A. Meyer (eds.), *Giardia* and giardiasis: Biology, pathogenesis, and epidemiology. New York: Plenum Press.

Johnston, L. 1978. An investigation of animals hosts for *Giardia lamblia* in the Bridger Wilderness Area. Unpublished paper. Bridger-Teton National Forest, Jackson, WY. 18 p.

Kirkpatrick, C. E., and J. P. Farrell. 1982. Giardiasis. Compend. Contin. Educ. 4(5):367-377.

Knotts, D. M. 1983. Purifying water in the wild. Sierra 68(4):57-59.

Kunkle, S. H., and J. R. Meiman. 1968. Sampling bacteria in a mountain stream. Colorado State University, Hydrology Paper Series No. 28. March 1968. 28 pp.

Lee, R. 1984. Experience with cartridge filters at Longmire, FY 1983 and January 1984. Unpublished report. National Park Service. Pacific Northwest Regional Office, Seattle, WA. 29 p.

Levine, N. D. 1961. Protozoan parasites of domestic animals and of man. Minneapolis: Burgess Publishing Co. 411 p.

Lin, S. D. 1985. Giardia lamblia and water supply. Am. Water Works Assoc. J. 77(2):40-46.

Lippy, E. C. 1978. Tracing a giardiasis outbreak at Berlin, New Hampshire. Am. Water Works Assoc. J. 70(9):512-520.

Logsdon, G. S., V. C. Thurman, E. S. Frindt, and J. G. Stoecker. 1985. Evaluating sedimentation and various filter media for removal of Giardia cysts. Am. Water Works Assoc. J. 77(2):61-66.

Manley, H. 1983. An easy preventative for "backpacker's disease." Backpacker 11(2):95.

McNenny, D. 1982. Giardia: Northern region experiences. Unpublished paper. U.S. Forest Service, Northern Region, Missoula, MT. 6 p.

Meredith, T. 1983. Natural history of the disease giardiasis. Unpublished paper. University of Colorado, Boulder. 11 p.

Metzmaker, J. B. 1983. An investigation into the potential for a Giardia lamblia contamination in the Rattlesnake NRAW. M.S. thesis, University of Montana, Missoula. 63 p.

Meyer, E. A. 1982. The incidence of Giardia infections in beaver and other semi-aquatic mammals in selected watersheds in Oregon. Final project report to EPA. Oregon Health Sciences University, Portland, OR. 13 p.

Meyer, E. A., and E. L. Jarroll. 1980. Giardiasis. Am. J. Epidemiol. 111(1):1-12.

Michaels, B. 1982. Giardia lamblia: A microscopic enigma. Unpublished paper. 14 p.

Monzingo, D. L. 1985. The prevalence of Giardia in a beaver colony and the resulting environmental contamination. Ph.D. diss., Colorado State Univ., Fort Collins, CO. (In press)

Moore, G. T., M. Cross, D. McGuire, C. S. Mollohan, N. N. Gleason, G. Healy, and L. H. Newton. 1969. Epidemic giardiasis at a ski resort. New England J. Med. 281(8):402-407.

Moss, V. 1984. Experts warn mountain water may cause intestinal disease: Purifying pump ensures safety of drinking water. In The Coloradoan (Fort Collins daily newspaper) (August 1, 1984):B1.

National Park Service. Giardiasis. Interim guidelines. GPO 868-934.

Oregonians find bad water a little hard to swallow. U.S. Water News (November 1984):15.

Osterholm, M. T., J. C. Forfang, T. L. Ristinen, A. G. Dean, J. W. Washburn, J. R. Godes, R. A. Rude, and J. G. McCullough. 1981. An outbreak of foodborne giardiasis. New England J. Med. 304(1):24-28.

Rendtorff, R. C. 1954. The experimental transmission of human intestinal protozoan parasites. II. Giardia lamblia cysts given in capsules. Am. J. Hygiene 59:209-220.

Rendtorff, R. C. 1975. Giardia in water. Letter to the editor. Ann. Intern. Med. 82(2):280.

Rosquist, A. E., Jr. 1983. A Giardia source investigation in a national forest municipal supply watershed. Unpublished paper. 8 p. (Available from: Lolo National Forest, Missoula, MT 59801.)

Rosquist, A. E., Jr. 1984. Lolo National Forest Giardia source investigation in Rattlesnake Creek, July 5-October 31, 1983. Report to District Ranger, U.S. Forest Service, Missoula, MT, 7 February 1984.

Schuman, S. H. 1983. Clues for suspecting giardiasis in a day-care center. Letter to the editor. The J. Fam. Pract. 17(1):23-24.

Singer, A. 1980. Giardiasis: Is it a public health problem in the United States? Unpublished paper. 15 pp.

Smith, P. D., C. O. Elson, D. B. Keister, and T. E. Nash. 1982. Human host response to Giardia lamblia. I. Spontaneous killing by mononuclear leukocytes in vitro. J. Immunol. 128(3):1372-1376.

Starr, R. 1981. Giardiasis confirmed at Olympic NP. Park Science 2(2):10.

State of New Mexico Health and Environment Department. 1981. Water disinfection for campers and backpackers. (Brochure issued by Health Services and Environmental Improvement Divisions, P.O. Box 968, Santa Fe, NM 87504-0968.)

Suk, T. J. 1983. Investigation of animal hosts for Giardia spp. in California's Sierra Nevada mountains. Cooperative Park Studies Unit, University of California, Davis, California. Contribution number CPSU/UCD 187/01. 21 p.

Thomas, E. F. 1982. Giardia occurrences in the Pacific Northwest region. Unpublished paper. U.S. Forest Service, Pacific Northwest Region, Portland, OR. 5 p.

Tipton, W. M. 1980. A case evaluation of excessive bivouac use, Rocky Mountain National Park. Unpublished paper. Rocky Mountain National Park, Estes Park, CO. 14 p.

Tucker, B. 1983. Giardia: Maybe it's the voles? Montana Kaimin (Missoula, MT) (Sept. 30):8+.

Tucker, B. 1983. Giardiasis medication may have side effects. Montana Kaimin (Missoula, MT) (Oct. 5):1+.

Tunnicliff, B., and S. K. Brickler. 1984. Drinking water treatment and procedures for Colorado River Corridor raft trips, Grand Canyon National Park. School of Renewable Natural Resources, Univ. of Arizona, Tucson. 52 p.

U.S. Department of Agriculture-Forest Service. 1980. What bugs you? 1980-680-250. U.S. Government Printing Office, Washington, D.C.

U.S. Department of Agriculture-Forest Service. Back country safety tips: Pacific Southwest Region. Brochure.

Vernon, T. M. 1975. Giardia in water. Letter to the editor. Ann. Intern. Med. 82:280.

Waterborne Giardia: It's enough to make you sick. 1985. Roundtable discussion. Am. Water Works Assoc. J. 77(2):14+.

Weniger, B. G., M. J. Blaser, J. Gedrose, E. C. Lippy, and D. D. Juranek. 1983. An outbreak of waterborne giardiasis associated with heavy water runoff due to warm weather and volcanic ashfall. Am. J. Public Health 73:868-872.

What if? 1985. Am. Survival Guide 7(2):10.

Williams, O. R. 1981. Giardia and the waterborne transmission of giardiasis: A general review. Watershed Systems Development Group Report No. WSDG-TP-00003, USDA Forest Service, Fort Collins, CO. 25 p.

Wilson, A. 1984. Mysterious Giardia. World Health (March 1984):22-24.

Wright, R. A. 1975. Giardial infection from water. Letter to the editor. Ann. Intern. Med. 82(4): 589-590.

Wright, R. A., H. C. Spencer, R. E. Brodsky, and T. M. Vernon. 1977. Giardiasis in Colorado: An epidemiologic study. Am. J. Epidemiol. 105(4):330-336.

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