PREVALENCE OF GIARDIA SP. IN A BEAVER COLONY AND THE RESULTING ENVIRONMENTAL CONTAMINATION

Authors: Monzingo, Don Lee, and Hibler, Charles P.

Source: Journal of Wildlife Diseases, 23(4) : 576-585

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-23.4.576

Journal of Wildlife Diseases, 23(4), 1987, pp. 576–585

PREVALENCE OF *GIARDIA* SP. IN A BEAVER COLONY AND THE RESULTING ENVIRONMENTAL CONTAMINATION

Don Lee Monzingo, Jr. and Charles P. Hibler
Department of Pathology, Colorado State University, Fort Collins, Colorado 80523, USA

ABSTRACT: The prevalence of *Giardia* sp. in a beaver (*Castor canadensis*) colony in Colorado was determined by the collection and analysis of fecal samples over a period of 14 mo. Environmental contamination was monitored through the use and analysis of water filter samples. Beaver shed cysts of *Giardia* sp. in their feces throughout the year with temporal variations in the prevalence, and became infected as kits and remained infected as juveniles and adults. Beaver served as amplification hosts for *Giardia* sp. and contaminated surface waters downstream from their dams in late spring and early fall. In slow moving waters the cysts of *Giardia* sp. settled rapidly. Muskrats (*Ondatra zibethicus*) were the only other species of wildlife shedding cysts of *Giardia* sp. on the study area.
Key words: Beaver, *Castor canadensis*, *Giardia* sp., prevalence, survey, water quality.

INTRODUCTION

Giardia duodenalis is the most frequently identified intestinal protozoan parasite in humans (Knight and Wright, 1978; Medical News, 1978). Although there is some controversy regarding the identification and speciation of the organisms responsible for human giardiasis, several modes of transmission in the human population have been documented. These include direct person-to-person transmission (Ormiston et al., 1942; Brown, 1948; World Health Organization, 1981), foodborne transmission (Gangarosa and Donadio, 1970; Osterholm et al., 1981), transmission from pets (Davies and Hibler, 1979; Box, 1981; Scholtens et al., 1982), transmission during sexual activity (Meyers et al., 1977; Owen, 1984) and waterborne transmission (Walzer et al., 1971; Brodsky et al., 1974).

From 1965 to 1981 waterborne outbreaks of giardiasis have occurred primarily in areas where surface waters are free of gross human sewage contamination and treatment is minimal (Craun, 1984). Untreated surface water or situations where disinfection was the only treatment accounted for 67% of the outbreaks and 52% of the cases of giardiasis. Ineffective filtration accounted for 12% of the outbreaks and 35% of the cases of waterborne giardiasis (Craun, 1984). Cysts of *Giardia* sp. were found in drinking water or water sources in eight of the outbreaks, and in three other outbreaks, cysts were recovered from beaver or beaver feces (Craun, 1984).

Giardia sp. has been found in a number of species of wild animals. Grant and Woo (1978) found 322 of 326 (99%) meadow voles (*Microtus pennsylvanicus*) and deer mice (*Peromyscus maniculatus*) infected with *Giardia* sp. in southern Ontario. Davies and Hibler (1979) found 44 of 244 (18%) beaver, two of 34 (6%) coyotes (*Canis latrans*), six of 85 (10%) cattle, one of four (25%) domestic cats, 10 of 78 (13%) dogs and two of 32 (6%) human fecal samples collected in the field in Colorado contained cysts of *Giardia* sp. Hibler (unpubl. data) found five of 100 (5%) domestic sheep originating from Wyoming and Colorado infected. Frost et al. (1980) examined commercially-trapped mammals in Washington. They found 6% of 173, 7% of 177 and 19% of 179 beaver infected with *Giardia* sp. in the 1976–1977, 1977–1978 and 1978–1979 trapping seasons, respectively. They also found 35% of 17 and 43% of 115 muskrats infected in the 1977–1978 and 1978–1979 seasons, respectively.

The association between beaver and epidemics of waterborne giardiasis, public health implications, and a high degree of concern by the public prompted an investigation to answer several questions: (1) Do beaver carry infections of *Giardia* throughout the year?; (2) If so, is there a cyclic pattern in numbers of cysts shed by a beaver colony through the year?; (3) Are other species of wildlife involved in the contamination of surface waters with *Giardia* sp.?; and (4) What is the extent of contamination with *Giardia* sp. of surface waters by a beaver colony?

MATERIALS AND METHODS

Study area

This study was conducted at the Hidden Valley Creek beaver ponds (Township 5N, Range 74W, Sections 13–14) in Rocky Mountain National Park 6 km west of the town of Estes Park, Colorado, at an elevation of 2,900 m. A beaver colony consisting of 19 well-established dams with large ponds (Fig. 1) and 10–12 individuals has existed in this area for many years. The area above the ponds was a small drainage basin with no beaver activity. The stream below the ponds flowed swiftly for 800 m followed by 400 m of slow moving stream in the meadow and continued approximately 1.5 km to its confluence with Fall River.

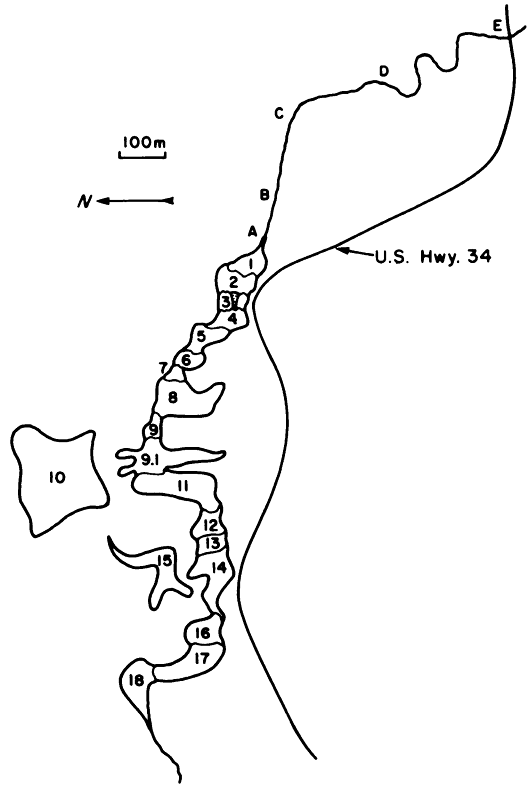


FIGURE 1. Hidden Valley study area, Rocky Mountain National Park, Colorado. Beaver ponds are numbered 1 through 18, and the water filter sites are lettered A through E.

Fecal collection

At intervals of 7–10 days in 1983 and 1984 collection trips were made to the beaver ponds. The same route upstream through the ponds was followed on each collection trip. Beaver fecal samples, which settle to the bottom of the ponds at the upstream face of the dams, were collected using a standard 5-cm diameter tea strainer fastened to a broom handle. Individual fecal samples were gently scooped off the pond bottom along the entire upstream face of each dam, placed into 50-ml plastic screw top tubes and labeled as to date, collection location and age group of the beaver. Tubes containing fecal samples were placed on wet ice in a cold chest and transported to the laboratory for analysis.

Age groups (adults, juveniles and kits) were determined by a simple size relationship of the fecal samples. By observing beaver, it was determined that fecals from adult animals were approximately 5 cm in diameter by 15 cm in length and fecals from juveniles were approximately 2 cm in diameter by 5 cm in length and had more of a pelleted appearance. From the middle of May, when the kits leave the lodge for the first time, until the end of July, their fecal samples were distinguishable from fecal samples of other juevenile beaver. Initially, kit fecals were less than one-half the size of juvenile beaver fecals, but increased in size to a point that the two became indistinguishable by the end of July.

Two methods were used to insure collection of only fresh beaver fecal pellets. The first was the use of color. When beaver fecal pellets are passed initially they are a bright greenish-yellow. As pellets age they slowly turn a dull gray in about 2 wk time. The second method to insure freshness of fecal samples was to destroy all evidence of beaver feces from the path across the face of a beaver pond each time the area was visited.

Fecal samples of other species of wild animals found on the periphery of the ponds were collected in 1984. Only moist fresh fecal samples from wild animals identifiable to species were collected. They were placed in 50-ml screw cap tubes, put on wet ice, and handled in the same manner as the beaver samples.

Beaver activity observations

As beaver ponds were traversed to collect fecal samples, observations were made as to the location, amount and type of beaver activity or signs of activity. The types of activities recorded were dam repair, food items gathered and eaten, location and use of bank dens and lodges, and movement patterns of beaver.

Fecal analysis

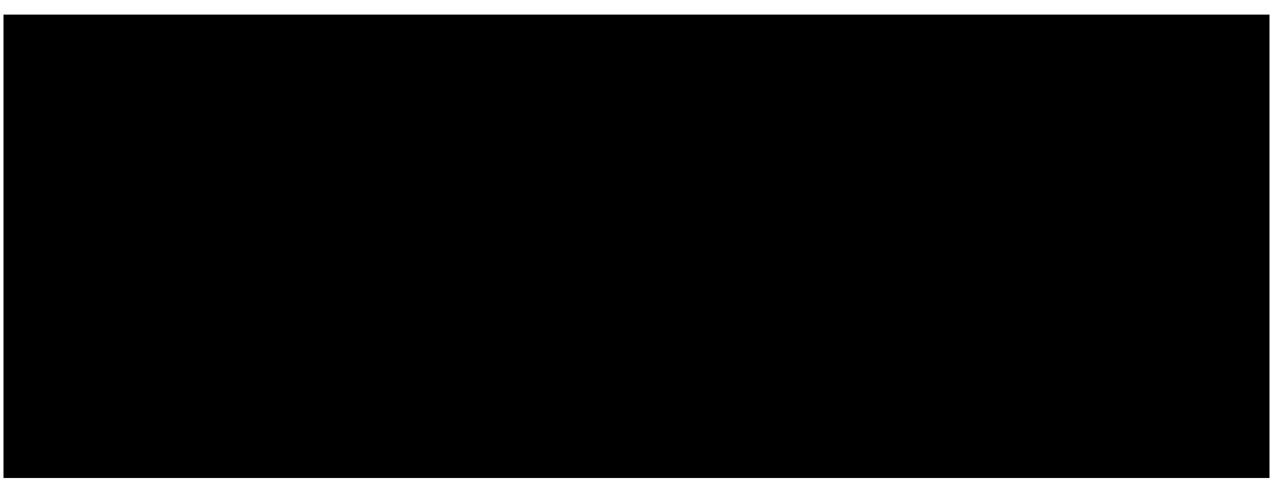
Fecal samples were refrigerated at 3 C in the laboratory until they could be examined using a modified zinc sulfate centrifugation technique. Samples were placed into 100-ml paper cups, and cold (3 C) distilled water was added to fill the paper cup. Fecal pellets were macerated and suspended in the distilled water using wooden applicator sticks. This suspension was filtered through a double layer of gauze into a 50-ml nalgene conical centrifuge tube, then centrifuged at 380 *g* for 5 min. The supernatant was siphoned to the pellet, resuspended in 10 ml of cold distilled water, transferred to a 15-ml nalgene conical centrifuge tube, and centrifuged at 380 *g* for 5 min. Supernatant from the tube was siphoned to the pellet, 3–4 drops of

ered by a 12-volt marine wet cell battery. The pump was suspended on the surface of the pond with a styrofoam collar so the water intake was 5 cm below the surface of the water. Water was pumped through a short section of 2-cm diameter hose to a filter housing (Type 1M1, AMF Cuno Division, Merden, Connecticut 06450, USA) containing a polypropylene 1-μm filter (Micro Wynd II Filter Cartridge, Catalog #DPPPY, AMF Cuno Division), then through a standard household water meter (Recordall Model 25, Badger Meter, Milwaukee, Wisconsin 53200, USA) and back into the stream. The second apparatus consisted of a custom made instream gravity flow V-funnel (Williams, 1981) which delivered water to the filter housing, filter and water meter. Water filtration equipment was set up at various locations (see Fig. 1) on each collecting trip, and allowed to operate for 3–4 hr as other samples were collected. At the end of this time period the filter housing was disconnected, and the inlet and outlet openings capped. The capped filter housing containing the filter was placed on wet ice in a cold chest and transported to the laboratory for analysis.

Experimental suspensions of cysts

To determine how far downstream from intact beaver dams that *Giardia* sp. cysts were carried by the current, beaver fecal samples containing *Giardia* sp. cysts (actual counts were not made) were mixed by hand into the water of the pond system. This was accomplished by shaking an open 50-ml tube of fecal suspension under the surface of the water immediately up-

centrifuged at 380 *g* for 5 min. The supernatant was siphoned to the pellet, resuspended in 10 ml of cold distilled water, and transferred to a 15 ml conical centrifuge tube. This tube was centrifuged at 380 *g* for 5 min. The supernatant was siphoned to the pellet, 3–4 drops of Lugol's iodine and 5 ml of 1.20 sp. gr. zinc sulfate solution added, and the pellet resuspended. Zinc sulfate solution was added in sufficient volume



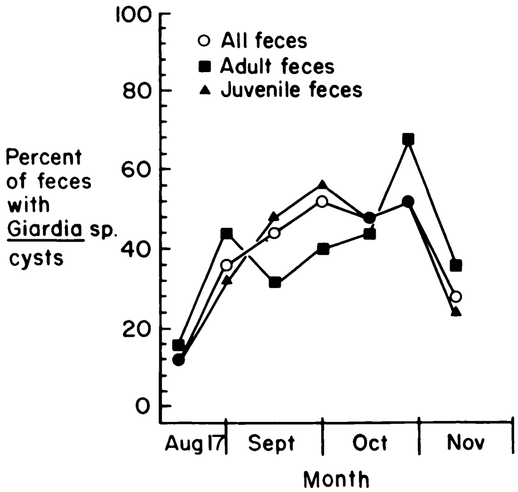


FIGURE 2. Percentage of biweekly beaver fecal samples containing cysts of *Giardia* sp. by age and month of collection, 1983.

to form a convex meniscus, a coverslip placed upon the tube, and centrifuged at 380 *g* for 5 min. The coverslip was removed, placed upon a glass slide, and examined at 100×.

Statistical analysis

To aid in the graphic display of the data, 14-day periods were blocked out from the first collection day of each year (10 August 1983 and 14 May 1984). The data obtained in each of these 14-day (biweekly) periods were pooled and plotted on graphs. Due to the flatline characteristics of the biweekly graph of data collected in 1984 on beaver feces, these data were pooled by month of collection and high-level/low-level activity periods. The high-level activity period corresponded to the period of time, September and October, when the entire beaver colony was involved in preparation of the winter pond area, winter lodge and winter food cache. The low-level activity period corresponded to the period of time when collection trips could be made (the ponds were not frozen) and the beaver were not actively preparing for winter: August and November 1983, and May, June, July and August 1984. Changes in the prevalence of *Giardia* sp. cysts in pooled data for monthly and activity level periods were tested for statistical significance using the Z-test for large sample size (Mendenhall and Lyman, 1980). Changes in the prevalence of *Giardia* sp. cysts were accepted as significant if they were in the 90% confidence interval ($P < 0.10$). This lower confidence interval was utilized to detect subtle changes in prevalence of *Giardia* sp. cysts in beaver fecal samples when a limited number of fecal samples could be collected.

RESULTS

Beaver fecal samples

Figures 2 and 3 show the prevalence of *Giardia* sp. cysts in fecal samples collected in 1983 and 1984, respectively. In 1983 (Fig. 2) the prevalence increased in August, September and October followed by a decline in November for both the total population and the juvenile population. The adult population showed a similar pattern except for a slight decline in prevalence in early September. Figure 3 (1984) shows a higher overall prevalence, but not the pattern apparent in 1983.

Since the prevalence of *Giardia* sp. cysts was relatively stable in 1984, data were pooled by months for both 1983 and 1984 (Tables 1 and 2, respectively). Statistically significant differences were found in the prevalence of cysts in the 1983 juvenile population, an increase between August and September ($Z = 3.44$, $P < 0.01$) and a decrease between October and November ($Z = 2.36$, $P < 0.01$). The adult pop-

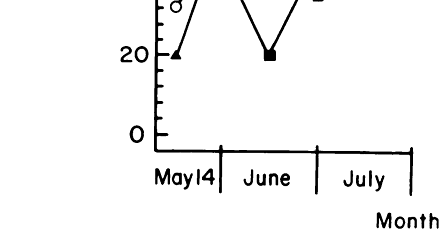


FIGURE 3. Percentage of biweekly beaver fecal samples containing cysts of *Giardia* sp. by age and month of collection, 1984.

TABLE 1. Prevalence of cysts of *Giardia* sp. in fecal samples from beaver according to month of collection and age of beaver, 1983.

	Total population			Adults			Juveniles		
Month	Number tested	Number positive	% *Giardia* sp.[a]	Number tested	Number positive	% *Giardia* sp.	Number tested	Number positive	% *Giardia* sp.
Aug.	127	34	26	41	14	34	86	20	23
Sept.	176	76	43[b]	56	20	36	120	56	47[f]
Oct.	147	75	49	40	23	58[d]	107	52	47
Nov.	32	7	22[c]	9	2	22[e]	23	5	22[g]
Total	482	192	39	146	59	40	336	133	40

[a] % *Giardia* sp. = (number positive divided by number tested) × 100.
[b] $Z = 5.47$, $P < 0.01$.
[c] $Z = 2.79$, $P < 0.01$.
[d] $Z = 2.12$, $P < 0.05$.
[e] $Z = 1.92$, $P < 0.10$.
[f] $Z = 3.44$, $P < 0.01$.
[g] $Z = 2.36$, $P < 0.01$.

ulation in 1983 showed a statistically significant increase from September to October ($Z = 2.12$, $P < 0.05$) and decrease from October to November ($Z = 1.92$, $P < 0.10$). In 1984 (Table 2) the total population, adults and juveniles, showed a statistically significant increase in prevalence from September to October ($Z = 1.87$, $P < 0.10$). Both the adult and juvenile subpopulations showed a statistically significant change in cyst production from May to June 1984 but in opposite directions. An increase in prevalence was found for juveniles ($Z = 1.91$, $P < 0.10$) and a decrease in prevalence was found for adults ($Z = 2.03$, $P < 0.05$).

A statistically significant increase in the prevalence of cysts was found in 1983 in juvenile fecals from low-level to high-level activity periods ($Z = 4.33$, $P < 0.01$) (Table 3). Although not statistically significant, the prevalence of cysts in adult fecals was elevated during the high-level activity period. A statistically significant increase in prevalence of cysts in the entire population occurred between the low-level and high-

TABLE 2. Prevalence of cysts of *Giardia* sp. in fecal samples from beaver according to month of collection and age of beaver, 1984.

	Total population			Adults			Juveniles		
Month	Number tested	Number positive	% *Giardia* sp.[a]	Number tested	Number positive	% *Giardia* sp.	Number tested	Number positive	% *Giardia* sp.
May	81	32	40	22	13	59	59	19	32
June	106	46	43	32	10	31[c]	74	36	49[d]
July	164	68	42	34	15	44	130	53	41
Aug.	180	81	45	40	20	50	140	61	44
Sept.	170	70	41	46	24	52	124	46	37
Oct.	74	40	54[b]	27	17	63	47	23	50
Total	775	337	44	201	99	49	574	238	42

[a] % *Giardia* sp. = (number positive divided by number tested) × 100.
[b] $Z = 1.87$, $P < 0.10$.
[c] $Z = 2.03$, $P < 0.05$.
[d] $Z = 1.91$, $P < 0.10$.

TABLE 3. Prevalence of cysts of *Giardia* sp. in fecal samples from beaver according to activity level and age of beaver, 1983.

Activity	Total population			Adults			Juveniles		
	Number tested	Number positive	% *Giardia* sp.[a]	Number tested	Number positive	% *Giardia* sp.	Number tested	Number positive	% *Giardia* sp.
Low level	159	41	26	50	16	32	109	25	23
High level	323	151	46[b]	96	43	45	227	108	48[c]
Total	482	192	39	146	59	40	336	133	40

[a] % *Giardia* sp. = (number positive divided by number tested) × 100.
[b] $Z = 4.46$, $P < 0.01$.
[c] $Z = 4.33$, $P < 0.01$.

level activity periods during 1983 ($Z = 4.46$, $P < 0.01$). Results for 1984 did not show a statistically significant change in cyst prevalence between activity periods (Table 4).

Kit beaver fecal samples

Beaver kits were shedding cysts when they first emerged from the lodge and continued to do so for as long as their fecal samples were distinguishable from samples of older beaver. A total of 76 kit fecal samples was collected from 21 May through 30 July. Thirty-four (44.7%) of these samples contained *Giardia* sp. cysts.

Non-beaver fecal samples

A total of 55 fecal samples from other wildlife species was collected during 1984. The only species in which cysts of *Giardia* sp. were found was muskrat (*Ondatra zibethicus*) (five of six samples). Cysts were not found in samples from 27 elk (*Cervus elaphus nelsoni*), 13 bighorn sheep (*Ovis canadensis*), four mule deer (*Odocoileus hemionus*), three coyotes (*Canis latrans*), one chipmunk (*Eutamias umbrinus*) and two mallard ducks (*Anas platyrhynchos*).

Mud samples

Four of 50 (8%) mud samples contained cysts of *Giardia* sp., three with one cyst and one with four cysts.

Beaver activity

Observations of beaver activity were not initiated until August 1983. Early in September the beaver colony began to repair dams and raise the water level in the entire pond system. By the first of October they were concentrating their activity around pond 14, the 1983–1984 winter lodge pond. By the end of October all preparations for winter were complete, including a large food cache composed mainly of aspen and willow limbs.

TABLE 4. Prevalence of cysts of *Giardia* sp. in fecal samples from beaver according to activity level and age of beaver, 1984.

Activity	Total population			Adults			Juveniles		
	Number tested	Number positive	% *Giardia* sp.[a]	Number tested	Number positive	% *Giardia* sp.	Number tested	Number positive	% *Giardia* sp.
Low level	531	227	43	128	58	45	403	169	42
High level	244	110	45	73	41	56	171	69	40
Total	775	337	44	201	99	49	574	238	42

[a] % *Giardia* sp. = (number positive divided by number tested) × 100.

The entire pond system was frozen on 11 November 1983 and did not thaw until 14 May 1984. A slight amount of dam repair was evident in mid-May 1984, immediately after spring thaw, and in late July when stream flow decreased. In September and October 1984 the beaver prepared for winter as they did in 1983 except they utilized an old lodge in pond 8 as the 1984–1985 winter lodge. Ponds were frozen on 19 October, 3 wk earlier than in 1983.

Beaver activity throughout the year could be divided into three broad categories. The first category was during winter when beaver ponds were frozen. The Hidden Valley beaver colony during this time period had an unmeasurable stream flow under several feet of ice and snow. Beaver rarely ventured out above the ice and the pond system was basically closed and isolated. Little is known about beaver interactions during this period.

The second category of activity was from spring thaw in May until approximately the first of September. During this time period there was a moderate amount of dam repair and little stressful social interaction (breeding season, exclusion of juveniles, etc.) within the beaver colony. The beaver colony had an abundant food supply and enough water to provide protection from predators. Presumably, this was the least physically stressful period for individual beaver or the entire colony.

The third category of beaver activity was in September and October when beaver became very active, preparing for winter. There was extensive repair of all dams within the pond system. Dams were crisscrossed with small willow branches and then plastered and capped with mud from the bottom of ponds. The pond to be utilized as the winter pond was deepened by pushing mud from the bottom and sides of the pond up onto the banks. A winter lodge was built or an existing lodge was repaired. A winter food cache of aspen limbs was gathered and placed in the bottom of the winter lodge pond. For further information about the life history of beaver the reader is referred to Duncan (1984).

The amount of beaver activity during preparation for winter in September and October was extremely high. Beaver must leave the protection of the ponds and travel some distance up hillsides to gather aspen limbs necessary to sustain them throughout the winter. Beaver in the Hidden Valley colony crossed a paved road and foraged several hundred meters up a steep hillside to obtain aspen. This period of time probably was stressful because of the increased activity and the exposure of beavers to predators (and automobiles) while gathering a winter food cache.

Water filters

A summary of the numbers of *Giardia* sp. cysts found at each sample site is presented in Table 5. Cysts were not detected in the stream above the beaver ponds in 11 filter samples totaling 13,592 liters of filtered water and spanning the 1984 collection period. *Giardia* sp. cysts were detected downstream from the ponds under natural conditions in two distinct time periods. The first time period was in June,

TABLE 5. Total volume of water sampled, total number of *Giardia* sp. cysts found and *Giardia* sp. cysts/liter of water sampled at each sampling site for the entire study period.

Site	Volume of water (liters)	Total number of *Giardia* sp. cysts	*Giardia* sp. cysts/liter of water
A	13,985	401	0.029
B	15,893	188	0.012
C	5,200	71	0.014
D	19,862	45	0.002
E	5,602	0	0
Pond 1	1,370	0	0
Pond 6	545	112	0.206
Pond 8	795	486	0.611
Pond 9	2,123	33	0.016
Pond 12	10,750	323	0.030
Pond 14	5,671	764	0.135
Above ponds	13,592	0	0

during highest stream flow and minor dam repair activity by the beaver. The second time period was September and early October, during low stream flow and intensive dam repair activity by the beaver. In both time periods cysts were detected as far downstream as fast flowing waters were present (about 800 m). Cysts were not detected below the slow moving section of the stream, about 400 m in length.

When fecal samples containing cysts of *Giardia* sp. were suspended into water in pond 1, cysts were detected immediately below pond 1 in the swiftly flowing stream, but not further downstream. Cysts were suspended twice in water in pond 13, and water filters established 5 m below the dam in pond 12 contained cysts. Cysts were suspended once in pond 13, and a water filter apparatus set at 25 m below the dam in slow moving water did not contain cysts.

The only other water filter samples in which *Giardia* sp. cysts were found were samples taken within the pond system (nine of 16 filters were positive). Filters taken from the winter lodge pond on 7 May 1984 and 15 January 1985, when the ponds were frozen, had the greatest concentration of cysts, 0.460 and 0.611 cysts/liter, respectively.

DISCUSSION

Fecal samples

The higher prevalence of *Giardia* sp. cysts during September and October 1983 compared to August and November 1983 (Table 1) may have been a response to stress because this was observed to be the period of increased activity. This trend was not as clear in 1984 (Table 2) since individual subgroups (adults and juveniles) did not show a significant increase in *Giardia* sp. prevalence from September to October.

The decrease from May to June 1984 (Table 2) in the prevalence of *Giardia* sp. cysts in feces from adult beaver may have been due to less social stress, to a change in diet (from limbs stored in the water to fresh limbs) or to a decreased production of cysts in the females following a postpartum rise in early May. A postpartum rise is known to occur in pregnant dogs infected with *Giardia* sp. (Hibler, unpubl. data) and in some other host species harboring various gastrointestinal parasites (Blitz and Gibbs, 1972). The increase in prevalence of cysts in feces from juvenile beaver from May to June 1984 could have resulted from greater social stress to these animals when they were forced away from the female and young-of-the-year, a change in diet and/or some other factor.

The 1983 data suggested that production of *Giardia* sp. cysts in beaver is cyclic and probably related to behavior, resulting in a higher production of cysts in the early fall when the beaver are preparing for winter. The 1984 data did not show this cyclic pattern. This may have resulted from several factors, the investigators' activities, a change in visitor use when the pond system was opened to fishing and/or unrecognized factors.

Detection of cysts in fecal samples from young-of-the-year on 21 May indicated that the kits became infected with *Giardia* sp. prior to, or shortly after, leaving the winter lodge. Young are born in May and leave the lodge to follow the female within a week or two of birth. Presence of *Giardia* sp. in young-of-the-year as they initially leave the lodge suggests direct beaver-to-beaver transmission or waterborne transmission among the beaver. A factor which aids the maintenance of giardiasis in wild beaver populations is their coprophagic behavior (Buech, 1984). By ingesting their own feces directly from the rectum, infected beaver are constantly being re-exposed.

Water filters

Sampling for *Giardia* sp. within the stream was done to determine the distance that cysts were distributed downstream from intact beaver dams before settling. Results indicated that there were two time periods during the year, June during high stream flow and September through October during high amounts of beaver activity, when cysts were carried downstream for any significant distance from beaver colonies with intact dams. High stream flow alone will carry cysts downstream, but intensive dam repair by beaver facilitates the downstream spread of cysts.

Mud from the bottom of ponds is used to plaster the upstream face and top of dams. Any fecal pellets present in mud at this time would be pushed up with the mud. Not only would this introduce any cysts in broken fecal pellets into the stream flow, but it would allow also some intact fecal pellets that may contain cysts to be washed over the dams. *Giardia* sp. cysts may settle rather quickly in still water. Cysts were detected 5 m, but not 25 m, below dam 13 in slow moving water when cysts were suspended experimentally in the water. Cysts were absent at the most distant downstream filter station that was below the 400 m section of slow moving stream. If cysts settle as quickly as our downstream collection data indicate, beaver would need to be very near to a municipal water intake for a surface water treatment system to be at risk. If water intakes for municipal systems were located in a reservoir, beaver would need to be active in the reservoir near the intake to place the system at risk unless demand for water created a significant current within the reservoir.

Water filters taken in winter, when ponds were frozen, yielded the highest counts of cysts (0.460 and 0.611 cysts/liter). At this time of year beaver were confined to their winter lodge pond and stream flow was near zero. Cyst production rates in beaver at this time of year are unknown, but the cysts that are produced were concentrated in the winter lodge pond.

Results of this study indicate that infections of *Giardia* sp. are firmly established in this beaver population. Other studies have shown that beaver are a source of contamination of municipal water supplies using surface water and, therefore, contribute to the risk of human giardiasis. However, it should be noted that there are benefits to the presence of beaver on a stream. They reduce the potential for erosion, trap massive amounts of sediment, dampen fluctuations in run-off and effect nutrient cycling (Duncan, 1984). Beaver are being utilized in Wyoming to stabilize stream flow and reduce erosion along selected streams (Brayton, 1984). Removal of beaver from a stream, followed by lack of dam maintenance, reduced wildlife and fish habitat (Duncan, 1984). All of these factors need to be considered when management decisions are being made to remove beaver from a watershed in order to prevent the possibility of an outbreak of giardiasis.

ACKNOWLEDGMENTS

We wish to thank David R. Stevens, Chief Biologist, Rocky Mountain National Park, for allowing the research to be conducted in Hidden Valley and for the support which was given to complete the project. Heartfelt gratitude is extended to my wife, Lisa Monzingo, for her patience and understanding. Her help in editing and typing the original manuscript has made me forever indebted to her. Thanks are extended also to Esta Amen for final preparation of this manuscript.

LITERATURE CITED

BLITZ, N. M., AND G. C. GIBBS. 1972. Studies on the arrested development of *Haemonchus contortus* in sheep. II. Termination of arrested development and the spring rise phenomenon. International Journal for Parasitology 2: 13–22.

BOX, E. D. 1981. Observations on *Giardia* of budgerigars. Journal of Protozoology 28: 491–494.

BRAYTON, D. S. 1984. The beaver and the stream. Journal of Soil and Water Conservation 39: 108–109.

BRODSKY, R. E., H. C. SPENCER, JR., AND M. G. SCHULTZ. 1974. Giardiasis in American travelers to the Soviet Union. Journal of Infectious Diseases 130: 319–323.

BROWN, E. H. 1948. *Giardia lamblia*: The incidence and results of infections of children in residential nurseries. Archives of Disease in Childhood 23: 119–128.

BUECH, R. R. 1984. Ontogeny and diurnal cycle of fecal reingestion in North American beaver (*Castor canadensis*). Journal of Mammalogy 65: 347–350.

CRAUN, G. F. 1984. Waterborne outbreaks of giardiasis, current status. *In Giardia* and giardiasis, S. L. Erlandsen and E. A. Meyer (eds.). Plenum Press, New York, New York, pp. 243–261.

DAVIES, R. B., AND C. P. HIBLER. 1979. Animal reservoirs and cross-species transmission of *Giardia*. *In* Waterborne transmission of *Giardia*, W. Jakubowski and J. C. Hoff (eds.). U.S. Environmental Protection Agency, Cincinnati, Ohio, pp. 104–125.

DUNCAN, S. L. 1984. Leaving it to beaver. Ecology 26: 41–45.

FROST, F., B. PLAN, AND B. LIECHLY. 1980. *Giardia* prevalence in commercially trapped mammals. Journal of Environmental Health 42: 245–249.

GANGAROSA, E. J., AND J. A. DONADIO. 1970. Surveillance of foodborne disease in the United States: A comparison of data 1968–1969. Journal of Infectious Diseases 122: 354–358.

GRANT, D. R., AND P. T. K. WOO. 1978. Comparative studies of *Giardia* spp. in small mammals in southern Ontario. I. Prevalence and identity of the parasites with a taxonomic discussion of the genus. Canadian Journal of Zoology 56: 1348–1359.

JAKUBOWSKI, W. 1984. Detection of *Giardia* cysts in drinking water: State of the art. *In Giardia* and giardiasis, S. L. Erlandsen and E. A. Meyer (eds.). Plenum Press, New York, New York, pp. 263–286.

KNIGHT, R., AND S. G. WRIGHT. 1978. Intestinal protozoa. Progress Report. Gut 19: 241–248.

MEDICAL NEWS. 1978. Intestinal parasites ranging far afield in the United States. Journal of the American Medical Association 239: 2756.

MENDENHALL, W., AND D. LYMAN. 1980. Understanding statistics. Duxbury Press, North Scituate, Massachusetts, pp. 197–200.

MEYERS, J. D., H. A. KUHARIC, AND K. K. HOLMES. 1977. *Giardia lamblia* infections in homosexual men. British Journal of Venereal Disease 53: 54–55.

ORMISTON, G., J. TAYLOR, AND G. S. WILSON. 1942. Enteritis in a nursery home associated with *Giardia lamblia*. British Medical Journal 2: 151–154.

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 Journal of Medicine 304: 24–38.

OWEN, R. L. 1984. Direct fecal-oral transmission of giardiasis. *In Giardia* and giardiasis, S. L. Erlandsen and E. A. Meyer (eds.). Plenum Press, New York, New York, pp. 329–339.

SCHOLTENS, R. G., J. C. NEW, AND S. JOHNSON. 1982. The nature and treatment of giardiasis in parakeets. Journal of the American Veterinary Medical Association 180: 170–173.

WALZER, P. D., M. S. WOLFE, AND M. G. SCHULTZ. 1971. Giardiasis in travelers. Journal of Infectious Diseases 124: 170–173.

WILLIAMS, O. R. 1981. *Giardia* and the waterborne transmission of giardiasis; a general review. Watershed Systems Development Group Report WSDG-TP-00003. U.S. Forest Service, Fort Collins, Colorado, 25 pp.

WORLD HEALTH ORGANIZATION. 1981. Intestinal protozoan and helminthic infections. World Health Organization Technical Report Series, Report No. 666. Geneva, Switzerland, 150 pp.

Received for publication 20 May 1986.