

Relationship Between Beef Production and Waterborne Parasites

(Cryptosporidium spp. and Giardia spp.)

in the North Saskatchewan River Basin Alberta, Canada

– OVERVIEW –

Summary prepared by
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June 2002

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The following is a summary of the technical report of the same name. The study deals primarily with the part of the North Saskatchewan River basin upstream of Edmonton and downstream of Rocky Mountain House, except where noted otherwise. If you would like more detail on how the research study was conducted or results and conclusions, please see the technical report. To help you understand technical terms (in bold the first time used in the document), see the glossary at the end of this document.

Research funding provided by the Canada-Alberta Beef Industry Development Fund, Alberta Agricultural Research Institute- Alberta Environmentally Sustainable Agriculture Program, and Health Canada. Substantial in-kind funding was provided by Alberta Environment, EPCOR, Alberta Research Council, University of Calgary, University of Alberta and Alberta Agriculture, Food and Rural Development.

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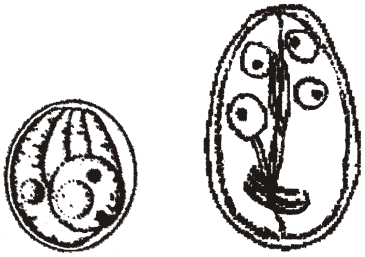
Introduction

Cryptosporidium spp. (cryptosporidium) and *Giardia* spp. (giardia) are intestinal **parasites** that can infect humans, domestic livestock and wildlife, as well as other animals, including birds. They are single-celled organisms called **protozoa**. Human symptoms of infection include profuse, watery diarrhea, fever and nausea. Although giardia infections (popularly called "beaver fever") are treatable with drugs, cryptosporidium infections are not. As well, **cryptosporidiosis** can be life threatening for people with poorly functioning immune systems, such as those with AIDS or cancer, infants and the elderly. Consequently, these parasites represent a significant risk to public health.

Neither of these organisms can grow or reproduce outside of the digestive tracts of warm-blooded animals. These parasites form cysts or oocysts within the gut and are shed with feces. The cyst or oocyst allows the organism to survive outside of their host until ingested again, when they come out of their cyst and begin reproducing in the new host, and the cycle is repeated.



Cryptosporidium oocyst *Giardia* spp. cyst

The spp. after their scientific name means more than one species may be present. There are several species of giardia and cryptosporidium such as *Cryptosporidium parvum* and *Cryptosporidium muris*. A cyst is a protective capsule produced by individual protozoa, whereas an oocyst is produced through sexual reproduction, like an egg.
Note: Diagram not to scale.

Cryptosporidium and giardia are transmitted by ingesting contaminated feces or drinking water. They are commonly found in aquatic environments. If they enter public water supplies, many people can become infected, and they have been responsible for outbreaks of waterborne disease worldwide.

In Canada, outbreaks have occurred in Collingwood, Ontario, Cranbrook and Kelowna, British Columbia, and more recently in North Battleford, Saskatchewan.

Domestic livestock, including beef and dairy cattle, are often perceived to be the leading environmental source of waterborne parasites. Several studies in North America have also found these organisms in treated sewage effluent and wildlife. Very few studies, however, have attempted to determine relationships between these sources and **concentrations** of protozoan parasites in streams throughout a large **watershed**.

In the spring of 1997, very high levels of cryptosporidium and giardia were present in the North Saskatchewan River, the raw water supply for the city of Edmonton. At the time, the river had high levels of **turbidity**, which made optimum treatment difficult (although the two City plants were able to meet regulatory standards at all times). As a result of the high number of parasites in the raw water, a few organisms reached the finished drinking water, and a precautionary boil-water advisory was issued for people with poorly functioning immune systems. Fortunately, no disease outbreak occurred.

Because much of the North Saskatchewan River basin upstream of Edmonton is used for livestock production, cattle were suggested as the main contributor to the high levels of these parasites in the river. In 1998, a study was launched to assess the relative contributions from the three potential sources in the watershed: agriculture, municipal sewage effluent and wildlife.

The research team was multi-disciplinary and included researchers from government, universities and private industry. It was funded through grants from the Canada-Alberta Beef Industry Development Fund, Alberta Agricultural Research Institute and Health Canada, as well as in-kind support from Alberta Agriculture, Food and Rural Development, Alberta Environment, Alberta Research Council, EPCOR, the University of Alberta and the University of Calgary.

The primary objectives of the study were to answer the following questions:

- Do cattle contribute significant amounts of cryptosporidium and giardia to surface water compared with wildlife and municipal sewage?

- Do watersheds with high densities of cattle and other livestock contribute greater quantities of parasites to the North Saskatchewan River than non-agricultural (forested) watersheds?

Because much of the watershed above Rocky Mountain House had little agricultural production, the study focused on the river basin between Rocky Mountain House and Edmonton. The three-year study included:

- Characterization of land use in the watershed;
- **Prevalence** of parasites in fecal material from livestock, wildlife and sewage;
- Water quality assessment of 20 streams draining to the river, wastewater effluent and raw/ treated drinking water; and

- Statistical comparisons of various land use activities with water quality.

The research program was designed to be comprehensive – it covered all potential major sources of protozoan parasites. But because it is nearly impossible to locate or measure specific sources directly over such a large area, indirect methods were used. If concentrations of parasites in a stream were positively correlated with a certain land use factor, there is a good chance that the factor was responsible (at least in part) for the concentration.

The study did not attempt to deal with human health issues related to the rural population in the basin or whether the organisms found in samples were alive or infective. As well, different species in samples were not identified, because drinking water treatment plants have to assume that all species are potentially infective to human.

Watershed Characterization and Selection

The watershed of the North Saskatchewan River upstream of the city of Edmonton drains approximately 28,000 km^2. The study area, the basin draining the area from Rocky Mountain House to the city of Edmonton, consists of approximately 14,000 km^2 or half of the total upstream basin area (Figure 1). On average, 61% of the flow in the river at Edmonton comes from the watershed above Rocky Mountain House (average excludes the winter months). Of the 20 study streams, Nordegg and Baptiste rivers are the largest. During the study, the 20 streams contributed an average of about 14% of the flow in the river at Edmonton.

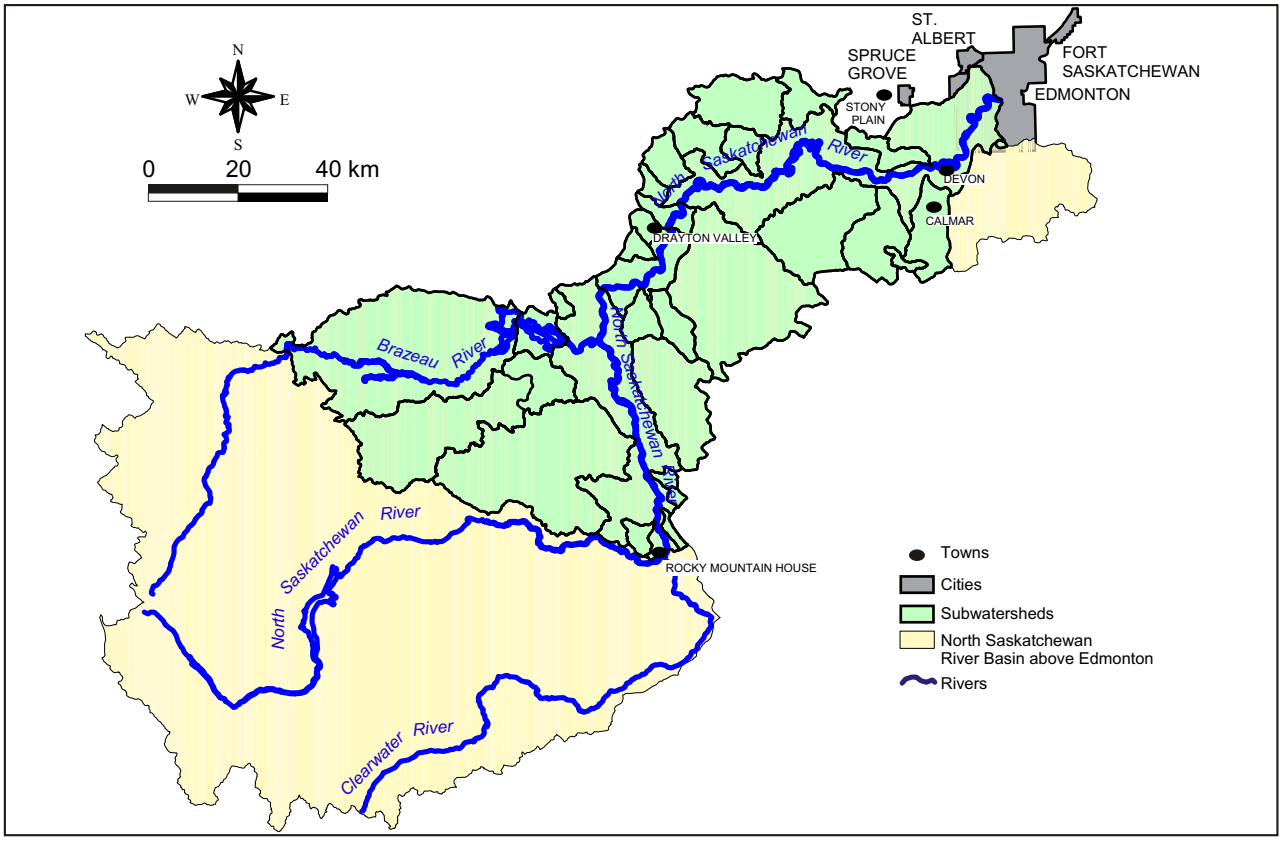


Figure 1. Map of study area.

Contaminants in streams, including protozoan parasites, are usually transported by flowing water. Water that drains from the surrounding land during snowmelt and rainstorms, carries various **chemicals**, organisms and soil particles - some natural and some the result of human activity. When human activities contribute any sort of chemical or biological substances that may adversely affect a desired use of water, it is called pollution.

Non-point source pollution is that from diffuse or undefined sources, mainly carried from the land in **runoff**. It is much more difficult to assess non-point sources of pollutants than those from **point sources**, such as from a pipe discharging from sewage treatment plants or drainage from confined livestock feeding operations. When a multitude of different land use activities occur in a watershed, the task of pinpointing sources becomes even more difficult.

Watershed-scale assessments of non-point sources of contaminants require detailed land-based and **water quality** information. Not all areas of a watershed contribute contaminants equally. To understand the link between water quality in a creek or river and human activities in the watershed, we must first identify and understand characteristics of the watershed: topography, geology, runoff potential, types of vegetation, density of people and livestock. Then, human activities that influence water quality the most can be identified and later targeted for remedial measures to reduce the movement of contaminants from land and water.

There are very few confined livestock feeding operations in the basin - agricultural activities are widespread on the landscape as opposed to being concentrated in specific areas. Of the total number cattle in Alberta, about 5% are in the North Saskatchewan River basin above Edmonton. When adjusted for the land base suitable for agriculture in the province, this area is the third most intensive

area for beef cattle production in Alberta (about 9 animals per square kilometre, compared with the highest at 10 per km^2). Most of the cattle production is concentrated in the area between Drayton Valley and Edmonton.

Figure 2 shows livestock density in each of the 20 study watersheds in animal unit equivalents per hectare. An animal unit equivalent is based on the size of the animal, and therefore amount of manure each type of livestock would produce. For example, a calf would produce less manure than a cow, so the number of calves is multiplied by 0.275. Cattle make up about 68% of the livestock in these watersheds.

Trees and shrubs are the predominant land cover in the study area (about 40% of the area). Other types of land cover include forage (21%), grassland (13%) and crops (10%). Most of the crop and forage land is located between Drayton Valley and Edmonton, whereas much of the upper basin is treed.

About 76,000 people live in the river basin above the city of Edmonton. Most of the region is rural, although there are 18 hamlets, eight summer villages, four villages and five towns scattered throughout the area. Only about 23,000 people are serviced by wastewater treatment facilities. The remainder is serviced by private septic systems.

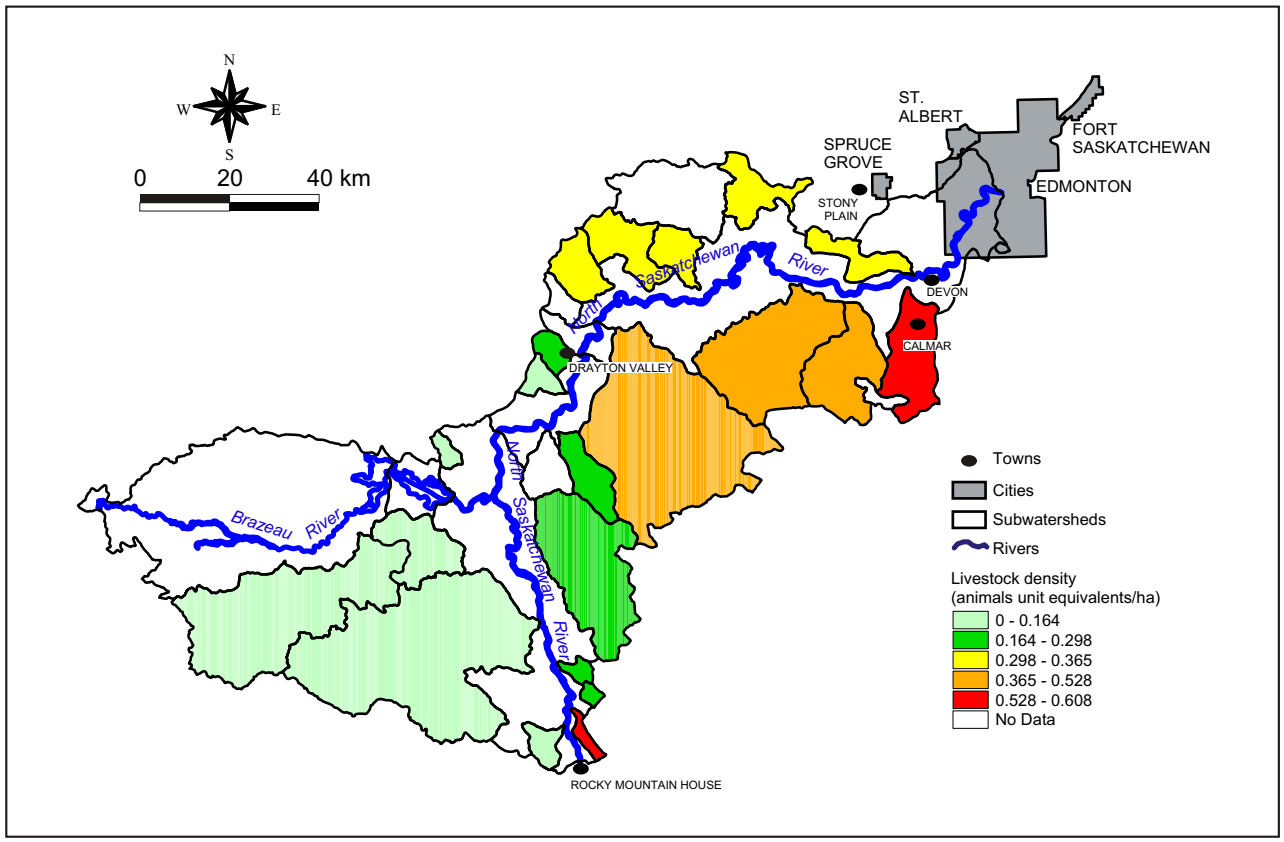


Figure 2: Density of total livestock in each study watershed in the North Saskatchewan River basin.

Overland runoff is an important factor influencing water quantity and quality. A model was used to estimate runoff potential from information on soils, slope, erosion, land cover and distance to stream for each of the 20 study watersheds. Forested streams ranked lowest for the likelihood of runoff, whereas watersheds with more cleared land and agriculture ranked highest.

Agricultural intensity in the 20 study watersheds, such as number of livestock and proportion of area farmed, was used to select six watersheds for more intensive study. Baptiste and Nordegg river watersheds have very little livestock production and are mainly forested. They are influenced primarily by wildlife. Throughout this report and the technical one, these control watersheds are called "non-agricultural or forested." Four agricultural watersheds were also chosen. Mishow and Tomahawk creek watersheds were ranked as having moderate agriculture, mostly cow-calf production. Compared with the other study watersheds, Strawberry and Weed creek watersheds have a high density of livestock, including beef cattle, dairy cattle, hogs and ranched elk and bison.

Parasite Prevalence

An obvious starting point for the study was to find out whether protozoan parasites were present in fecal material from livestock, wildlife and municipal sewage. This part of the study was not designed to determine whether or not parasites in animal feces or sewage actually did contaminate waterways, but only to determine whether the potential for contamination was there.

Cooperation with land owners and producers enabled the collection of fecal samples from beef and dairy cattle, hogs, ranched elk and bison, and wildlife. Livestock samples were generally collected in spring when calves were about three to six weeks old. Seven cow-calf operations were sampled in 1998, four operations were sampled in 1999 and six during 2000. Wildlife feces were collected in the spring immediately after snowmelt from 39 locations on forested land and along creeks in 18 of the 20 study watersheds. Thus, wildlife samples were collected from both agricultural and non-agricultural watersheds. Beaver and muskrat feces were collected from animals killed by trappers or county workers, which were likely fresher than feces of other wildlife collected from the ground. Even so, for other wildlife, samples collected from the ground, whether fresh or dried, represent the potential for contamination (in other words, the total "manure pack") from wildlife – if parasites in old or frozen feces are dead, they pose no risk to waterways.

Municipal sewage samples were collected from 16 treatment facilities. These samples were collected from storage cells or inflow lines at the facilities, and therefore represent raw or partly treated sewage, not treated sewage effluent (see next section for results of treated sewage effluent sampling). In total, more than 3800 samples were analyzed for parasite **prevalence**.

Prevalence was estimated as the percentage of the total number of samples in which parasites were present (i.e., positive samples). For example, 1561 fecal samples from beef cattle were examined. Of these, 458 contained giardia cysts (29%) (see Table 1). This is a fairly high prevalence. Concentration (number of parasites per gram of feces) in each positive sample was also estimated. For example, an average concentration of 3,742 cryptosporidium oocysts per gram was present in ranched elk, which is high compared with other agricultural sources (no parasites were detected in wild elk feces). A combination of high prevalence and high concentration would represent the greatest risk for contaminating surface water.

The results of the prevalence study confirm that agriculture, municipal sewage and wildlife are all potential sources of waterborne parasites. Except for muskrat, feces from beef cows and calves had the highest concentration and prevalence of giardia among all animals surveyed (see Table 1). The prevalence in partly treated sewage was high, but this is likely because parasites are more evenly distributed in sewage than in individual fecal samples. Thus, the chance that a sample would contain parasites is greater than for feces, resulting in higher prevalence.

Concentration in sewage is not reported, because the samples were greatly diluted by water, and therefore not representative of that in human feces.

The highest concentration of cryptosporidium was found in feces from ranched elk and bison. Cryptosporidium was not observed in feces from adult cattle, although samples were collected only in spring. For beef cattle feces, parasite concentration and prevalence varied considerably from year to year and between cattle operations.

Table 1. Prevalence and concentration of giradia cysts and cryptosporidium oocysts in fecal samples from livestock and wildlife, and prevalence in partially treated municipal sewage samples. Prevalence (Prev) is percentage of fecal samples with parasites. Concentration is number per gram in positive samples. NA = not applicable.

		Sample Size	*Giardia* spp.		*Cryptosporidium* spp.	
			Prev (%)	Average Concentration	Prev (%)	Average Concentration
Livestock:	Beef Cattle	1561	29	5801	3	267
	Dairy Cattle	92	18	16	18	254
	Hogs	40	17	16	0	0
	Elk (ranch)	38	16	1665	21	3742
	Bison (ranch)	41	15	2649	5	2369
	Horse	1	0	0	0	0
Total samples		1773				
Average concentration				5433		700
Municipal Sewage:		166	49	NA	10	NA
Wildlife:	Lynx	1	0	0	0	0
	Marten	4	0	0	0	0
	Fisher	3	0	0	0	0
	Porcupine	8	0	0	0	0
	Deer	649	<1	1168	<1	12
	Moose	177	<1	168	0	0
	Elk (wild)	34	0	0	0	0
	Coyote	99	5	1577	0	0
	Wolf	2	0	0	0	0
	Hare	453	0	0	0	0
	Snow Goose	20	0	0	0	0
	Canada Goose	57	0	0	0	0
	Grouse	50	0	0	0	0
	Squirrel	15	0	0	0	0
	Mouse	2	0	0	0	0
	Beaver	334	9	1654	2	509
	Muskrat	23	78	9574	0	0
Total samples		1931				
Average concentration				4196		444

Of the three major sources (livestock, wildlife and sewage), wildlife was the least important source of cryptosporidium, in terms of prevalence. Of the nearly 2000 wildlife scat samples collected, cryptosporidium was present in only nine samples, eight of which were beaver and one was deer. Although the prevalence in beaver samples was low, the concentration was moderately high. The percentage of wildlife samples containing giardia was very low or zero for all species except muskrat and beaver. Even for beaver, less than 9% of samples contained giardia (compared with 78% for muskrat). The concentration of giardia in muskrat feces was quite high. It is not clear why beaver feces had lower prevalence of giardia than those of muskrat as both animals are exposed to similar contaminated waterways.

Water Quality

Water flowing over the land can pick up parasites, nutrients, organic matter, fecal bacteria and other water quality constituents. This runoff gathers in streams and eventually reaches the North Saskatchewan River. Sometimes cysts and oocysts are attached to soil particles or organic matter, or they may be picked up directly by water and carried along. During runoff**,** such as spring snow melt and summer rains, concentrations of many substances (including parasites) in the river increase. Therefore, the water sampling for the study focussed on runoff periods, although a few samples were collected during periods of low river flow.

The study was designed to obtain more intensive information each year, because little was known about water-borne parasites in the basin. During the three-year study, about 600 water samples were collected from **tributary** streams, municipal sewage effluent and raw/treated drinking water.

Each year, water samples were collected from 20 major tributaries in the North Saskatchewan River basin. This was called the "Longitudinal Survey." This survey provided an overview of the water quality in a variety of streams, as well as year-to-year differences.

In 1999, six streams were chosen from the 20 streams for more intensive sampling, called the "Intensive Watershed Survey." The six streams were chosen based on watershed characteristics, including livestock numbers, and were sampled in 1999 and 2000. The main purpose of this survey was to be able to relate concentrations of parasites and other water quality characteristics with land use. Two of these streams were chosen because very few cattle and other livestock were in the watersheds. These study watersheds were called "non-agricultural" or "forested" streams and serve as controls or references for the other four watersheds (called "agricultural streams"). Also in 1999, samples were collected upstream and downstream of three cattle operations to determine their impact on the stream ("Upstream-Downstream Study").

In 2000, two of the Intensive Watershed streams were sampled at several sites to determine whether some areas of the watersheds contributed more parasites than others ("Synoptic Survey").

Treated sewage effluent from the continuously discharging facilities which discharge directly to the river was also sampled every two months or monthly year-round, and from municipal sewage lagoons when they discharged. As well, samples were collected from the raw and treated drinking water at each drinking water treatment plant that uses the North Saskatchewan River as a source.