Assessing the Link Between Rangeland Cattle and Water-borne *Cryptosporidium parvum* Infection in Humans

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Background

Cryptosporidium parvum (*C. parvum*) is a tiny protozoal parasite that can cause gastrointestinal illness in a wide variety of mammals, including humans, cattle, sheep, goats, pigs, and horses. It also occurs in various wildlife species such as deer, raccoons, opossums, and rabbits (Fayer et al. 1990, Ungar 1990). In cattle, clinical disease and shedding of the parasite is usually limited to calves under a few months of age (National Animal Health Monitoring System 1994, Kirkpatrick 1985, Anderson and Hall 1982). Although not confirmed by studies done in the U.S., researchers in England and in Spain have reported the shedding of *C. parvum* in adult beef cattle (Scott et al. 1994, Lorenzo Lorenzo et al. 1993). In humans, clinical disease and shedding can appear at all ages, but is typically more common among children (Ungar 1990). The predominant clinical sign is profuse, watery diarrhea lasting from a few days to several weeks in normal (immunocompetent) calves (Kirkpatrick 1985) and humans (Jokipii and Jokipii 1986). While this disease is usually self-limiting in immunocompetent calves and humans, it can be prolonged and life-threatening among immunocompromised people such as AIDS patients. An effective treatment for eliminating this parasite from the gastrointestinal track still does not exist. A few antibiotics may show some promise in reducing the amount of oocyst shedding in AIDS patients, but further clinical trials are needed to fully evaluate their efficacy (White et al. 1994, Goodgame et al. 1993). The severity of this disease for the immunosuppressed and the fact that this parasite was implicated in recent large scale water-borne outbreaks of gastroenteritis in humans (MacKenzie et al. 1994, Hayes et al. 1989) has prompted the U.S. Environmental Protection Agency (U.S. EPA), Centers for Disease Control and Prevention, state and local public health agencies and regional water districts to seek ways to reduce surface water contamination of this parasite. Some of this attention has focused on identifying the primary sources of *C. parvum* in surface water. Cattle are often perceived to be a leading environmental source of water-borne *C. parvum*. For example, the U.S. EPA has explicitly warned that inclusion of *C. parvum* into the proposed Enhanced Surface Water Treatment Rule will likely result in new restrictions being placed on the location and management of livestock operations situated within watershed regions (U.S. EPA 1994). Presented below is a brief summary of the medical ecology of *C. parvum* in calves and in humans and the existing scientific evidence that addresses the claim that grazing of cattle on watershed regions puts humans at significant risk for water-borne infection of *C. parvum*.

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Life Cycle

In calves and in humans, transmission occurs when an infected individual fecally sheds oocysts (eggs) of this parasite into the environment and a susceptible individual inadvertently ingests these oocysts either directly or indirectly through such vectors as contaminated water. The parasite then invades the epithelium of the intestine, replicates, and through sequential reproductive cycles can result, as in the case of calves, in the fecal shedding of up to 10^{10} oocysts per day and up to 10^7 oocysts per gram of feces (Blewett 1989). Shedding of oocysts can last for 3–12 days in calves (Anderson 1981), allowing for heavy concentrations of oocysts to build up in confined operations. A similar pattern is seen in humans, whereby infected individuals can shed up to 10^5–10^7 oocysts per gram of feces (Goodgame et al. 1993), with a duration of shedding varying widely from individual to individual and which can range from a few to more than 50 days (Jokipii and Jokopii 1986). Once shed, these oocysts are immediately infective to another individual, allowing for the rapid spread of this parasite within a group of susceptible individuals.

Oocysts shed from one species of mammal appear to be infectious to other species of mammals. Oocysts from humans have been shown to be infectious to a wide variety of livestock and companion animals (Fayer et al. 1990). Oocysts from calves and possibly other mammals appear to be infectious to humans (Dupont et al. 1995, Fayer et al. 1990). People working with diarrheic calves infected with *C. parvum* have themselves become infected with *C. parvum*, presumably from the calf. However, working with diarrheic calves is not common for the general public.

The Issue

The critical issue is how does *C. parvum* from calves gain access to surface waters and end up in drinking water supplies. The essential steps must include calves becoming infected and shedding the oocysts in their feces. These oocysts must then enter a surface water supply and remain ineffective as they journey downstream to water treatment plants and distribution systems.

How common is it for calves with access to surface water to shed this parasite? Few studies have been done in beef calves, with most research conducted on dairy calves. One of the largest surveys to date on shedding of *C. parvum* in beef calves was conducted by the USDA's National Animal Health Monitoring System in cooperation with USDA's National Veterinary Services Laboratories in which 20% of diarrheic calves (n=391) and 11% of non-diarrheic calves (n=1,053) from a total of 210 operations were found to be shedding *C. parvum* oocysts at the time of sampling (National Animal Health Monitoring System 1994). Around 40% of these 210 operations had one or more calves shedding *C. parvum* oocysts at the time of sampling. In this same study shedding of oocysts was documented in 9% of asymptomatic calves between 3 and 6 months of age, indicating that shedding can occur in these older age groups and without clinical signs. In Manitoba, Canada, 22% of beef calves from 148 herds known to have problems with neonatal diarrhea were found to shed *C. parvum* (Mann et al. 1986). In England, 36–39% of diarrheic beef calves tested positive for *C. parvum* while only 8% of healthy beef and dairy calves tested positive (Reynolds et al. 1986). From across the United States, 22% of 7,369 dairy calves tested positive for this parasite (Garber et al. 1994). This parasite appears to be relatively common in dairy calves, but we need much better information on the distribution of *C. parvum* shedding in beef cattle herds located on open range with access to important watersheds.

Wildlife Considerations

Little is known about the prevalence of shedding among wildlife species with access to surface waters or what contribution humans themselves make to surface water contamination. In a survey of 100 raccoons, 13 juveniles had oocysts in their feces (Snyder 1988). Cryptosporidial infection has been confirmed in grey squirrels (Sundberg et al. 1982) and in a large variety of neonatal captive deer, including mule deer (Heuschele et al. 1986). Thirty percent (35/115) of wild mice trapped at a dairy shed contained oocysts (Klesius et al. 1986). Oocysts obtained from these mice were shown to be infective to calves, perhaps indicating a mouse-calf cycle.

Human Considerations

The prevalence of shedding among groups of people is highly dependent on country and population and can range from 0–60%, with the higher proportion of shedding among diarrheic individuals (Ungar 1990). The Centers for Disease Control and Prevention estimates that the overall background prevalence of shedding in the United States is around 0.5–1.0%, but the relationship between shedding in humans and levels of viable *C. parvum* oocysts in surface water contamination remains unknown. Outbreaks of human cryptosporidiosis have been linked to swimming in pools (Bell et al. 1993). Also unknown is what proportion of cryptosporidiosis in humans is due to water-borne infection as opposed to human-to-human direct infection.

Survivability

How long do *C. parvum* oocysts survive in the environment once they are shed in feces? Oocysts became nonviable after several hours of in-door drying at room temperature (Robertson et al. 1992). Oocysts recovered from calf fecal patties which had been kept inside a barn (summer) or inside an unheated shed (winter) became non-infective for 3–7 day old mice in 1–4 days (Anderson 1986). If fecal material thoroughly dries before reaching water, the oocysts would presumably become non-infectious for animals and humans. Ten or more days of freezing at –22°C caused over 90% of oocysts to become non-viable (Robertson et al. 1992). Oocysts in distilled water became non-infective if heated to 72.4°C or higher for 1 minute or if heated to 64.2°C or higher for 2 minutes (Fayer 1994). What if fecal material is deposited directly in a stream? One study found that after 33 days in river water, an estimated 34–40% of purified oocysts were incapable of excystation. After 176 days, 89–99% were estimated to be incapable of excystation (Robertson et al. 1992). It may be that most oocysts do not remain infective as they journey from infected calves to surface water to water treatment plant to human consumption. Although there are severe environmental pressures for oocysts to remain infective when excreted on land, apparently only a few oocysts would need to remain viable in order to pose a risk to humans. Experimental studies in healthy humans determined that the infectious dose at which 50% of subjects acquire infection (ID_{50}) was 132 calf-derived oocysts, with as few as 30 oocysts sufficient to induce cryptosporidiosis (Dupont et al. 1995).

Cattle and *Cryptosporidium* in Water

What evidence directly links the presence of *C. parvum* in surface water supplies to livestock production? In attempting to answer this question, one must test water samples which is a procedure with some limitations. Environmental studies to date have had a difficult time determining if the *Cryptosporidium* found in surface water is *C. parvum* or some other *Cryptosporidium* species not infectious to humans yet detected by one of the laboratory assays used for environmental testing. For example, it appears that *C. muris* which is shed by cattle, rodents, and other mammals and *C. meleagridis* which can be shed by turkeys, both of which are not infectious to humans, can cross-react to some degree with the Merifluor monoclonal antibody produced by Meridian Diagnostics, Inc. (Smith and Rose 1990). We have confirmed in our laboratory that isolates of *C. muris* obtained from adult dairy cattle from the central San Joaquin Valley in California can cross react with the Merifluor monoclonal antibody. Hence, the possibility of false positives does exist. On the other hand, the recovery efficiency for testing raw water samples, which is the estimated proportion of oocysts recovered out of all oocysts initially present, can vary from below 10% to as high as 60% (Smith and Rose 1990). Hence, water samples with lower concentrations of oocysts could be erroneously classified as negative. With these limitations in mind (likelihood of false positives or false negatives), *Cryptosporidium* oocysts are quite common throughout the surface water supplies of the United States. For example, 50–60% of raw water samples from primarily Midwest and East Coast surface water sources were positive for *Cryptosporidium* oocysts. The geometric mean of detectable levels of *Cryptosporidium* oocysts was 2.4–2.7 oocysts/liter, with a range between 0.07 and 484 oocysts/liter (LeChevallier and Norton 1995, LeChevallier et al. 1991). Rose, 1988, detected *Cryptosporidium* oocysts in 51% of 111 raw surface water samples from 13 states. Large west coast rivers in Washington and in California were found to have concentration of *Cryptosporidium* oocysts ranging from 2 to 112 oocysts/liter, with a mean of 25 oocysts/liter (Ongerth and Stibbs 1987). Yet, the link between cattle grazing and elevated levels of *Cryptosporidium* oocysts in surface water is not very clear. For example, one study found little difference in the concentration of *Cryptosporidium* oocysts from protected surface waters (0.3–4.0 oocysts/liter) as compared to surface waters subject to agricultural run-off (0.1–2.0 oocysts/liter) (LeChevallier et al. 1991). Moreover, 68% of these oocysts had become non-viable. Another study measured 5,800 oocysts/liter in irrigation canal water running through agricultural acreage with cattle pastures (beef or dairy not specified), compared to 127 oocysts/liter in river water subject to human recreation and 0.8 oocysts/liter for stream water exposed to ranch land runoff (Madore et al. 1987). Finally, concentrations of *Cryptosporidium* oocysts from pristine surface waters have been found to contain 0.005–18 oocysts/liter, indicating that this organism occurs naturally in pristine watersheds (Madore et al. 1987). This would suggest that wildlife will need to be carefully examined for their role in contaminating surface water with this parasite.

Conclusion

The scientific evidence supporting the claim that cattle are a significant source of *C. parvum* for surface water is incomplete and contradictory in some cases. Until we have more detailed studies that clarify this rangeland-public health issue and provide a causal link between grazing practices and elevated levels of infective *C. parvum* in associated surface water, it would be premature at this time to claim that cattle production is a leading environmental source of infective *C. parvum* for water. If, in the words of US EPA (1994), we are to "minimize the potential for source water contamination" by *C. parvum*, then we must first identify the primary quantitative source(s) of this parasite in the environment, be it livestock, wildlife, humans, companion animals, or human-associated sewage effluent, and strive to unravel the medical ecology of this parasite.

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