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Quantitative Risk Assessment of *Cryptosporidium* Species Infection in Dairy Calves

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ABSTRACT

Cryptosporidium parvum is a zoonotic protozoan that infects many different mammals including cattle and humans. Cryptosporidiosis has become a concern for dairy producers because of the direct losses due to calves not performing well and the potential for environmental contamination with *C. parvum*. Identifying modifiable control points in the dynamics of infection in dairy herds will help identify management strategies that mitigate its risk. The quantitative risk assessment approach provides estimates of the risk associated with these factors so that cost-effective strategies can be implemented. Using published data from epidemiologic studies and a stochastic approach, we modeled the risk that *C. parvum* presents to dairy calves in 2 geographic areas: 1) the New York City Watershed (NYCW) in southeastern New York, and 2) the entire United States. The approach focused on 2 possible areas of exposure—the rearing environment and the maternity environment. In addition, we evaluated the contribution of many risk factors (e.g., age, housing, flies) to the end-state (i.e., total) risk to identify areas of intervention to decrease the risk to dairy calves. Expected risks from *C. parvum* in US dairy herds in rearing and maternity environments were 41.7 and 33.9%, respectively. In the NYCW, the expected risks from *C. parvum* in the rearing and maternity environments were 0.36 and 0.33%, respectively. In the US scenarios, the immediate environment contributed most of the risk to calves, whereas in the NYCW scenario, it was new calf infection. Therefore, within the NYCW, risk management activities may be focused on preventing new calf infections, whereas in the general US population, cleaning of calf housing would be a good choice for resource allocation. Despite the many assumptions inherent with modeling techniques, its usefulness to quantify the likelihood of risk and identify risk management areas is illustrated.

(**Key words:** cattle, risk assessment, *Cryptosporidium*, watershed)

Abbreviation key: NYCW = New York City Watershed, **P1**, **P2**, **P3** = probabilities of sources of *C. parvum* from infected calves (P1), oocysts in the calf rearing environment (P2), or oocysts on fomites (P3).

INTRODUCTION

Cryptosporidium parvum is a zoonotic protozoan recognized as one of the primary pathogens causing diarrhea in neonatal calves (de la Fuente et al., 1999; Naciri et al., 1999). The organism, depending on genotype (Morgan et al., 1997; Peng et al., 1997), causes usually self-limiting diarrhea in immunocompetent human patients, but causes life-threatening disease in those with immunodeficiencies (O'Donoghue, 1995). It has emerged as one of the most recognized causes of waterborne outbreaks of gastrointestinal illness (MacKenzie et al., 1994) as well as being associated with foodborne outbreaks (Quiroz et al., 2000) and sporadic cases (McLauchlin et al., 2000). By their location in watersheds, cattle have been implicated as a source of *C. parvum* associated with these examples (Smith and Rose, 1990), despite lack of direct evidence. The possible losses to a dairy operation from *C. parvum* are many. One is the direct loss in profitability from calves that do not perform as well due to morbidity. Other losses include less directly quantifiable losses that may arise from government restrictions on animal agriculture because of the zoonotic potential of the organism, as well as decreased consumer confidence in animal agricultural products.

It is necessary to find management approaches to prevent the risk of cryptosporidiosis. There are multiple reasons to take a preventive approach to this disease, not least among them is that there are no consistently effective and approved chemotherapeutics for cattle or humans (Woods et al., 1996; Blagburn and Soave, 1997). Furthermore, at recommended concentrations, most commercial disinfectants are not effective at killing *C. parvum* oocysts (Campbell et al., 1982; Ares-Mazas et al., 1997). Because of their small size, oocysts evade

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most water treatment facilities attempts to remove them and thus remain in finished water. To date, no vaccines have been marketed that have proven efficacious in preventing cryptosporidiosis, although there is current experimental work in this area (Perryman et al., 1999). Another reason to prevent the disease is that the life cycle of *C. parvum* is such that oocysts are immediately infective upon excretion and are transmitted via the fecal-oral route.

To design cost-effective strategies to minimize the associated risk of *Cryptosporidium* in dairy herds, a systematic approach of examining the dynamics of infection in the population and its environment is necessary. Quantitative risk assessment is one approach that provides a means to assess the risk and its impact (Vose, 2000), including microbial risk assessments for potentially zoonotic pathogens such as *Escherichia coli* O157:H7 and *Listeria monocytogenes* (Bemrah et al., 1998; Ebel et al., 2004). Two common risk assessment models are currently used of which an adaptation to animal health has been proposed by the Office Internationale des Epizooties (OIE, 2001). Carrying out a comprehensive risk assessment for cryptosporidiosis in watersheds is a complex task. A reasonable approach is the parsimonious one in which the complex risk scenario is partitioned into complementary units that can be integrated through multiple studies toward a comprehensive risk assessment.

The many factors associated with cryptosporidiosis and their complex interaction necessitates a systematic investigation of a multistep process that incorporates the inherent uncertainty involved at each step. Risk assessment, one of the components of risk analysis, offers a means to a systematic investigation. The present investigation focused on the risk *C. parvum* poses to dairy calves, on-farm, using data from 2 different geographic areas—the New York City Watershed (**NYCW**) and the United States as a whole. The process also identified some areas for potential risk mitigation activities that could decrease the likelihood of this protozoan on dairy farms.

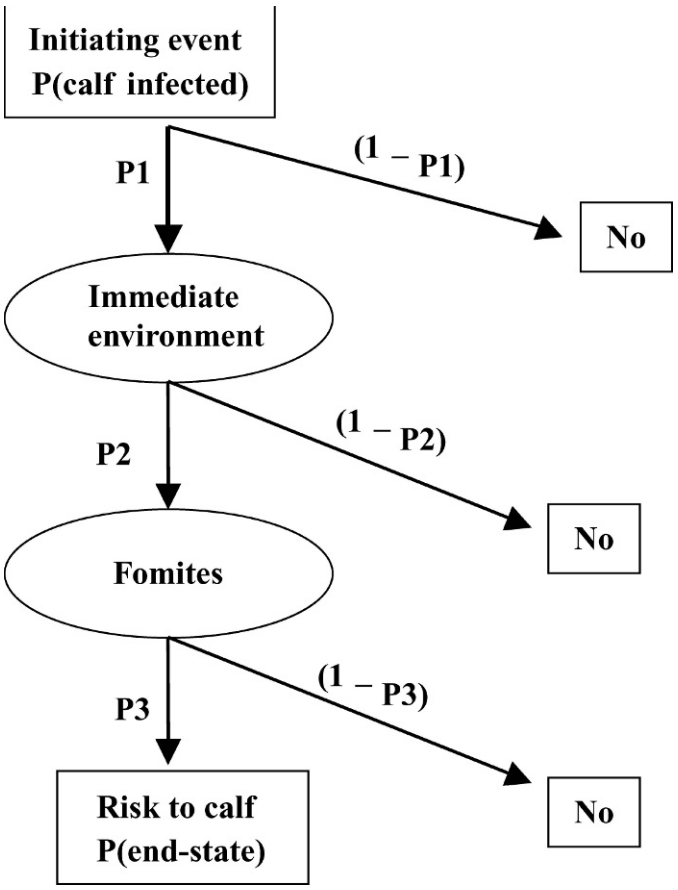

Figure 1. The conceptual framework for the event tree used in the model to describe the dynamics of *Cryptosporidium parvum* in dairy calves. P1, P2, and P3 represent the probability of *C. parvum* at each stage. Downward arrows indicate a route of transmission. No = Absence of risk.

MATERIALS AND METHODS

We adopted a risk assessment approach to address the stated objectives. This involves organizing and analyzing the information to arrive at an estimate of the probability of the risk occurring. The model we are following is based on the model of Covello and Merkhofer (1993) and adopted by the Office Internationale des Epizooties. The framework of the model consists of 4 steps: release assessment, exposure assessment, consequence assessment, and risk characterization. We used the scenario pathway analysis and event-tree methods to describe the dynamics of infection of *Cryptosporidium* in dairy calves. A conceptual framework for the event tree is presented in Figure 1. The end-state or final probability represents the risk (likelihood) of infection to susceptible calves in the dairy environment (Figure 1). Four different risk scenarios were investigated in this study: rearing environment on dairies in the NYCW (1a; Figure 2); maternity environment on dairies in the NYCW (1b); rearing areas on dairies in the United States at large (2a); and maternity environment on dairies in the United States (2b); each generating an end-state probability.

Release Assessment

The focus in this investigation was on *C. parvum* genotypes that are infective to calves. The primary source of *C. parvum* in the analysis was cattle; other potential sources of oocysts such as wildlife and humans