COMPARISON OF HOST, HERD, AND ENVIRONMENTAL FACTORS ASSOCIATED WITH SEROPOSITIVITY TO *NEOSPORA CANINUM* AMONG ADULT DAIRY AND BEEF CATTLE IN ALBERTA

A Thesis

by

MARK COLTON DIETZ

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2008

Major Subject: Epidemiology

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Approved by:

Chair of Committee, H. Morgan Scott
Committee Members, Bo Norby
Karen Snowden
Head of Department, Evelyn Tiffany-Castiglioni

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ABSTRACT

Comparison of Host, Herd, and Environmental Factors Associated with Seropositivity to *Neospora caninum* Among Adult Dairy and Beef Cattle in Alberta. (December 2008)

Mark Colton Dietz, B.S., The University of Texas at Austin

Chair of Advisory Committee: Dr. H. Morgan Scott

This study represents an analysis of serological and risk factor data collected previously in Alberta, Canada, involving neosporosis in beef and dairy cattle. The causative agent of neosporosis, *Neospora caninum* (NC), is a single-celled, apicomplexan protozoan parasite in which domesticated dogs have been identified as the definitive host. The primary economic impact involves beef and dairy cattle due to associated abortions and neonatal mortality. The data used in this study were collected for cattle in both dairy and beef herds in an identical manner permitting a direct comparison of host-, herd-, and environmental risk factors for neosporosis among beef and dairy cattle using descriptive statistical methods and the construction of multivariable models. The outcome assessed in the multivariable models was cow-level seropositivity for antibodies to *N. caninum*. Individual-level fixed, herd-level fixed, and random effects were evaluated with respect to the outcome. In the final multivariable models, there were few statistically significant potential risk factors identified. In the beef multivariable model, the significant explanatory factors were related to acreage of farm, site of calving, and pH of soil. Among the potential risk factors identified in the three multivariable models it appeared seropositivity to NC among beef cattle is more related to environmental conditions; on the other hand, it seems that seropositivity to NC

in dairy cattle pertains to associated management factors. In the future, longitudinal studies are needed to explore the validity of the current knowledge regarding *N. caninum* by investigating potential risk factors that have been identified due to the fact that cross-sectional studies can not prove association.

DEDICATION

I would like to dedicate this thesis to my family. They have been a source of support from the very beginning to the end. I appreciate my parents' sacrifices that they made so that I would have the opportunities that have led me to where I am today.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. H. Morgan Scott, for his help throughout my education here at Texas A&M University. I appreciate his willingness to help me find this new project when the original project hit a seemingly permanent road block. I greatly appreciate his time and willingness to help me succeed within the program and beyond. I would like to thank the rest of my committee members, Drs. Bo Norby and Karen Snowden, who were always willing to help and offer advice. In addition, I would like to thank Dr. James Thompson for permitting me to use the risk maps that he developed using this data set.

I would like to thank my fellow graduate students who were always willing to help in a time of need. Their support throughout this process has been tremendous and greatly appreciated.

Lastly, I would like to thank the beef producers, dairy producers, and the Alberta Johne's Control Program-accredited veterinarians who participated in the study. The scientists and technical staff of the Agri-food Laboratories Brand of the Food Safety Division of Alberta Agriculture, Food and Rural Development (AAFRD) are owed a word of thanks for their efforts. In addition, the resource specialists from the Conservation and Development Division of AAFRD and from Agriculture and Agri-food Canada are owed thanks for providing geographical information systems (GIS) and AGRASID 3.0 Alberta soil data analysis.

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CHAPTER I

INTRODUCTION

Neosporosis is an infectious disease caused by *Neospora caninum* (NC), an apicomplexan protozoan, which has been linked to abortions and neonatal mortality in cattle throughout the world. In 1984, the parasite was first recognized in dogs (Bjerkas et al., 1984) and, in 1988, it was proposed as a new genus and species called *Neospora caninum* (Dubey et al., 1988).

While the life cycle of NC is not yet fully understood, there has been a great effort to identify the definitive and intermediate hosts that allow NC to persist in domestic bovine populations. It is believed that domestic dogs (McAllister et al., 1998; Lindsay et al., 1999) and coyotes (Gondim et al., 2004a) are definitive hosts, and many other species of mammals including cattle, sheep, horses, deer (Dubey and Lindsay, 1996), rodents (Huang et al., 2004) may serve as intermediate hosts. The existence of a sylvatic cycle for NC in North America may make the control of the disease difficult (Gondim et al.; 2004b), (Vianna et al., 2005) due to the interaction between wildlife and domestic farm animals.

This thesis will follow the journal, *Preventive Veterinary Medicine*.

The importance of neosporosis in Canadian cattle was recently reviewed (Haddad et al., 2005). The authors concluded that there was a need for more research to better understand the disease and associated risk factors (Haddad et al., 2005). In previous studies, conclusions concerning risk factors for NC among beef and dairy cattle were drawn from vastly different study designs, making comparisons between studies, and particularly the two herd types, difficult. Therefore, the use of these studies in comparisons of potential risk factors for neosporosis among beef and dairy cattle should not be considered valid.

The unique design of the present study facilitates direct comparisons and contrasts of the host-, herd-, and environmental factors associated with seroprevalence of NC in dairy and beef cattle herds throughout Alberta, Canada (Scott et al., 2006; Scott et al., 2007). The objectives of this cross-sectional study were to: 1) analyze various agro-ecological features in an effort to further understand the factors related to NC seropositivity in beef and dairy cattle, and 2) to investigate the differences in seroprevalence between beef and dairy cattle, as cited in previous works (Haddad et al., 2005; Scott et al., 2006; Scott et al., 2007). The final objective was to provide the beef and dairy producers with useful information relating to methods to reduce seropositivity on the farms and potentially lessen economic losses due to NC. In this study, we have expanded upon the current literature regarding neosporosis in cattle by providing information concerning the varying levels of within-herd variances when comparing beef and dairy cattle herds. This information is important in elucidating the herd-level differences and potential for control of neosporosis in beef and dairy cattle.

CHAPTER II

LITERATURE REVIEW

In 1988, *Neospora caninum* (NC) was named as the etiological agent of the disease, neosporosis, which may affect a variety of species including canine, bovine, and a wide variety of wildlife. Prior to 1988, infections with NC were often misdiagnosed as toxoplasmosis in dogs, which is caused by *Toxoplasma gondii* (Dubey et al., 1988). Since this discovery, there have been numerous studies investigating NC and associated disease in cattle and wildlife (Dubey et al., 2003). The primary focus of previous research has been on the disease processes leading to abortion and neonatal death in cattle due to the associated substantial economic losses (Dubey, 2003). This chapter provides a brief ecological description of Alberta, Canada, and a review of the current knowledge of *Neospora caninum* primarily in cattle. The review includes: the ecology of Alberta, the life cycle, risk factors for infection and abortion, overview of economic impact, and control measures for disease.

Agro-ecological Description of Alberta, Canada

This section is meant to familiarize the reader with the diverse agroecological regions of the province of Alberta. The land area in Alberta, Canada, is vast comprising 661,848 square kilometers extending from 49° latitude to 60° latitude (Atlas of Canada, 2006). The Canadian Rockies form the southwestern border of the province with the remainder of the province comprised of plains and rolling hills. The primary agricultural areas, extending from 49° to 56° latitude, are composed of several unique agroecological regions varying in types of soil and climate. The agroecological regions are a composite of various soils, climate, and vegetative factors (AGRASID, 2006). As can be seen in Figure 2.1, the four major agro-ecological regions are the grasslands, parklands, montane, and boreal forest.

The grassland areas are located in the southeastern portion of the province being comprised of fertile soils and a climate consisting of slight to moderate heat and precipitation moisture limitations. The parkland areas adjoin the grassland areas, and they are characterized by black and dark gray soils with climate conditions ranging from slight to severe moisture and heat limitations. The montane areas are classified by dark brown and thin black top-soils with climatic conditions ranging from slight to severe moisture and heat limitations. The boreal forest areas have been classified by dark gray soils and climatic conditions ranging from slight to severe moisture and heat limitations (AGRASID, 2006). The heat and moisture limitations mentioned above refer to the types of vegetation that may grow in the region based on temperatures and rainfall in the region.

Life Cycle of *Neospora caninum*

Neospora caninum is an apicomplexan coccidian parasite with a life cycle and morphology very similar to *Toxoplasma gondii* (Dubey, 2003). The main differences involve the host species, because neosporosis is primarily a disease of cattle and canids; whereas, toxoplasmosis is a disease involving a feline-rodent life cycle with humans, sheep, goats being accidental hosts. In humans, antibodies to NC have been discovered, but the parasite has not been isolated from tissue (Lobato et al., 2006; Tranas et al., 1999).

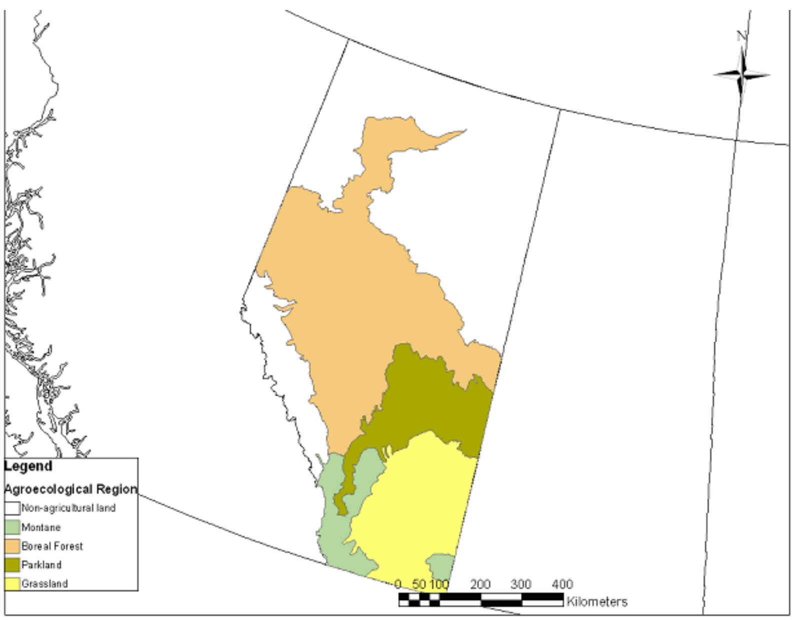

Figure 2.1. Map of Agroecological Regions in Alberta, Canada.
Scott, H. Morgan et al. Seroprevalence and agroecological risk factors for MAP and NC in Alberta, Canada. CVJ. Vol. 48. 2007

The life cycle of NC is typical of an apicomplexan parasite with an indirect life cycle using a predator (definitive host) and a prey (intermediate host) or carnivore/herbivore cycle as seen in Figure 2.2. It is characterized by three infectious stages: tachyzoites, tissue cysts (bradyzoites), and oocysts (Dubey, 2003). Tachyzoites are rapidly asexually replicating intracellular stages found in tissues in active infection, and tissue cysts are inactive clusters of parasites found in the tissues of the intermediate host. Bradyzoites are the individual parasites, found clustered within the tissue cyst, having a slowed metabolism and maintain infection in the intermediate host. Oocysts are environmentally resistant stages that result from sexual replication in the gut of the definitive host and shed to the environment in feces requiring a period of time for sporulation to occur producing infectious oocysts (Dubey, 2003). The definitive host has been found to be the domestic dog (Dubey et al., 1988) and coyote (Gondim et al., 2004a). In the Gondim et al. (2004a) study, a low number of oocysts were shed in the feces of coyotes. In addition to domestic dogs and coyotes, intermediate host species in which *N. caninum* tachyzoites have been identified include: cattle, sheep, white-tailed deer, and water buffalo (Gondim et al., 2004b; Koyama et al., 2001; Rodrigues et al., 2004, Vianna et al., 2005).

The transmission of NC occurs through a combination of mechanisms involving vertical and horizontal routes of infection (Dubey et al., 2007). Vertical transmission refers to the passage of tachyzoites from the mother to offspring through the placenta before birth or within the first two weeks after birth due to consumption of milk or colostrum containing tachyzoites. Horizontal transmission in intermediate and definitive hosts involves a fecal-oral route of ingestion of infectious sporulated oocysts that have been shed to the environment by a definitive host. In addition, in the canid definitive host, horizontal transmission may occur through the consumption of tissue from intermediate hosts that are infected with bradyzoites or tissue cysts.

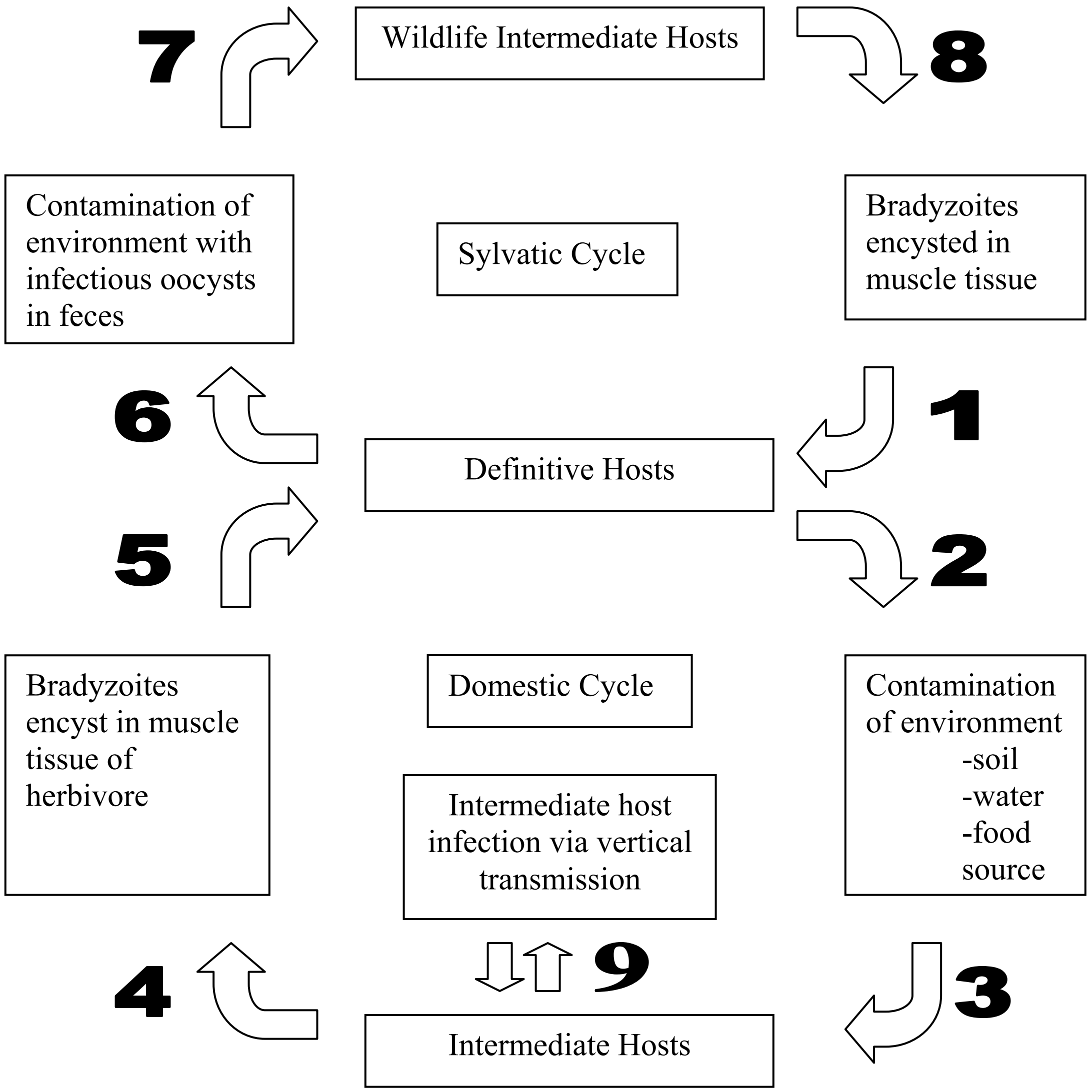

Figure 2.2. Life Cycle of *Neospora caninum* (adapted from Dubey and Trees). 1. Definitive hosts are infected by consuming tissue infected with bradyzoites from wildlife intermediate hosts. 2. Definitive hosts shed oocysts to the environment in the feces. 3. Infective oocysts are consumed by intermediate hosts. 4. Bradyzoites encyst in the muscle tissue of the intermediate host. 5. Definitive host is infected by consuming infected muscle tissue. 6. Definitive hosts shed oocysts in to the environment via feces. 7. Intermediate hosts are infected when consuming infectious oocysts. 8. Bradyzoites become encysted in muscle tissue. 9. Vertical transmission maintains infection within the bovine intermediate host herd.

Recently, it has been suggested that vertical transmission should be further categorized using the terms exogenous transplacental transmission and endogenous transplacental transmission (Trees and Williams, 2005). Exogenous transplacental transmission implies that the pregnant dam contracts a primary oocyst-derived infection during gestation while endogenous transplacental transmission occurs in a persistently infected dam after recrudescence of the infection during pregnancy. The most common route of infection in cattle is via vertical transmission; whether exogenous or endogenous in origin (Trees and Williams, 2005). In addition, it has been experimentally shown that vertical transmission may occur in newborn calves after ingestion of milk and colostrum contaminated with tachyzoites (Davison et al., 2001; Uggla et al., 1998); however, it is not known whether this may occur under natural conditions. A proposed mechanism of horizontal transfer occurs via postnatal point-source exposure of cattle related to common housing and occupancy by domestic dogs; that is, those shedding oocysts resulting in a contamination of feedstuffs (McAllister et al., 2000; Dijkstra et al., 2002). Currently, there are few reports in the literature of horizontal transfer occurring via cow-to-cow by direct transfer of excretions or secretions from adult asymptomatic cows (Barling et al., 2001).

A critical gap in the literature pertains to the survivability of NC infectious oocysts in the environment after being shed from the host. This information would aid in the understanding of the biology of *Neospora caninum* and provide a starting point for refining management practices to curb infection rates. It should be noted that there has been much research pertaining to the ability of *Toxoplasma gondii* oocysts to survive various environmental conditions which may be extrapolated to *Neospora caninum* given that the structure of the oocysts are very similar. The oocysts of *T. gondii* are very resistant to extremely harsh environmental conditions of low pH and high salinity favoring transmission over long periods of time (Lindsay et al., 2003). However, a European review article cited numerous differences regarding molecular mechanisms between NC and *T. gondii* which may not allow analogous comparisons as research continues in the future (Hemphill et al., 2000).

Potential Explanatory Factors for NC Infection and Abortion

The majority of research conducted on neosporosis and potential risk factors associated with infection and abortion has consisted of cross-sectional seroprevalence studies (Barling et al., 2001; Gondhim et al., 2005; Lindsay et al., 1999; Otranto et al., 2005). These studies were adequate for providing presumptive associations for seroprevalence and potential risk factors, but not adequate to establish a causal relationship. The value of cross-sectional studies is established when multiple studies identify the same risk factors as being significant in the outcome.

In a review by Dubey et al. (2007), significant risk factors for *N. caninum*-associated seropositivity and abortion in cattle include: age of cattle, presence of dogs and wild canids on the farm, presence of intermediate hosts, contamination of food and water supply with infectious oocysts, cattle stocking density, herd size, and climate (Dubey et al., 2007). Each of these risk factors will be assessed below as a critique of current knowledge and areas that need further research (Barling et al., 2000; Barling et al., 2001; Haddad et al., 2005; Otranto et al., 2003; Rinaldi et al., 2005).

Age of Cattle

The age of cattle does not appear to be a reliable predictor for infection or abortion. Several studies have shown varied and inconsistent results in regards to the association between the age of cattle and seroprevalence. In a study of U.S. beef cattle, there tended to be a higher seroprevalence in cattle less than 3 years old versus cattle greater than 6 years of age (Sanderson et al., 2000). In a European study, it was observed that the age effect on seropositivity varied with differing regions (Bartels et al., 2006b). In Sweden, the odds of seropositivity decreased with age while in Spain the opposite was observed (Bartels et al., 2006b). It has been suggested that the age effect might be influenced by differences in probability of horizontal transfer, management practices, and environment (Bartels et al., 2006b).

Presence of Domesticated Dogs and Other Canids

In two cross-sectional studies, the presence of domesticated dogs on dairy farms was associated with a higher seroprevalence to *N. caninum,* which was expected due to dogs' status as a definitive host (Lindsay et al., 1999; Corbellini, 2006). As of yet, no studies involving beef farms have shown domestic dogs as a positive risk factor for NC infection. The reasons for this lack of association remain unclear, but may be linked to less common interaction amongst the beef cattle and domestic dogs.

Regarding age of the dog, experimental studies have shown that the rate of shedding oocysts varies with younger dogs (less than one year of age) shedding greater numbers of oocysts than dogs greater than one year old, but duration of shedding may be variable for each dog (Gondim et al., 2005). The majority of dogs become infected with NC after birth and the infection is not likely to persist in a population of dogs without horizontal transfer (Dubey et al., 2005).

Currently, the ability to conduct research on shedding rates of oocysts by domestic dogs and experimentation in other species is limited by lack of availability of oocysts for experimentation. There have been several studies that have shown that experimentally infected domestic dogs shed NC oocysts but the numbers are highly variable (Dubey et al., 2007; Gondim et al., 2004b). The diagnosis of naturally infected dogs reported in the literature is relatively rare (Basso et al., 2001; McGarry et al., 2003).

Coyotes have also been shown to be definitive hosts for NC (Gondim et al., 2004a) but it is not known whether the information presented above regarding domestic dogs will apply equally to coyotes. In addition, further research is needed to investigate the potential sylvatic cycle between wild canids, such as wolves and coyotes, and the deer and wild ungulate populations (Gondim et al., 2004b). This may be especially important in North America where there is a great abundance of deer and elk, and their predators, such as coyotes and wolves. It has been shown that wolves in northeastern

Minnesota had a high NC seroprevalence (39%) which was thought to be maintained by their diet consisting mostly of wild ruminants (Sanderson et al., 2000). In coyotes, the seroprevalence (11%) was much lower, likely due to a more diverse diet (Gondim et al., 2004b) with an emphasis on smaller mammals. In Canada, there is a lack of information pertaining to the interaction of wild canids, ruminants, and other wildlife with domestic beef and dairy cattle.

It is likely that there are other wild definitive hosts that play a significant role in the life cycle of NC, due to the fact that NC is infrequently diagnosed in domestic dogs and occurrence of coyotes is not sufficient to sustain the disease around the world.

Potential Intermediate Hosts of NC

In addition to cattle and canids, many other species of animals have been identified as having a potential role in maintenance and spread of neosporosis. Several studies have demonstrated potential associations between poultry, rodents, and various cervids as related to the transmission of neosporosis between intermediate and known definitive hosts (Barling et al., 2001; Huang et al., 2004; Vianna et al., 2005). A study conducted in south Texas has shown that the presence of poultry on beef farms was related to an increased risk of seropositivity to NC (Barling et al., 2001). In this study, it should be noted that the poultry were not tested for seropositivity but were identified as a potential risk factor in the multivariable models built by the researcher. In future studies, it may be found that poultry can serve as intermediate hosts for NC. The probable relationship between poultry and NC is that definitive hosts were found at greater densities in the areas adjacent to poultry farms. In another study, the wild brown rat was identified as a carrier for NC which may promote horizontal transfer on farms where various carnivores such as domesticated dogs, coyotes, foxes, and wolves may also be present (Huang et al., 2004). Additionally, NC has been isolated from white-tailed deer which should be considered an important intermediate host for disease due to large population numbers in North America (Vianna et al, 2005).

Contaminated Feed and Water

The contamination of feed and feeding areas with infectious oocysts has been associated with increased seropositivity to NC via the fecal-oral route in cattle. In south Texas, the use of hay rings was associated with an increased seropositivity in beef cattle (Barling et al., 2001). The hypothesis for this association is that dogs may defecate in the hay providing a source of infectious oocysts that may remain viable for long periods of time. The same study stated that beef cattle often calve, abort, or expel placentas near the hay rings whereby the placenta would provide a source of infectious material if eaten by other cattle or another intermediate host (Barling et al., 2001).

Barling et al. (2001) observed that a self-contained feeder for cow supplements that would limit access to wildlife was associated with a decreased seropositivity to NC. An additional study in the northwestern United States showed that cattle grazing on rangeland in the summer versus cows not managed on rangeland were at a lower risk of infection (Sanderson et al., 2000). This observation may be associated with decreased exposure to the infectious oocysts or relate to survival of the oocyst in the particular environment of the study location.

In a study conducted in France, the use of surface water ponds as a primary drinking source versus municipal water supply for dairy cattle was shown to be associated with increased seropositivity to NC (Ould-Amrouche et al., 1999). The probable source of this contamination was the presence of domestic dogs on the farms. This finding has not been supported in other studies but may be due to a lack of investigation. The importance of this finding could be tremendous as horizontal transmission in cattle occurs primarily via a point-source infection; therefore, the source of water should be investigated as a potential source of infection in future studies. This is because surface water sources are usually built in a manner that collects all surface rain run-off. This makes the surface pond a potential site for concentrating high numbers of infectious oocysts that may have been in the soil, thereby increasing the likelihood of an animal ingesting an infectious dose of oocysts.

Cattle Stocking Density and Size of Farm

Cattle stocking density has been shown to be an important factor regarding seroprevalence in beef and dairy cattle. Contemporary literature shows that the acreage of a farm is more important in beef versus dairy cattle (Corbellini et al., 2006). This is primarily due to the differing ways in which beef and dairy cattle are managed. In

Canada, dairy cattle are housed primarily in barns where the actual size (acreage) of the farm is irrelevant and stocking density in barns and loafing areas becomes a more important explanatory factor. On the other hand, beef cattle are typically raised on pastures and open range and so stocking density and size of herd vary greatly by eco-region.

In two studies in Texas, high stocking density in beef cattle was identified as a potential risk factor for seropositivity to NC (Barling et al., 2000, Barling et al., 2001). An additional study in the northwestern United States observed a similar effect (Sanderson et al., 2000). In this study, the hypothesis was that the increased seropositivity was related to increased consumption of commercial feeds by the cattle that may have been contaminated by oocysts from a definitive host in the storage bins or after placement in the feed troughs. It should be noted that the definition of the term 'high-stocking density' is a relative term that will vary among differing ecological environments and should be evaluated in each particular circumstance. A measurement of the amount of supplemental commercial feeds given per herd may provide a surrogate means to compare farms that differ ecologically and by size.

Herd Size

In a German study, herd size was evaluated as a potential risk factor for seroprevalence in dairy cattle (Schares et al., 2004). The researchers concluded that herd size was not directly related to increased/decreased seroprevalence but was a surrogate for an unknown factor. The most probable explanation given was that herd size was related to the hygiene status of the farm. An additional study also found that herd size was not directly related to seroprevalence, but concluded that it was a surrogate for the number of dogs on the farm (Otranto et al., 2003). It was noted that the number of dogs on the farm increased with herd size resulting in an increased seroprevalence.

Climate

Regarding neosporosis, there is much to be learned about how the climate will affect the onset and recrudescence of disease in cattle. The literature has primarily been focused on temperature as related to the rate of sporulation of the oocysts in the environment. In general, it has been stated that the higher temperatures may favor a faster sporulation rate in the environments where cattle may come in contact with the infectious oocysts. In Italy, it was found that the higher the minimum temperature was in the spring was a potential risk factor for increased seropositivity which relates to the theory that sporulation of *N. caninum* oocysts are temperature-dependent (Rinaldi et al., 2005).

Currently, there is a gap in the literature pertaining to how temperature affects abortion rates, milk production in latently/persistently infected cattle, and survival of oocysts in the environment. There have been several studies that indicated that NC associated epidemic abortions were more common in the summer months but it was not clear whether this is associated with increased sporulation of oocysts, heat stress, or an increased frequency of calving in the spring and summer based upon breeding patterns (Barling et al., 2001; Schares et al., 2004).

Economic Impact

The majority of economic losses in cattle can be contributed to reproductive failure. In addition to the direct economic costs associated with fetal loss, there are indirect costs associated with diagnostic procedures to determine the reason for abortion, rebreeding, possible detrimental effects on milk production, and replacement costs if cows are culled.

The process of identifying whether a cow aborted a fetus due to a *N. caninum* infection can be time consuming and very costly (Dubey et al., 2006; Ortega-Mora et al., 2006). It is important to note that the detection of NC associated antibodies in an aborted fetus is not adequate to establish NC as the cause of the abortion (Dubey et al., 2006). The process involves a combination of epidemiological and molecular methods to identify the causative organism due to its close morphologic resemblance to with *T. gondii.*

As of yet, it is not clear whether NC seropositivity is associated with decreased milk production in dairy cattle, as several studies have provided conflicting results. The economic losses associated with decreased milk production may be more associated with abortion status rather than NC seropositivity. In Canada, a large case-control study analyzing NC seropositivity and milk production in 140 dairy herds involving 6,864 cows reported that abortion status, and not seropositivity, affected milk production (Hobson et al., 2002). In the Netherlands, Bartels et al. (2006a) reported that NC seropositive cows' milk production was affected for the first year following an abortion storm.

In the cattle industries, it is common practice to cull both beef and dairy cows that have repeated abortions. The reasons for these abortions are diverse and may include bacterial, viral, or protozoan infections. Most often, no definitive diagnosis can be made as to causation for a bovine abortion. In California, a retrospective study of 2,000 dairy cows showed that NC seropositive dairy cows were 1.6 times more likely to be culled than seronegative cows (Thurmond and Hietala, 1996). In accordance with the previous study, there have been several other studies that reported an association between NC seropositivity and the practice of culling (Tiwari et al., 2005; Bartels et al., 2006b). Conversely, in Canada, a study conducted in a similar fashion found that amongst 56 dairy herds containing 3,416 cows showed that NC seropositivity was not associated with culling (Cramer et al., 2002). The reason for culling was associated with a presence/absence of NC-associated abortions on the farm. It is not clear whether this is the only association, but investigation in future studies may help refine culling practices to lessen economic losses.

Control Measures

Among *N. caninum*-free farms, the primary focus should be to prevent introduction of the protozoan to the farm (Haddad et al., 2005). The most effective method to obtain this goal is to create a closed system where there is no introduction of new cattle to the herd. In many cases, this may not be possible due to a need for replacement cows due to loss of performance or genetic reasons. All animals that are purchased should ideally come from herds that have been shown to have disease-free status with an active monitoring program to confirm that NC is not present in the herd (Haddad et al., 2005). However, as indicated in Scott et al. (2006; 2007), truly infection-free herds are likely the exception, rather than the rule, in Alberta. In addition to monitoring the cattle on the farm, the contact with known definitive hosts, such as domestic dogs and coyotes, should be minimized in order to prevent infection and neosporosis in the cattle.

In cattle herds containing test positive animals, it is crucial to prevent further vertical and horizontal transmission. Several studies have concluded that screening cows for NC prior to breeding and culling positive animals may be the most effective means of limiting vertical transmission (Larson et al., 2004; Häsler et al., 2006a; Häsler et al., 2006b). The problem associated with this practice is that the serological tests used are imperfect resulting in some false negatives (leaving truly infected animals in the herd) and false positives (resulting in wrongly culled animals). Wapenaar et al. (2007) compared several commonly used serological tests for detecting antibodies to NC in which the sensitivity was ≥ 89% and specificity ≥ 94%, and the IDEXX Herdchek indirect ELISA (IDEXX Corp.,Westbrook, ME, USA) was shown to have a sensitivity of 93% (95% CI: 0.86-1.0) and specificity of 94% (95% CI: 0.91-0.96) using a sample-to-positive control (S/P) ratio of 0.5. Horizontal transmission can be reduced by implementing sanitary practices comprised of cleaning feeders, preventing fecal contamination of stored feedstuffs, and eliminating the interaction of dogs and rodents around livestock. These practices should be easier to implement in dairy cattle versus beef cattle operations due to the differences in management. In beef cattle herds, the reduction of interaction canids with wildlife may be beneficial in reducing the exposure of cattle to NC oocysts.

In addition, another means of lessening seropositivity in cattle would be to reduce the interaction of canids with cattle. In regards to limiting contact of domestic dogs with livestock this would be easily implemented whereas it may be more difficult to prevent exposure to wild canids and feces. It is important to remember that the cattle can become infected by ingesting feces that may have been present in the environment for an extended period of time.

A potential vaccine for neosporosis was created in 2003, (Neogard™, Intervet, The Netherlands), a killed protozoan vaccine designed to be administered in the first trimester of pregnancy with a second dose to be given 3 – 4 weeks after the initial dose. The field effectiveness of the vaccine is still under observation (Georgieva et al., 2006).

Conclusion

In conclusion, it is evident that there is much more to be learned about *N. caninum*. As a general trend, the seroprevalence of NC among beef and dairy cattle, assuming there was not a recent abortion outbreak, is approximately 9% and 18% for beef and dairy cattle respectively (Dubey, 2003). There are many areas concerning NC that need additional investigation including: risk factors for infection and abortion in cattle, interaction of NC with definitive and intermediate hosts in the environment, survival of oocysts in the environment, and the discrepancy in seroprevalence between beef and dairy cattle.

The majority of the previous studies have tried to compare beef and dairy cattle based upon differing methods, serological tests and study design, in each study which may limit comparability of the results. This research project was the first attempt in Alberta, Canada, to investigate the potential risk factors for NC infection in beef and dairy cattle concurrently using identical study design in regards to survey administration, sample collection, and serological testing. While this is a cross-sectional study capable of demonstrating presumptive associations with the various risk factors, there is great value in this study as it may provide a starting point for longitudinal studies in Canada that would be sufficient to demonstrate causal relations between the explanatory factors and neosporosis.

Objectives

The objectives of this cross-sectional study were to: 1) analyze various herd-level and agro-ecological factors in an effort to further understand the factors related to NC seropositivity in beef and dairy cattle, and 2) to investigate the differences in seroprevalence between beef and dairy cattle, as cited in previous works (Haddad et al., 2005; Scott et al., 2006; Scott et al., 2007).

CHAPTER III

MATERIALS AND METHODS

The results presented hereafter arose from secondary analyses of *Neospora caninum* seroprevalence data that were collected during a previous study (Scott et al., 2006; Scott et al., 2007). The risk factor data collected in a survey administered at the same time blood samples were collected have not previously been analyzed or published for either the beef or dairy herds in Alberta. The information for this study was collected from both dairy and beef cattle herds in an identical manner (Scott et al., 2006; Scott et al., 2007). This permitted the direct comparison of risk factors for neosporosis among beef and dairy herds.

This study describes and compares potential risk factors for beef and dairy cattle NC seropositivity using descriptive and analytical statistical methods. Multivariable models were used to elucidate potential risk factors for NC amongst beef and dairy cattle. In addition, the models were used as a means to attempt to provide a reason for the apparent discrepancy between the seroprevalence for beef and dairy cattle using the identified potential risk factors in the final multivariable models. In the following sections, the methods by which the data were collected will be provided as well as methods for data analysis and model development.

Selection of Herds and Data Collection

A two-stage random sampling procedure was employed for both dairy and beef herds. The target population was comprised of all adult cattle in beef and dairy herds in Alberta, Canada. The study population encompassed the adult cattle in herds owned by the client base of all participating veterinarians who were accredited by the Alberta Johne's Control Program as of January 2002. The list included 102 veterinarians working throughout Alberta, Canada with 68 of the 102 veterinarians participating in the study. Before enrollment of each of the dairy and beef herds began, a letter of introduction, a basic information packet, and an enrollment form was mailed to all of the accredited veterinarians and a list was compiled of those interested in participating in the study. Also, each veterinarian was asked to provide the number of: 1) dairy herds, and/or 2) beef cow-calf (purebred) and/or 3) beef cow-calf (commercial) herds in their practice. If more than one veterinarian volunteered from a practice then the numbers of herds among the practice were split evenly for the purposes of weighted sampling (Scott et al., 2006; Scott et al., 2007). Sampling of herds was proportionate to the size of client base, with a fixed number of animals (n=30 adult cattle ≥ 36 months of age) sampled within each herd. The herds were selected randomly from ordered client lists, which had been assigned a random number by the researchers. If a particular client did not wish to participate, the next client from the ordered list was selected. The sampling protocol for selecting the cattle within the herds was performed using a systematic random sampling protocol (n/30 sampling interval (k), with a random starting point (from 1-k)).

The agro-ecological data were compiled using various resources such as: Agricultural Region of Alberta Soil Inventory Database (AGRASID, 2007), and the Alberta Environmentally Sustainable Agriculture Agreement, Soil Inventory Project Procedures Manual (CAESA, 2002). All management, bio-security, individual level, herd level, and production data were derived from a survey administered by the qualified veterinarians to the participating producers.

Sample Collection

The veterinarians collected 5-8 ml/vial of blood from the caudal tail vein of each randomly selected animal. The individual animal's identification number was marked on each vial and on the submission form. In addition the age, sex, and breed (and pregnancy status for beef cows, but not dairy cows) were recorded on the submission form. Four vials were collected from each adult cow. The veterinarian could submit the serum separator tube without further processing or centrifuge and decant the serum into a new red-top vacutainer vial. The serum separator tubes remained in a vertical position and were cooled to 4°C during transport to the diagnostic laboratory.

Serology

The diagnostic testing was performed at the Agri-Food Laboratories Branch (AFLB) of the Food Safety Division of Alberta Agriculture, Food and Rural

Development in Edmonton, Alberta, Canada. A commercially available IDEXX® Herdchek® ELISA test kit (IDEXX Laboratories, Inc., Westbrook, ME, USA) was used to determine the presence of *Neospora caninum* antibodies in the collected samples. The 96-well microtitration plates were coated with *Neospora* antigen. Upon incubation, specific antibodies would bind to the *N. caninum* antigen coating the wells of the microplate. After washing away unbound material from the wells, an enzyme-labeled anti-bovine IgG secondary antibody was employed to detect the antigen-antibody complex attached to the microplate. The final step was to wash the unbound conjugate and apply a substrate. The colorimetric reaction of the enzyme substrate solution reflected the amount of the immune complex formed. The IDEXX® Herdchek® ELISA for *N. caninum* antibody was automated using the Beckman Biomek 2000 automation workstation (Beckman Coulter, Fullerton, CA, USA).

In this study, a sample-to-positive (S/P) ratio >= 0.4 (manufacturer suggested 0.5 S/P cut point) was used to classify a sample as positive. The 0.4 S/P test cut point has been validated in the AFLB laboratory, using a positive control, with sensitivity estimated at 97.6% and specificity at 99.5% for detection of antibodies to *N. caninum* antigens in bovine serum (Wu et al., 2002). In the serological analysis, samples ranging from 0.2 to 0.39 were considered suspect samples. However, for purposes of statistical analysis, suspect samples were aggregated with negative samples so as not to introduce false positives which may have skewed the results.

Survey

Comprehensive surveys (see Appendices D and E) involving individual-animal-level and herd-level characteristics for beef and dairy cattle and herds were administered to participating herd owners by the accredited veterinarians. Complete information in all categories of the survey was required for the information to be included in the data analysis. The minimum inclusion criteria for inclusion in the study were: herds must have at least 30 adult cattle (females ≥ 2^{nd} lactation (or, 36 months of age), and males ≥ 36 months of age). The first-calf heifers and bulls <3 years of age were excluded from the study.

Statistical Analysis

All statistical analyses were performed using commercially available software (Intercooled STATA® ver. 9.1., StataCorp, College Station, TX, 77845). The data sets from the dairy and beef surveys were aggregated into a single combined file using Microsoft Access database software. Although there was a single dataset, the features of the statistical software allowed the creation of separate descriptive statistics for beef and dairy data which then were followed by the descriptive statistics for combined data. Once the data sets were combined, there were multiple manipulations required before the data could be analyzed. These manipulations included: creation of new categorical variables from linear response variables, dichotomizing risk factor responses from the surveys that were administered to the producers, and proofing the data set for missing or erroneous data. As one example, the variable '*cattle stocking density*' (cows per acre), was calculated by dividing the total number of cows on farm by total number of acres of farm.

Individual-Animal Explanatory Factors

In this study, the individual-animal explanatory factors evaluated were age, sex, and predominant breed of the animal. The age of the cattle, recorded in months, was categorized in the following manner: 36 to < 72, 72 to <108, and ≥ 108. The pre-dominant breeds in the study included: Black Angus, Red Angus, Charolais, Hereford, Limousin, Simmental, and Holstein; while additional breeds of cattle were classified as "other" if the total number of animals in the study did not exceed 100 in the final data set.

Agro-ecological Explanatory Factors

The agro-ecological, agro-climatic, and soil features were reclassified from the original format (Scott et al., 2006; Scott et al., 2007). The new classifications were achieved by cross-tabulating each explanatory variable versus agro-ecological region and combining similar categories (using biological criteria) not overlapping other agro-ecological regions. Eco-regions were collapsed to represent four categories: boreal forest, grassland, montane, and parkland. In the construction of the multivariate models, parkland was designated the referent. The reclassification of agro-climate regions involved combining the severe and very severe heat limitation classes because there was only one herd in the very severe heat limitation category. The soil zones were similarly collapsed into five categories: black, black/dark-gray, brown, dark gray/black-gray and thin-black soil types.

Model Design

Initially, bivariate analyses, using a level of significance of $P < .05$, were used to select individual explanatory variables for further assessment in the multivariable models. Some of the explanatory variables were exclusive to either beef or dairy; hence, they were not considered in the combined beef/dairy model. Some variables were forced into the multivariable models, based on prior biological knowledge of potential factors or their importance as a potential confounder. Interaction terms were included based upon any known or suspected biological association between the explanatory variables and production type (beef versus dairy); otherwise, they too were assessed at $P < .05$. . In addition, confounding factors were identified as those factors causing a > 20% change in the adjusted log odds of the other risk factors and forced into the final model where appropriate. The final completed model consisted of an evaluation of fixed effects at the individual level, ecological risk factors, fixed (herd-level) variables, and random (nuisance) effects attributed to the herd to which each animal belonged. The final models were built by assessing the significance of each explanatory variable using the likelihood ratio test at each step of entry or exit from the model using forward stepwise regression.

Three multivariable generalized linear models using a binomial distribution and logit link function, a random effect for herd, and fixed effects for individual-, herd management-, and environmental-factors were created (i.e., beef cattle herds only, dairy cattle herds only, and both beef and dairy cattle herds) using the *xtlogit* command (Intercooled STATA® ver. 9.1., Stata Corp, College Station, TX, 77845). The random effect for herd adjusted for any remaining intra-herd correlation between animals that wasn't adequately explained by herd-level management factors. Therefore, when correlation (ρ) was zero, the panel-level variance component was considered unimportant, and the panel estimator was not different from the pooled estimator. A likelihood-ratio test of this effect formally compared the pooled estimator (logit) with the panel estimator (Stata Corp, 2005). In the multivariable models, ρ was reported in the base-line model without any herd-level variables and again in the final model as a means to account for the percentage of variance attributed to herd-level variables.

The final models provided presumptive associations between explanatory factors from the surveys and NC sero-status in beef and dairy cattle, while adjusting for unmeasured herd effects. In addition, the models intended to provide information about the discrepancy between seroprevalence between beef and dairy cattle which is lacking in the current literature.

CHAPTER IV

RESULTS

A total of 5,815 blood samples [2,819 (arising from 81 herds) dairy and 2,996 (arising from 101 herds) beef cattle] were collected from October 2002 through January 2003 (Scott et al., 2006; Scott et al., 2007). In the current study, complete serological and herd-survey data were available for 2,311 dairy (77 herds) and 2,968 beef (99 herds) cattle resulting in 807 positive, 4,239 negative, and 233 suspect samples using the IDEXX® Herdchek® ELISA to detect the *Neospora caninum* antibody. For the analysis, the serological results were dichotomized whereby the 233 suspect samples were classified as negative resulting in 807 positive and 4472 negative samples (Scott et al., 2006; Scott et al., 2007). As Scott et al. (2006; 2007) reported previously, the survey-design adjusted seroprevalence of NC in beef cattle was 9.7% and in dairy cattle the seroprevalence was 18.5%.

Descriptive Statistics for Beef Study Cattle

Individual Animal Level Characteristics for Beef Study Cattle

The study included only 5 adult male beef cattle, primarily due to the sampling scheme that was used by the veterinarians, with the remainder being 2,963 adult female beef cattle. The age of the beef cattle ranged from 36 to 243 months (median = 73; mean = 78.14; standard deviation 33.49). The dominant beef breeds (≥ 100 animals per breed, in this study) included: Black Angus, Red Angus, Charolais, Hereford, Limousin, and Simmental; while the remainder of the cattle breeds where classified as "other" in the analysis (Table 4.1). The breeds indicated as "other" included: Ayrshire, Beef Booster, Blonde d' Aquitane, Gelbvieh, Guernsey, Holstein, Jersey, Maine Anjou, Murray Gray, Saler, Shorthorn, and Tarantais.

Table 4.1. Breeds in beef cattle study.

Breed	**Number of Cattle**	**Percent**
Simmental	704	23.72
Charolais	593	19.98
Angus	509	17.15
Hereford	434	14.62
Red Angus	250	8.42
Limousin	129	4.35
Other	349	11.76
Total	2,968	100

Herd Level Characteristics for Beef Study Cattle

A total of 99 out of 101 (98%) beef herds had complete serological and survey data and were used in the analysis. The herd sizes ranged from 32 to 875 adult cattle (median = 119; mean = 155.4, standard deviation = 128.68). Eighty-nine of 99 (89.9%) beef herds had at least one individual animal test positive for NC antibodies.

All beef cattle study herds were located between 49° latitude and the 56° latitude with the majority of the cattle herds located between 52° and 54° latitude (see Figure 4.1). The area north of 56° latitude is considered largely non-agricultural land and the most southwestern area of Alberta is comprised of the Canadian Rocky Mountains.

Presence of Domestic Dogs and Wild Canids on Beef Study Farms

Dogs were present on 90 (90.1%) out of 99 beef farms or ranches. The number of dogs ranged 0 to 5 (median = 2; mean = 1.73; standard deviation = 1.1). The survey question regarding the number of wild canids seen on the farm was not reported herein because of a lack of a standardized counting system to obtain population numbers. However, within the year prior to the administration of the survey, wild canids (coyotes, foxes, wolves) were reported to have been seen on all beef study farm locations.

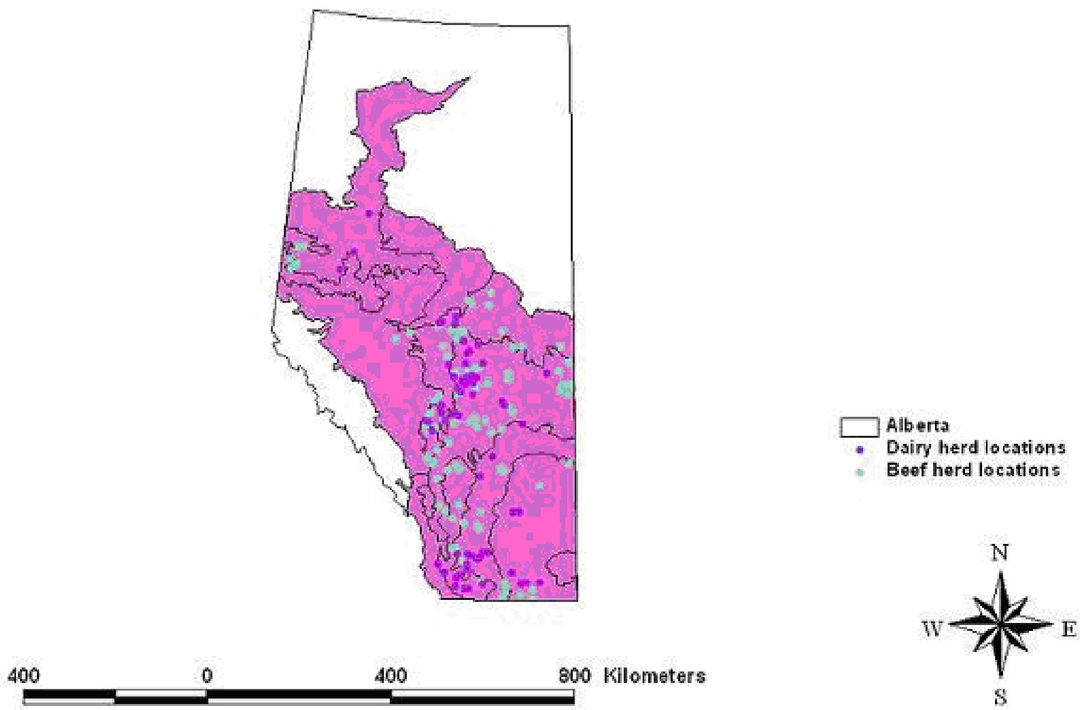

Figure 4.1. Position of Beef and Dairy Study Herds within Alberta, Canada.

Descriptive Statistics for Dairy Study Cattle

Individual Animal Level Characteristics for Dairy Study Cattle

The age of the sampled dairy cattle ranged from 36 to 195 months (mean = 61.59; median = 61.8; standard deviation = 21.5). There were 2,311 (2,310 female, 1 male) dairy cattle samples with complete serological and survey data that were analyzed during the study. The breeds involved in the dairy cattle study included: Holstein, Jersey, Ayrshire, and Guernsey. The number of cattle that were Holstein was vastly greater than for any other breed (Table 4.2).

Table 4.2. Breeds in dairy cattle study.

Breed	**Number of Cattle**	**Percent**
Holstein	2,262	97.88
Ayrshire	31	1.34
Guernsey	12	0.5
Jersey	6	0.26
Total	**2,311**	100

Herd Level Characteristics for Dairy Study Cattle

A total of 81 dairy herds were sampled, from which complete sample and survey data were available for use in 77 of the herds (Scott et al., 2006; Scott et al., 2007). Among these 77 herds, only one herd was reported to not have any seropositive individuals out of the 30 cattle tested. The herds used in the analysis ranged in number from a minimum of 30 to a maximum of 405 adult cattle (median = 89; mean = 111.06; standard deviation 68.11). Similar to the beef study herds, the dairy cattle were found in the highest density between the 52° and 54° lines of latitude with only one dairy herd found above 56° of latitude (see Figure 4.1).

Presence of Domestic Dogs and Wild Canids on Dairy Farms

The number of domestic dogs on dairy study farms ranged from a minimum of 0 to a maximum of 13 (median = 1; mean = 1.92; standard deviation = 2.1). There were 30 of 81 dairy herds sampled where dogs were not present. Other than domestic dogs, wild canids (coyotes, wolves, foxes) were reported to have been seen multiple times over the last 12 months on 76 of 81 dairy study farm sites.

Explanatory Factor Analysis

Bivariate Analysis

All explanatory variables, excluding vaccination procedures, were evaluated in bivariate analyses (random effect likelihood ratio test) and tested for significance ($P < .05$) for further inclusion in the multivariable models. The bivariate analyses indicated that only a small proportion of the potential explanatory factors were found to be significantly associated with NC seropositivity from the total number of survey questions. The other potential explanatory factors evaluated can be found in Tables A.1., B.1., and C.1. of Appendices A, B, and C respectively. The serological status indicated in the tables used the established cutpoints (i.e., breakpoint at S/P of 0.40) as indicated in the materials and methods.

In the beef cattle bivariate analyses, the significant factors included: breed (P = 0.02), agroecological region (P = 0.001), acreage of farm (I) (P =0.002), and calving site (P = 0.02) (Table 4.3). In addition, other factors are included in Table 4.3 due to the fact that they were found to be significant in several other studies (Otranto et al., 2003; Bartels et al., 2006a). Those factors also assessed, but not found to be significant, are listed in Table A.1. of Appendix A.

Table 4.3. Cross-tabulation of potential risk factors by serological status for antibodies to *Neospora caninum* (NC) for the beef study cattle (*n* = 2968).

Factor	Factor Level	NC Serological Status		***P*-value**[a]
		Frequency [%][b]		
		(-)	(+)	
Age	36 to < 72 months	1203 [90.4%]	128 [9.6%]	0.48
	72 to < 108 months	877 [90.4%]	93 [9.6%]	
	≥ 108 months	572 [88.1%]	77 [11.9%]	
Herd Size	< 70 cattle	580 [88.1%]	78 [11.9%]	0.47
	70 to < 89 cattle	293 [88.8%]	37 [11.2%]	
	89 to < 129 cattle	471 [92.4%]	39 [7.6%]	
	≥ 129 cattle	1324 [90.1%]	146 [9.9%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table 4.3. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Dominant Breed	Angus	472 [92.7%]	37 [7.3%]	0.02
	Red Angus	237 [94.8%]	13 [5.2%]	
	Charolais	526 [88.7%]	67 [11.3%]	
	Hereford	409 [94.2%]	25 [5.8%]	
	Limousin	113 [87.6%]	16 [12.4%]	
	Simmental	98 [13.9%]	606 [86.1%]	
	Other	44 [12.6%]	305 [87.4%]	
Agroecological Region	Grassland	543 [95.3%]	27 [4.7%]	0.001
	Montane	168 [93.3%]	12 [6.7%]	
	Parkland	1168 [90.5%]	122 [9.5%]	
	Boreal Forest	789 [85.0%]	139 [15.0%]	
Acreage of Farm (I)	≤ 1500 acres	1113 [86.4%]	175 [13.6%]	0.003
	> 1500 acres	1555 [92.6%]	125 [7.4%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table 4.3. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Acreage of Farm (II)	≤ 3000 acres	1967 [88.7%]	251 [11.3%]	0.04
	> 3000 acres	701 [93.5%]	49 [6.5%]	
Acreage of Farm (III)	≤ 5000 acres	2393 [89.7%]	275 [10.3%]	0.62
	> 5000 acres	275 [91.7%]	25 [8.3%]	
Site of Calving	Other	1475 [87.9%]	203 [12.1%]	0.02
	Corral / Feedlot	1193 [92.5%]	97 [7.5%]	
Farm Tech Equipment Cleaned	No	1739 [89.3%]	209 [10.7%]	0.41
	Yes	929 [91.1%]	91 [8.9%]	
Number of Domestic Dogs on Farm	No Dogs Present	239 [88.5%]	31 [11.5%]	0.77
	1 - 2 Dogs	1883 [89.8%]	215 [10.2%]	
	> 2 Dogs	546 [91.0%]	54 [9.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

In the dairy herds, the significant potential explanatory variables included: the presence of other cows at calving (*P* = 0.05), and cleaning of farm tech equipment (*P* = 0.02). Several other factors, such as age (*P* = 0.54), acreage of farm (> 1500 acres, *P* = 0.93; >3000 acres, *P* = 0.42; > 5000 acres, *P* = 0.37), and number of dogs present on the farm (*P* = 0.2) have been reported in the literature as being potentially associated with NC, therefore, they are reported for this study to provide a means of comparison (Table 4.4). The other potential explanatory variables can be found in Table B.1, Appendix B.

Table 4.4. Cross-tabulation of potential risk factors by serological status for antibodies to *Neospora caninum* (NC) for the dairy study cattle (*n* = 2311).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Age	< 36 months	25 [86.2%]	4 [13.8%]	0.54
	36 to < 72 months	1208 [78.3%]	334 [21.7%]	
	72 to < 108 months	494 [77.1%]	147 [22.9%]	
	≥ 108 months	77 [77.8%]	22 [22.2%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table 4.4. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Farm Tech Equipment Cleaned	No	675 [72.6%]	255 [27.4%]	0.02
	Yes	1129 [81.8%]	252 [18.2%]	
Agroecological Region	Grassland	495 [82.5%]	105 [17.5%]	0.13
	Montane	227 [84.1%]	43 [15.9%]	
	Parkland	725 [73.2%]	265 [26.8%]	
	Boreal Forest	357 [79.2%]	94 [20.8%]	
Acreage of Farm (I)	≤ 1500 acres	1217 [78.0%]	344 [22.0%]	0.93
	> 1500 acres	587 [78.3%]	163 [21.7%]	
Acreage of Farm (II)	≤ 3000 acres	1370 [77.4%]	401 [22.6%]	0.42
	> 3000 acres	434 [80.4%]	106 [19.6%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table 4.4. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Acreage of Farm (III)	≤ 5000 acres	1393 [77.3%]	408 [22.7%]	0.37
	> 5000 acres	411 [80.6%]	99 [19.4%]	
Number of Dogs on Farm	No Dogs	275 [83.1%]	56 [16.9%]	0.2
	1 - 2 Dogs	1142 [79.3%]	298 [20.7%]	
	> 2 Dogs	387 [71.7%]	153 [28.3%]	
Other cows present during calving	No	1108 [75.3%]	363 [24.7%]	0.05
	Yes	696 [82.9%]	144 [17.1%]	
Herd Size	< 70 cattle	458 [80.4%]	112 [19.6%]	0.81
	70 to < 89 cattle	429 [75.3%]	141 [24.7%]	
	89 to < 129 cattle	435 [76.3%]	135 [23.7%]	
	≥ 129 cattle	482 [80.2%]	119 [19.8%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

The combined beef and dairy potential explanatory factors were limited in number due to the fact that some factors were applied to either beef or dairy exclusively (Table C.1., Appendix C). The explanatory variables that were significant in the combined beef and dairy bivariate analysis included acreage of farm (> 1500 acres) (*P* = 0.002) and cow type (*P* < 0.001). Other explanatory factors that have been reported in the literature are listed in the table below (Table 4.5).

Table 4.5. Cross-tabulation of potential explanatory factors by serological status for antibodies to *Neospora caninum* (NC) for the combined beef and dairy study cattle (*n* = 5279).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Age	< 36 months	41 [87.2%]	6 [12.8%]	0.63
	36 to < 72 months	2411 [83.9%]	462 [16.1%]	
	72 to < 108 months	1371 [85.1%]	240 [14.9%]	
	≥ 108 months	649 [86.8%]	99 [13.2%]	
Acreage of Farm (I)	≤ 1500 acres	2330 [81.8%]	519 [18.2%]	0.002
	> 1500 acres	2142 [88.1%]	288 [11.9%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table 4.5. (Continued).

Factor	Factor Level	NC Serological Status		P-value[a]
		Frequency [%][b]		
		(-)	(+)	
Agroecological Region	Grassland	1038 [88.7%]	132 [11.3%]	0.09
	Montane	395 [87.8%]	55 [12.2%]	
	Parkland	1893 [83.0%]	387 [17.0%]	
	Boreal Forest	1146 [83.1%]	233 [16.9%]	
Acreage of Farm (II)	≤ 3000 acres	3337 [83.7%]	652 [16.3%]	0.056
	> 3000 acres	1135 [88.0%]	155 [12.0%]	
Acreage of Farm (III)	≤ 5000 acres	3786 [84.7%]	683 [15.3%]	0.88
	> 5000 acres	686 [84.7%]	124 [15.3%]	
Cowtype	Dairy	1804 [78.1%]	507 [21.9%]	< .001
	Beef	2668 [89.9%]	300 [10.1%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table 4.5. (Continued).

Factor	Factor Level	NC Serological Status		P-value[a]
		Frequency [%][b]		
		(-)	(+)	
Herd Size	< 70 cattle	1803 [90.5%]	190 [9.5%]	0.15
	70 to < 89 cattle	722 [80.2%]	178 [19.8%]	
	89 to < 129 cattle	906 [83.9%]	174 [16.1%]	
	≥ 129 cattle	1806 [87.2%]	265 [12.8%]	

a The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
b This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Multivariable Models

Beef Only Model

The multivariable beef-only model (99 herds) constructed with those potential explanatory variables found to be significant ($P < .05$) and those additional individual and herd factors forced into the final model are listed in Table 4.6. In the multivariable beef-only model, although not significant in bivariate analysis, herd size was forced in to the model as it is commonly a surrogate for important factors. The agroecological region (with parkland designated as the referent), was highly significant ($P < .001$). The agroecological regions corresponding to a non-significantly increased risk of seropositivity to NC were montane (OR: 1.35, 95% CI: 0.53--3.44) and boreal forest (OR: 1.17, 95% CI: 0.74--1.85) indicating that herds in these regions were 1.35 and 1.17 times more likely to be seropositive to NC than herds outside the respective areas. On the other hand, the grassland agroecological region was associated with a significantly decreased risk of seropositivity (OR: 0.7, 95% CI: 0.36-0.96). The age of the cattle was a factor that was forced in to the model to account for any unknown factors regarding the relationship of NC seropositivity due to the existing conflicting evidence of the effect of age in the literature (Sanderson et al., 2000; Bartels et al., 2006a). The acreage of the farm was found to be a significant explanatory factor ($P = 0.03$) in the beef study cattle model. On farms that were 1500 acres or greater, with referent category < 1500 acres, there was a decreased risk of seropositivity (OR: 0.59, 95% CI: 0.39-0.88) to *N. caninum*. The calving location, common corral / feedlot versus pasture, was found to be statistically significant ($P = 0.005$) in the final model. If cattle calved in the common corral / feedlot, with referent indicated as pasture, there was a decreased risk of seropositivity (OR: 0.63, 95% CI: 0.42-0.96) to NC. The final potential explanatory factor in the model, pH of the soil, was evaluated, and this variable was highly significant ($P = 0.009$) in the multivariable model indicating that with each increase in pH above a pH of 7 there was a decreased risk of seropositivity (OR: 0.61, 95% CI: 0.42--0.87).

Table 4.6. Multivariable model utilizing a generalized linear model with a random effect for herd, and fixed effects for host-, herd-, and agroecological explanatory factors for beef study cattle and herds (n = 2968).

Explanatory Factor	**Level of Explanatory Factor**	**Odds ratio (OR)**	**95% confidence interval (OR)**	***P*-value[a]**
Herd Size	--	--	--	0.81
	70 to < 89 cattle	0.94	0.43--2.14	
	89 to < 129 cattle	0.58	0.28--1.2	
	≥ 129 cattle	0.76	0.44--1.33	
Agroecological Region	Parkland	--	--	0.001
	Montane	1.35	0.53--3.44	
	Grassland	0.7	0.36--0.96	
	Boreal Forest	1.17	0.74--1.85	
Age of Cattle	36 to < 72 months	--	--	0.52
	72 to < 108 months	0.69	0.14--3.4	
	> 108 months	0.85	0.17--4.19	
Acreage of Farm (I)	< 1500 acres	--	--	0.03
	≥ 1500 acres	0.59	0.39--0.88	
Site of Calving	Pasture	--	--	0.005
	Common Corral/Feedlot	0.63	0.42--0.96	
pH of the water	< pH 7	--	--	0.009
	≥ pH 7	0.61	0.42--0.87	

[a] The p-value is derived from bivariate analysis using the least likelihood ratio test of signficance.

In the beef model, the amount of variance attributed to the herd effect was 19.6 percent in the base-line model (i.e., with no explanatory variables). The additional significant bivariate significant explanatory variables that were not included in the model ($P > .05$) were: presence of other cattle at time of calving, soil type, climate, and breed. In the final model, the amount of variance attributed to herd was reduced to 12.3 percent from the base-line model. The most significant reduction in the herd effect was attributed to the addition of agroecological region and size of the farm, resulting in a combined 5.0 % reduction.

In the final model, the interactions that were tested for statistical significance were: acreage of farm versus calving site, age of cattle versus calving site, and agroecological region versus calving site. None of the possible 2-way interactions were found to be statistically significant ($P > .05$).

Dairy Only Model

The potential explanatory factors that were found to be statistically significant ($P < .05$) in the multivariable model are listed in Table 4.7. In the final multivariable dairy model (77 herds), age was not statistically significant but was forced into the model to account for any unknown associations between the effect of age of cattle, the remaining risk factors in the model, and the likelihood of exhibiting seropositivity to NC. The presence of other cows at the time of calving was statistically significant and associated with a decreased risk of seropositivity to NC (OR: 0.52, 95% CI: 0.29--0.94).

In addition, the practice of cleaning the farm tech equipment was associated with a decreased risk of seropositivity to NC (OR: 0.48, 95% CI: 0.28-0.84). In this model, no significant interactions were observed.

The percentage of the variance within the model attributed to the herd effect was explained only a minimal amount by the risk factors included in the final multivariable dairy model. In the base-line model, the herd effect was 29.6 % of the overall variance. In the final multivariable model, the herd effect was reduced minimally to 26.8 percent.

Table 4.7. Multivariable model utilizing a generalized linear model with a random effect for herd, and fixed effects for host-, herd-, and agroecological explanatory factors for dairy study cattle and herds (n = 2311).

Explanatory factor	Level of explanatory factor	Odds ratio (OR)	95% confidence interval (OR)	*P*-value[a]
Herd Size	< 70 cattle	--	--	0.81
	70 to < 89 cattle	1.33	0.59--3	
	89 to < 129 cattle	1.21	0.53--2.74	
	≥ 129 cattle	0.93	0.41--2.1	
Age	36 to < 72 months	--	--	0.62
	72 to < 108 months	0.95	0.31--4.13	
	> 108 months	1.13	0.26--4.26	
Other cows present during calving	No	--	--	0.05
	Yes	0.52	0.29--0.94	

a The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

Table 4.7. (Continued).

Explanatory factor	**Level of explanatory factor**	**Odds ratio (OR)**	**95% confidence interval (OR)**	***P*-value[a]**
Farm Tech Equipment Cleaned	No	--	--	0.009
	Yes	0.48	0.28--0.84	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

Combined Beef and Dairy Model

The combined beef and dairy multivariable model (176 herds) was limited to those potential explanatory variables common to both beef and dairy cattle and herds. The potential explanatory factors that were significant in the combined multivariable model were: cow-type (i.e., beef versus dairy), agroecological region, and cleansing of farm tech equipment. The combined multivariable model confirmed that beef cattle have decreased seropositivity (OR: 0.28, 95% CI: 0.19-0.41) versus dairy cattle. The agroecological region, with parkland as the referent level, was statistically significant ($P = 0.004$) in the final combined beef and dairy multivariable model. The agroecological regions, grassland and montane, indicated a sparing effect, (OR: 0.51, 95% CI: 0.32-0.81), (OR: 0.52, 95% CI: 0.27-1.01) respectively, regarding the risk for seropositivity to NC. The boreal forest agroecological region was associated with a non-significantly increased odds (OR: 1.09, 95% CI: 0.71-1.67) for seropositivity to NC. In addition, the practice of cleansing farm tech equipment was associated with a decreased risk (OR: 0.66, 95% CI: 0.46-0.95) of seropositivity to *N. caninum*. The potential risk factor, age, was forced in to the model, due to reasons similar to the other models that were created, to account for potential effects of NC seropositivity and age.

Table 4.8. Multivariable model utilizing a generalized linear model with a random effect for herd, and fixed effects for host-, herd-, and agroecological explanatory factors for the combined beef and dairy study cattle and herds.

Explanatory factor	Level of Explanatory Factor	Odds ratio (OR)	95% confidence interval (OR)	*P*-value[a]
Age	36 to < 72 months	--	--	0.28
	72 to 108 months	1.13	0.92--1.37	
	> 108 months	1.15	0.87--1.54	
Herd Size	< 70 cattle	--	--	0.15
	70 to < 89 cattle	1.34	0.73--2.44	
	89 to < 108 cattle	0.93	0.52--1.66	
	≥ 108 cattle	0.71	0.43--1.18	
Cowtype	Dairy	--	--	< 0.001
	Beef	0.28	0.19--0.41	
Agroecological Region	Parkland	--	--	0.004
	Grassland	0.51	0.32--0.81	
	Montane	0.52	0.27--1.01	
	Boreal Forest	1.09	0.71--1.67	
Farm Tech Equiment Cleaned	No	--	--	0.03
	Yes	0.66	0.46--0.95	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

The variance attributed to the herd effect, in the base-line model, was 28.8 percent. As the herd-level explanatory factors were added in to the final combined beef and dairy multivariable model, the variance attributed to the herd effect was reduced to 22.5 percent.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Introduction

Since 1988, many cross-sectional studies throughout the world have been conducted in an attempt to assess factors associated with *Neospora caninum* seropositivity in cattle. A common problem with comparing results from these studies is that a variety of methodologies, study design, serological testing and data collection have been used making comparison of results difficult.

In Canada, there remains a lack of research pertaining to the potential factors associated with seropositivity to *N. caninum*. To the best of our knowledge, this was the first attempt to perform an analysis of the potential factors associated with NC seropositivity among beef and dairy cattle in Alberta, Canada. This project was a further analysis of data collected in Alberta, Canada, which focused on determining the baseline seroprevalence of NC and several other diseases in the province (Scott et al., 2006; Scott et al., 2007). The study design by Scott et al. (2006; 2007) allowed the direct comparison of potential risk factors among beef and dairy study cattle by using identical methodologies for survey and sampling procedures. This is the major advantage of this study, whereas previous comparisons of potential risk factors among beef and dairy cattle have involved the extrapolation of results from independent studies with different study designs. When attempting to combine results (e.g., with meta-analyses) from studies with different study designs, biases may be introduced, changing the interpretation of the results from the original studies.

The following discussion will focus on a comparison and contrasting of the potential important factors reported in the existing literature and from the current study. The primary focus will be on discussing the results in an effort to better elucidate the differences in seroprevalence among beef and dairy cattle as they relate to the factors examined in our study.

Potential Explanatory Factors

Individual Level Risk Factors

In this study, we evaluated host-, herd-, and agroecological factors in an effort to identify factors associated with NC seropositivity to beef and dairy herds. In both beef and dairy herds, the individual animal risk factors were first assessed in the bivariate analysis. In beef and dairy cattle, age was not statistically significant in bivariate analysis. In the literature, there is contradicting evidence suggesting that increasing age or gestation number is a potential risk factor for NC seropositivity (Rinaldi et. al., 2005; Sanderson et. al., 2000). A study in Canada reported that increasing age led to a decreased seropositivity to NC (Waldner et. al., 1998) providing evidence contrary to the studies by Rinaldi et al. (2005) and Sanderson et al. (2000). In the Waldner et al. study, it was noted that seropositive cows had a higher risk of being culled which potentially eliminated older seropositive cattle, thus modifying the age effect. In addition, a European study noted a decreased risk of seropositivity in cattle with increasing age (Bartels et al., 2006a). As can been seen by the evidence, it is quite unclear regarding the effect of age as associated with seropositivity to NC. In our study, there was a non-significant trend towards decreased seropositivity in older animals (Tables 4.6 and 4.8) with the major differences in age categories most obvious in the beef cattle. It may be possible that the risk of seropositivity increases with age due to a greater opportunity for exposure, but decreases as a result of increased culling risk. Alternatively, expression of seropositivity may decrease due to development of immunity, or latent infection not stimulating antibody production. Certainly, culling pressures related to reproductive shortcomings make prevalence data less-than-appealing when evaluating the real impact of age on seroprevalence, or vice versa.

In the present study, dominant breed was a significant risk factor in bivariate analysis for beef cattle, with Angus, Simmental, and Charolais exhibiting the highest seroprevalences (10-13%). In another reported study, breed was related to an increased risk of seropositivity to NC infection in dairy cattle (Bartels et al., 2006a). The comparisons that were made in that study varied between very intensively managed Holstein Friesian dairy cattle and the extensively reared beef breeds in Spain with very low stocking density, therefore, it should be noted that this observed effect could have been the result of comparing differing management systems among the breeds. In the current study, the majority of dairy cattle were Holsteins with very few numbers of other dairy breeds; therefore, particular dairy breeds were not evaluated for an increased/decreased seroprevalence regarding neosporosis.

Presence of Domestic Dogs and Other Canids

The domestic dog has been shown to be a definitive host of *N. caninum* (Lindsay et al., 1999; Corbellini, 2006). Therefore, it should be expected that the presence of dogs on the farm would lead to an increased seroprevalence for NC. The bivariate results indicated that on the Alberta study farms, the presence of dogs was not a significant risk factor to be considered for the multivariable modeling. The presence of dogs was categorized at the median number of dogs, and as the presence or absence of dogs on the farms. In this study, the age of dogs was not a question in the survey that was administered to the participating farmers; but it was noted that the majority of the dogs present on the farms were spayed or neutered, thereby suggesting that there would not be a new source of young dogs (i.e., those more likely to shed large numbers of infectious NC oocysts). In the literature, there is evidence that the rate of domestic dogs shedding oocysts decreases with age of the dog exceeding two months (Gondim et al., 2005). Although the ages of the dogs were not assessed in this study, if it is assumed that the majority of dogs are not neutered or spayed until approximately four to six months of age, the decreased numbers of shed oocysts in the assumed older study dogs may explain why the presence of dogs or differing age groups of dogs was not a significant factor in the bivariate analysis.

Since wild canids were seen on the majority of the farms, it was not possible to assess the variable for significance as the presence/absence of wild canids. The coyote has been shown to be a definitive host for *N. caninum*, therefore, should be considered a source of potential infection for future studies (Gondim et al., 2004a). There is no information about the rate at which dogs or coyotes shed oocysts in the natural environment, making it difficult to assess the role they may have in bovine neosporosis. In addition, in Alberta, Canada, there is a lack of information pertaining to the densities of wild canids and other wildlife in the province. Once this critical gap in the knowledge base is filled, an assessment of *N. caninum* among wild canids, other wildlife, beef and dairy cattle will be generated expanding the understanding of neosporosis.

As seen in the previous maps of relative risk for seropositivity to NC in beef cattle, it was noted that the highest level of risk was in the northern portion of the agricultural areas (Thompson and Scott, 2007). This corresponds to the boreal forest agro-ecological region where there may be more habitat capable of supporting higher populations of wild canids. If it is found that this area has higher populations of wild canids versus other agro-ecological regions, a critical point in reducing the seroprevalence in beef cattle would be to reduce wild canid exposure in areas that beef cattle are present.

Herd Size and Cattle Stocking Density

The potential explanatory risk factor, herd size (total number of cattle on the farm) was not statistically significant in the bivariate analysis for either beef or dairy study herds. This result is consistent with other studies that concluded that herd size is most likely a surrogate for hygiene status on the farm (Otranto et al., 2003). In addition, cattle stocking density was not statistically significant in beef cattle. The method used to calculate the cattle stocking density was to divide the total number of cattle by the acreage of the farm. In this study, it was not possible to discern if the beef cattle had access to all the acreage which may have potentially created problems in the analysis of this explanatory variable due to the method of calculation. Regarding dairy cattle in Canada, since the majority of the dairy cattle are managed in barns or drylots, the total acreage of the farm is likely not the important factor in calculating the cow density. We were not able to assess the impact of stocking density within the barns due to a lack of information about the size of the barns and numbers of cattle within each barn.

Acreage of the Farm

The acreage of the farm was evaluated for beef and dairy cattle. As expected, the acreage of the farm was not a significant explanatory variable concerning dairy cattle due to the nature of the management systems. The acreage of farm for beef cattle was dichotomized at the median of 1500 acres for the assessment. The results indicated that there was a decreased risk of seropositivity with an increased acreage of the farm. The biological mechanisms for this observation are not known, especially as the effect remained important even after adjusting for the agro-ecological region. One hypothesis that was stated in another study with similar results concluded that on larger farms there is less interaction between domestic dogs and cattle (Corbellini et al., 2006), where the dogs tend to stay close to the farm house and out-buildings. In addition, larger farms may present less potential for a localized point-source exposure (i.e. contaminated commercial feeds and water) due to likely greater grazing areas and reduced intensive feeding practices as compared to smaller acreage farms. If larger grazing areas exist this could be viewed as providing a mechanism to dilute the concentration of infectious oocysts that were in the environment when comparing farms less than or greater than 1500 acres. A caveat to be considered is that on larger farms there may be an increased chance that the disease is spread by wild canids, such as the coyote, but in the current literature there is no evidence to support this hypothesis.

Multivariable Models

The multivariable models created from the data collected for this study were produced in an attempt to elucidate the differences in seropositivity between beef and dairy cattle by analyzing associated host-, herd-, and agroecological risk factors. The multivariable models were largely unsuccessful at identifying potential risk factors from our survey, although a potentially important observation was noted pertaining to a spatial disease process that exists in beef cattle versus dairy cattle (Thompson and Scott, 2007).

Beef Multivariable Model

The potential explanatory factors identified in the final beef multivariable model pertained predominantly to environmental factors rather than farm management factors. In this model, herd size was forced in to the model to account for unrecognized surrogate factors. The odds ratios associated with the agroecological regions suggest that the seroprevalence increased from the southern portions of Alberta in the grassland regions up to the more northern boreal forest agroecological region. An additional analysis utilizing this data set involved the spatial analysis of the risk of seropositivity to NC among beef and dairy cattle (Thompson and Scott, 2007). In Figure 5.1, the results of this study clearly show that there is a gradual increase in risk of seropositivity from the southern portion of Alberta extending to the northern regions, further supporting evidence from the multivariable model. These observations may reflect the fact that there are greater numbers of wild canids due to more abundant habitat and prey providing a greater source of infectious oocysts. Another possibility is that in the northern regions during winter months, assuming *N. caninum* oocysts are similar to *Toxoplasma gondii* oocysts regarding environmental survival, the sporulation of oocysts is delayed and when conditions are favorable for sporulation there is a greater concentration of infectious oocysts as compared to southern regions (Lindsay et al., 2002).

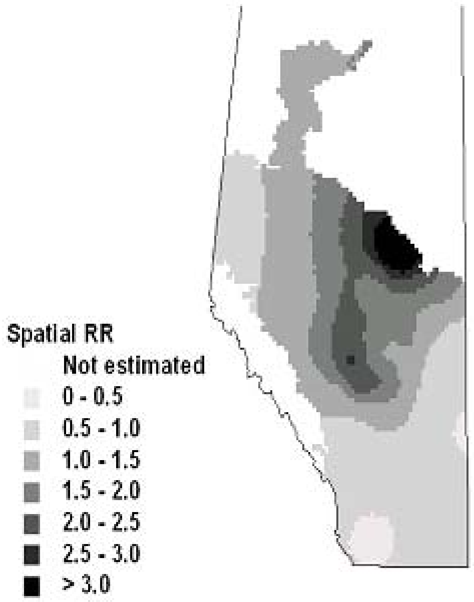

Figure 5.1. Spatial Relative Risk for Seropositivity to NC for Beef Herds.
Thompson J., Scott H.M. 2007. Bayesian kriging of serprevalence to MAP and NC in Alberta beef and dairy cattle. Can Vet J. 48:1281-1285

The location of the calving site may be an indication of horizontal transmission. The multivariable model indicated that cows calving in the corral versus calving in the pasture were associated with decreased odds for seropositivity to NC. This suggests that the corral is providing a protective factor. A possible explanation for this observation is that when calving occurs in the corral there is a reduced consumption of placental material by domestic dogs and wild canids limiting further shedding of infectious oocysts to the environment.

It would seem plausible that there would be an optimum soil pH in which oocysts would have a maximal survival rate, thereby extending the possibility of transmission to an intermediate or definitive host. It is not clear how the pH of the soil would affect the risk of seropositivity of NC specific antibodies in the beef and dairy cattle. To the author's knowledge there have not been studies conducted involving the treatment of infectious oocysts to different environmental conditions to test survivability; however, due to similarities to *T. gondii* oocysts it is assumed that NC oocysts are very stable in the environment.

Dairy Multivariable Model

In the dairy multivariable model there was a complete lack of the spatial effect that existed in the beef multivariable model (Figure 5.2). The potential explanatory factors that were identified related instead to herd management factors as opposed to the environmental factors identified in the beef multivariable model. This point further emphasizes that differences observed in seropositivity to NC in dairy versus beef cattle is related management practices (i.e. management within barns, thereby eliminating the effect of the external environment).

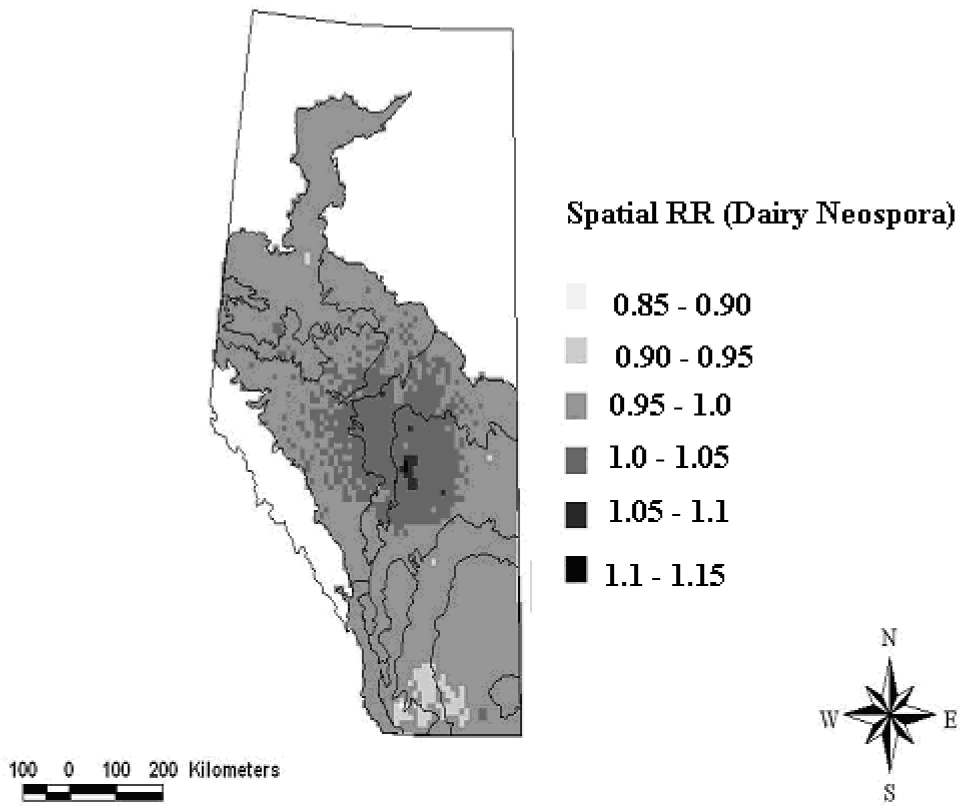

Figure 5.2. Spatial Relative Risk for Seropositivity to NC in Dairy Herds.
Thompson J., Scott H.M. 2007. Bayesian kriging of seroprevalence to MAP and NC in Alberta beef and dairy cattle. Can Vet J. 48:1281-1285

The presence of other cattle at calving corresponded to a decreased risk of seropositivity in the final dairy multivariable model. This observation may be explained by the fact that having numerous cattle present may limit contact of domestic dogs or wild canids with the calf and placenta, thereby reducing the rate of horizontal transfer of NC. The cleaning of the farm tech equipment was associated with a decreased risk of seropositivity to NC in the final multivariable dairy model. In this model herd size, although non-significant in bivariate analysis, was forced in the model as it is commonly a surrogate for other factors. In this study, it is believed that this factor is an overall surrogate for the level of hygiene on the farm.

Combined Beef and Dairy Multivariable Model

While the data for this study were collected in an identical manner for both beef and dairy cattle, there were several issues that arose in the creation of the combined multivariable model. Among the variables that were statistically significant in the bivariate analysis, several of the explanatory factors were exclusively associated with either beef or dairy cattle which limited the available potential explanatory variables that could be analyzed in the combined beef and dairy multivariable model.

In the final combined beef and dairy model, as expected from the reported seroprevalences in Alberta, Canada, beef were reported to have a decreased risk of seropositivity to NC when compared to dairy cattle. As noted beforehand, the difference in the seropositivity to NC among beef and dairy cattle seems to be related to the differences in management systems. In the combined beef and dairy model, agro-ecological region was not a significant variable in the multivariable model which was important in the beef multivariable model. The beef and dairy study herds were well distributed throughout the province of Alberta, spanning the agro-ecological regions studied and not being isolated to a particular region. Despite the apparent eco-region effect among beef cattle, this effect extended neither to the dairy cattle, nor to the joint model despite the assessment of an interaction term assessing region by cow-type effects. This suggests that the observed effect in beef cattle is an effect that is exclusive to extensively reared cattle.

Although the multivariable models did not entirely successfully explain the variance in seroprevalence between beef and dairy cattle it remains likely that differences may be due to varying management practices. In beef cattle operations, cows will be culled if there are breeding difficulties or a live calf is not produced every calendar year. In the dairy industry, the cows must still be bred in a timely manner but there is a greater chance that a dairy cow will be rebred following an initial failed breeding, given the much more intensive reproduction efforts, and willingness to have cows calve year-round. The dairy cow that has not been successfully bred will often be cycled with the next group of cows therefore having a decreased chance of being culled. If the cow, potentially infected with NC, is subsequently bred it will remain in the population and remain as a continuous source of NC. When calves of seropositive cows are kept in the herd as replacements there is a potential for the seroprevalence of NC to increase in that herd. The main mode of this action is via vertical transmission. If the above logic is correct, the differences in reproductive management between beef and dairy herds could create a difference when studying seroprevalence of NC. It is important to remember that seroprevalence reflects not only the incidence of news cases, but also the duration or longevity of infected cases within herds.

Study Limitations

The utilization of this data set provided a unique opportunity to analyze the host-, herd- and agroecological risk factors associated with seropositivity among beef and dairy cattle. The original survey was designed to collect a broad spectrum of information pertaining to four different diseases and was not designed to specifically only study *N. caninum* (Appendix D).

Due to the nature of the cross-sectional study design, the ability to prove causal associations between the risk factors and the outcome is not possible. In addition, it is not possible to determine when the exposure occurred in seropositive cattle which could potentially provide estimates of the rates of disease transfer among and within cattle herds. Therefore, in this study it was not possible to determine if those herds with the majority of cattle testing seropositive to NC were the result of an abortion storm or if the cattle had a longer period of potential exposure to NC leading to the increased percentage of seropositive cattle. Finally, the impact of differential culling risks for seropositive cattle will affect the observed seroprevalence among various herds which can make interpretation of seroprevalence among herds difficult if the history of culling practices is unknown.

As is the case with all diagnostic tests, there is an inherent degree of error associated with each of the tests. In the many studies involving neosporosis there have been several diagnostic methods used to evaluate the serological status of the sample sera; this in turn may create problems when comparing seroprevalence rates amongst different study areas.

Recommendations for Future Studies

In the case of infection with *Neospora caninum* (NC), seroprevalence to same, and its clinical manifestation of neosporosis, much of the current knowledge concerning NC in cattle is based upon multiple cross-sectional studies demonstrating similar associations. These cross-sectional studies have been important in influencing the direction of future research but are not sufficient to identify causal risk factors. In the future, longitudinal studies are needed to evaluate the relationships that have become accepted as factual without any experimental or longitudinal study evidence. Studies should instead focus on obtaining reliable estimates regarding the number of infectious oocysts that are shed by domestic dogs and other wild canids, such as the coyote, fox and wolf. In addition, investigations should be performed to identify other definitive hosts within the wildlife populations. It seems unlikely that the domestic dog and the coyote would be the only contributors of infectious oocysts into the environment, especially when considering how many different wildlife species have been shown to be seropositive for antibodies to *N. caninum* which may be found to be definitive hosts in the future.

The major problem facing future research regarding neosporosis is that there is not an acceptable animal model in which to study the disease. In addition, studies focused on modeling neosporosis will be hampered due to an inability to obtain a sufficient amount of infectious oocysts for experimentation.

Conclusions

To the author's knowledge this is the first study to assess potential risk factors among beef and dairy cattle using an identical study design. This study did not find any statistically significant differences regarding risk of seropositivity to NC as related to age, cattle breed, or the presence of domestic dogs. In addition, a significant spatial distribution related to the risk of seropositivity to NC was noted in beef cattle but not in dairy cattle. The significance of this finding is not yet fully understood but suspected to be related to the differences in which beef and dairy cattle are managed. In addition, the spatial distribution could be related to the distribution of wild canids in the environment with higher densities in northern Alberta where there is sufficient habitat to support the population.

As shown in this study, it is believed that the differences in seropositivity to NC between beef and dairy cattle and herds are primarily due to differences in management systems as discussed previously. In the future, longitudinal studies are needed to validate the potential risk factors that have been identified in previous cross-sectional studies.

REFERENCES

Agricultural Region of Alberta Soil Inventory Database (AGRASID). 2007. Available at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag3249.

Barling, K. S., McNeill J.W., Thompson J.A., Paschal J.C., McCollum E.T., Craig T.M., Adams L.G., 2000. Association of serologic status for *Neospora caninum* with post weaning weight gain and carcass measurements in beef calves. J. Am. Vet. Med. Assoc. 217**:**1356-1360.

Barling, K. S., McNeill, J.W., Paschal J.C., McCollum III, F.T., Craig, T.M., Adams, L.G., Thompson, J.A., 2001. Ranch-management factors associated with antibody seropositivity for *Neospora caninum* in consignments of beef calves in Texas, USA. Prev. Vet. Med. 52**:**53-61.

Bartels, C. J. M., van Schaik, G., Veldhuisen, J.P., van den Borne, B.H.P., Wouda, W., Dijkstra, T., 2006a. Effect of *Neospora caninum*-serostatus on culling, reproductive performance and milk production in Dutch dairy herds with and without a history of *Neospora caninum* associated abortion epidemics. Prev. Vet. Med. 77**:**186-198.

Bartels, C. J. M., Arnaiz-Seco, J.I., Ruiz-Santa-Quitera, A., Björkman, C., Frössling, J., von Blumröder, D., Conraths, F.J., Schares, G., van Maanen, C., Wouda, W., Ortega-Mora, L.M., 2006b. Supranational comparison of *Neospora caninum* seroprevalences in cattle in Germany, the Netherlands, Spain and Sweden. Vet. Parasitol. 137**:**17-27.

Basso, W., Venturini, L., Venturini, M.C., Hill, D.E., Kwok, O.C.H., Shen, S.K., Dubey, J.P., 2001. First isolation of *Neospora caninum* from the feces of a naturally infected dog. J. Parasitol. 87:612–618.

Bjerkås, I., Mohn, S.F., Presthus, J., 1984. Unidentified cyst-forming sporozoan causing encephalomyelitis and myositis in dogs. Z. Parasitenkd. 70**:**271-274.

Canada-Alberta Environmentally Sustainable Agriculture Agreement (CAESA). 2002. http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag3363/$file/index.pdf.

Corbellini, L.G., Smith, D.R., Pescador, C.A., Schmitz, M., Correa, A., Steffen, D.J., Driemeier, D., 2006. Herd-level risk factors for *Neospora caninum* seroprevalence in dairy farms in southern Brazil. Prev. Vet. Med. 74**:**130-141.

Cramer, G., Kelton, D., Duffield, T.F., Hobson, J.C., Lissemore, K., Hietala, S.K., Peregrine, A.S., 2002. *Neospora caninum* serostatus and culling of Holstein cattle. J. Am. Vet. Med. Assoc. 221**:**1165-1168.

Davison, H.C., Guy, C.S., McGarry, J.W., Guy, F., Williams, D.J.L., Kelly, D.F., Trees, A.J., 2001. Experimental studies on the transmission of *Neospora caninum* between cattle. Res. Vet. Sci. 70**:**163-168.

Dijkstra, T., Barkema, H.W., Hesselink, J.W., Wouda, W., 2002. Point source exposure of cattle to *Neospora caninum* consistent with periods of common housing and feeding and related to the introduction of a dog. Vet. Parasitol. 105**:**89-98.

Dubey, J.P. 2003. Review of *Neospora caninum* and neosporosis in animals. The Korean J. Parasitol. 41:1-16.

Dubey, J.P., Hattel, A.L., Lindsay, D.S., Topper, M.J., 1988. Neonatal *Neospora caninum* infection in dogs: isolation of the causative agent and experimental transmission. J. Am. Vet. Med. Assoc. 193**:**1259-1263.

Dubey, J.P., Lindsay, D.S., 1996. A review of *Neospora caninum* and neosporosis. Vet. Parasitol. 67**:**1-59.

Dubey, J.P., Knickman, E., Greene, C.E., 2005. Neonatal *Neospora caninum* infections in dogs. Acta Parasitol. 50**:**176-179.

Dubey, J.P., Schares, G., 2006. Diagnosis of bovine neosporosis. Vet. Parasitol. 141**:**1-34.

Dubey, J.P., Schares, G., Ortega-Mora, L.M. 2007. Epidemiology and control of neosporosis and *Neospora caninum*. Clinical Microbiology Reviews. p. 323-367.

Georgieva, D.A., Prelezov, P.N., Koinarski, V.T.S. 2006. *Neospora caninum* and neosporosis in animals—a review. Bulgarian J. Vet. Med. 9:1-26.

Gondim, L.F.P., McAllister, M.M., Pitt, W.C., Zemlicka, D.E., 2004a. Coyotes (*Canis latrans*) are definitive hosts of *Neospora caninum*. Int. J. Parasitol. 34**:**159-161.

Gondim, L.F.P., McAllister, M.M., Mateus-Pinilla, N.E., Pitt, W.C., Mech, L.D., Nelson, M.E., 2004b. Transmission of *Neospora caninum* between wild and domestic animals. J. Parasitol. 90**:**1361-1365.

Gondim, L.F.P., McAllister, M.M., Gao, L., 2005. Effects of host maturity and prior exposure history on the production of *Neospora caninum* oocysts by dogs. Vet. Parasitol. 134**:**33-39.

Haddad, J.P.A., Dohoo, I.R., VanLeewen, J.A., 2005. A review of *Neospora caninum* in dairy and beef cattle—a Canadian perspective. Can. Vet. J. 46**:**230-243.

Häsler, B., Regula, G., Stärk, K.D.C., Sager, H., Gottstein, B., Reist, M., 2006a. Financial analysis of various strategies for the control of *Neospora caninum* in dairy cattle in Switzerland. Prev. Vet. Med. 77:230-253.

Häsler, B., Stärk, K.D.C., Sager, H., Gottstein, B., Reist, M., 2006b. Simulating the impact of four control strategies on the population dynamics of *Neospora caninum* infection in Swiss dairy cattle. Prev. Vet. Med. 77:254-283.

Hemphill, A., Conraths, F.J., De Meerschman, F., Ellis, J.T., Innes, E.A., McAllister, M.M., Ortega-Mora, L.-M, Tenter, A.M., Trees, A.J., Uggla, A., Williams, D.J.L., Wouda, W. 2000. A European perspective on *Neospora caninum*. Int. J. Parasitol. 30: 877-924.

Hobson, J.C., Duffield, T.F., Kelton, D., Lissemore, K., Hietala, S.K., Leslie, K.E., McEwen, B., Cramer, G., Peregrine, A.S., 2002. *Neospora caninum* serostatus and milk production of Holstein cattle. J. Am. Vet. Med. Assoc. 221**:**1160-1164.

Huang, C.C., Yang, C.H., Watanabe, Y., Liao, Y.K., Ooi, H.K., 2004. Finding of *Neospora caninum* in the wild brown rat (*Rattus norvegicus*). Vet. Res. 35**:**283-290.

Koyama, T., Kobayashi, Y., Omata, Y., Yamada, M., Furuoka, H., Maeda, R., Matsui, T., Saito, A., Mikami, T., 2001. Isolation of *Neospora caninum* from the brain of a pregnant sheep. J. Parasitol. 87**:**1486-1488.

Larson, R.L., Hardin, D.K., Pierce, V.L., 2004. Economic considerations for diagnostic and control options for *Neospora caninum*-induced abortions in endemically infected herds of beef cattle. J. Am. Vet. Med. Assoc. 224:1597-1604.

Lindsay, D.S., Dubey, J.P., Duncan, R.B., 1999. Confirmation that the dog is a definitive host for *Neospora caninum*. Vet. Parasitol. 82**:**327-333.

Lindsay, D.S., Blagburn, B.L., Dubey, J.P. 2002. Survival of non-sporulated *T. gondii* oocysts under refrigerador conditions. Vet. Parasitol. 103:309-313.

Lindsay, D.S., Collins, M., Mitchell, S., Cole, R.A., Flick, G., Wetch, C.N., Lindquist, A., Dubey, J.P. 2003. Sporulation and survival of *Toxoplasma gondii* in seawater. J. Eukaryot. Microbiol. 50: 687-688.

Lobato, J., Silva, D.A.O., Mineo, T.W.P., Amaral, J.D.H.F., Segundo, G.R.S., Costa-Cruz, G.M., Ferreira, M.S., Borges, A.S., Mineo, J.R., 2006. Detection of immunoglobulin G antibodies to *Neospora caninum* in humans: high seropositivity rates in patients who are infected by human immunodeficiency virus or have neurological disorders. Clin. Vaccine Immunol. 13**:**84-89.

McAllister, M.M., Dubey, J.P., Lindsay, D.S., Jolley, W.R., Wills, R.A., McGuire, A.M., 1998. Dogs are definitive hosts of *Neospora caninum*. Int. J. Parasitol. 28**:**1473-1478.

McAllister, M. M., Björkman, C., Anderson-Sprecher, R., Rogers, D.G., 2000. Evidence of point-source exposure to *Neospora caninum* and protective immunity in a herd of beef cows. J. Am. Vet. Med. Assoc. 217**:**881-887.

McGarry, J.W., Stockton, C.M., Williams, D.J.L., Trees, A.J., 2003. Protracted shedding of oocysts of *Neospora caninum* by a naturally infected foxhound. J. Parasitol. 89:628–630.

Ortega-Mora, L.M., Fernández-García, A., Gómez-Bautista, M., 2006. Diagnosis of bovine neosporosis: recent advances and perspectives. Acta Parasitol. 51**:**1-14.

Otranto, D., Llazari, A., Testini, G., Traversa, D., di Regalbono, A.F., Badan, M., Capelli, G., 2003. Seroprevalence and associated risk factors of neosporosis in beef and dairy cattle in Italy Vet. Parasitol. 118**:**7-18.

Ould-Amrouche, A., Klein, F., Osdoit, C., Mohamed, H.O., Touratier, A., Sanaa, M., Mialot, J.P., 1999. Estimation of *Neospora caninum* seroprevalence in dairy cattle from Normandy, France. Vet. Res. 30**:**531-538.

Rinaldi, L., Fusco, G., Musella, V., Veneziano, V., Guarino, A., Taddei, R., Cringoli, G., 2005. *Neospora caninum* in pastured cattle: determination of climatic, environmental, farm management and individual animal risk factors using remote sensing and geographical information systems. Vet. Parasitol. 128**:**219-230.

Rodrigues, A.A., Gennari, R.S.M., Aguiar, D.M., Sreekumar, C., Hill, D.E., Miska, K.B., Vianna, M.C.B., Dubey, J.P., 2004. Shedding of *Neospora caninum* oocysts by dogs fed tissues from naturally infected water buffaloes (*Bubalus bubalis*) from Brazil. Vet. Parasitol. 124**:**139-150.

Sanderson, M.W., Gay, J.M., Baszler, T.V., 2000. *Neospora caninum* seroprevalence and associated risk factors in beef cattle in the northwestern United States. Vet. Parasitol. 90**:**15-24.

Schares, G., Bärwald, A., Staubach,C., Ziller, M., Klöss, D., Schroder, R., Labohm, R., Dräger, K., Fasen, W., Hess, R.G., Conraths, F.J., 2004. Potential risk factors for bovine *Neospora caninum* infection in Germany are not under the control of the farmers. Parasitol. 129**:**301-309.

Scott, H.M., Sorensen, O., Wu, J.T., Chow, E.Y., Manninen, K., VanLeeuwen, J.A., 2006. Seroprevalence of *Mycobacterium avium* subspecies paratuberculosis, *Neospora caninum*, bovine leukemia virus, and bovine viral diarrhea virus infection among dairy cattle and herds in Alberta and agroecological risk factors associated with seropositivity. Can. Vet. J. 47**:**981-991.

Scott, H.M., Sorensen, O., Wu, J.T., Chow, E.Y., Manninen, K., 2007. Seroprevalence of and agroecological risk factors for *Mycobacterium avium* subspecies paratuberculosis and Neospora caninum infection among adult beef cattle in cow-calf herds in Alberta, Canada. Can. Vet. J. 48:397-406.

StataCorp. 2005. Stata Statistical Software: Release 9 Multivariate Statistics. College Station, TX: StataCorp LP.

The Atlas of Canada. Facts about Canada. 2006. Available at: http://www.atlas.nrcan.gc.ca

Thompson, J., Scott, H.M., 2007. Bayesian kriging of seroprevalence to MAP and NC in Alberta beef and dairy cattle. Can Vet J 48:1281-1285.

Thurmond, M.C., Hietala, S.K., 1996. Culling associated with *Neospora caninum* infection in dairy cows. Am. J. Vet. Res. 57**:**1559-1562.

Tiwari, A., VanLeeuwen, J.A., Dohoo, I.R., Stryhn, H., Keefe, G.P., Haddad, J.P., 2005. Effects of seropositivity for bovine leukemia virus, bovine viral diarrhea virus, *Mycobacterium avium* subspecies *paratuberculosis*, and *Neospora caninum* on culling in dairy cattle in four Canadian provinces. Vet. Microbiol. 109:147-158.

Tranas, J., Heinzen, R.A., Weiss, L.M., McAllister, M.M., 1999. Serological evidence of human infection with the protozoan *Neospora caninum*. Clin. Diagn. Lab. Immunol. 6:765-767.

Trees, A.J., Williams, D.J.L., 2005. Endogenous and exogenous transplacental infection in *Neospora caninum* and *Toxoplasma gondii*. Trends Parasitol. 21**:**558-561.

Uggla, A., Stenlund, S., Holmdahl, O.J.M., Jakubek, E.B., Thebo, P., Kindahl, H., Björkman, C., 1998. Oral *Neospora caninum* inoculation of neonatal calves. Int. J. Parasitol. 28**:**1467-1472.

Vianna, M.C.B., Sreekumar, C., Miska, K.B., Hill, D.E., Dubey, J.P., 2005. Isolation of *Neospora caninum* from naturally infected white-tailed deer (*Odocoileus virginianus*). Vet. Parasitol. 129**:**253-257.

Waldner, C. L., Janzen, E.D., Ribble, C.S., 1998. Determination of the association between *Neospora caninum* infection and reproductive performance in beef herds. J. Am. Vet. Med. Assoc. 213:685-690.

Wu, J., Dreger, S., Chow, E., Bowlby, E., 2002. Validation of 2 commercial *Neospora caninum* antibody enzyme linked immunosorbent assays. Can Vet. J. 66: 264-271.

APPENDIX A

Table A.1. Bivariate analysis of potential explanatory variables by serological status to *Neospora caninum* (NC) for beef multivariable models (n = 2968).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	NC Serological Status Frequency [%][b] (+)	*P*-value[a]
Agroecological region	Grassland	543 [95.3%]	27 [4.7%]	0.08
	Montane	168 [93.3%]	12 [6.7%]	
	Parkland	1168 [90.5%]	122 [9.5%]	
	Boreal Forrest	789 [85%]	139 [15%]	
Dominant Breed	Angus	472 [92.7%]	37 [7.3%]	0.02
	Red Angus	237 [94.8%]	13 [5.2%]	
	Charolais	526 [88.7%]	67 [11.3%]	
	Hereford	409 [94.2%]	25 [5.8%]	
	Limousin	113 [87.6%]	16 [12.4%]	
	Simmental	606 [86.1%]	98 [13.9%]	
	Other	305 [87.4%]	44 [12.6%]	
Acreage of Farm	≤ 1500 acres	1113 [86.4%]	175 [13.6%]	0.002
	> 1500 acres	1555 [92.6%]	125 [7.4%]	
Acreage of Pasture	≤ 490 acres	687 [85%]	121 [15%]	0.005
	> 490 acres	1981 [91.7%]	179 [8.3%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status		*P* -value[a]
		Frequency [%][b]		
		(-)	(+)	
Acreage of Forage	≤ 350 acres	1265 [88%]	173 [12%]	0.09
	> 350 acres	1403 [91.7%]	127 [8.3%]	
Number Culled: Open heifers	None	1334 [89.1%]	164 [10.9%]	0.66
	At least one	1334 [90.7%]	136 [9.3%]	
Number Culled: Bred	None	2279 [89.4%]	269 [10.6%]	0.37
	At least one	389 [92.6%]	31 [7.4%]	
Number Culled: Adult	≤15	1443 [90.8%]	147 [8.2%]	0.4
	>15	1225 [88.9%]	153 [11.1%]	
Number Culled: Bulls	≤ 1	1363 [89.2%]	165 [10.8%]	0.83
	> 1	1305 [90.6%]	135 [9.4%]	
Number sold as feeders: pre-weaned calves	0	1618 [90%]	182 [10%]	0.87
	≥ 1	1050 [89.9%]	118 [10.1%]	
Number sold as feeders: post-weaned calves	≤ 2	1331 [90.5%]	139 [9.5%]	0.77
	> 2	1337 [89.2%]	161 [10.8%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status		***P*** **-value**[a]
		Frequency [%][b]		
		(-)	(+)	
Number sold as feeders: yearling heifers	0	1991 [89.8%]	227 [10.2%]	0.94
	≥ 1	677 [90.3%]	73 [9.7%]	
Number sold as feeders: yearling steers/bulls	0	1876 [89.4%]	222 [10.6%]	0.55
	≥ 1	792 [91%]	78 [9%]	
Number died last year: Pre-weaned calves	≤4	1530 [89.6%]	178 [9.4%]	0.42
	>4	1138 [48.1%]	122 [51.9%]	
Number died last year: post-weaned calves	0	1569 [87.3%]	229 [12.7%]	0.2
	≥1	799 [91.8%]	71 [8.2%]	
Number died last year: open heifers	0	2468 [89.5%]	290 [10.5%]	0.08
	≥1	200 [95.2%]	10 [4.8%]	
Number died last year: bred heifers	0	2362 [89.5%]	276 [10.5%]	0.22
	≥1	306 [92.7%]	24 [7.3%]	
Number died last year: adult cows	≤1	1512 [90.1%]	166 [9.9%]	0.48
	>1	1156 [89.6%]	134 [10.4%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Number died last year:	0	2349 [90.1%]	259 [9.9%]	0.58
	≥1	319 [88.6%]	41 [11.4%]	
Number purchased last year: post-weaned heifer	0	2358 [89.4%]	280 [10.6%]	0.17
	≥1	310 [94%]	20 [6%]	
Number purchased last year: post weaned bull	0	2515 [90.2%]	273 [9.8%]	0.18
	≥1	153 [85%]	27 [15%]	
Number purchased last year: open heifers	0	2233 [89.6%]	255 [10.4%]	0.78
	≥1	435 [90.6%]	45 [9.4%]	
Number purchased last year: bred heifers	0	1967 [88.7%]	251 [11.3%]	0.04
	≥1	701 [93.5%]	49 [6.5%]	
Number purchased last year: adult cows	0	1934 [89.6%]	224 [10.4%]	0.83
	≥1	734 [90.6%]	76 [9.4%]	
Number purchased last year: adult cow-calf pairs	0	2257 [89.6%]	261 [10.4%]	0.85
	≥1	411 [91.3%]	39 [8.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Number purchased last year: yearling bulls	≤1	1808 [88.7%]	230 [11.3%]	0.19
	>1	860 [92.5%]	70 [7.5%]	
Number purchased last year: adult bulls	0	1953 [89.3%]	235 [10.7%]	0.4
	≥1	715 [91.7%]	65 [8.3%]	
Major calving season	Spring	1956 [89.4%]	232 [10.6%]	0.62
	Summer	29 [96.7%]	1 [3.3%]	
	Winter	654 [90.8%]	66 [9.2%]	
Are cows and heifers housed separately pre-calving?	No	1039 [89%]	129 [11%]	0.79
	Yes	1629 [90.5%]	171 [9.5%]	
Are cows and heifers housed separately post-calving?	No	1372 [88.1%]	186 [11.9%]	0.08
	Yes	1296 [91.9%]	114 [8.1%]	
Where do cows generally calve-maternity pens?	No	709 [91%]	71 [9%]	0.48
	Yes	1959 [89.5%]	229 [10.5%]	
Where do cows generally calve-common corral?	No	1475 [87.9%]	203 [12.1%]	0.01
	Yes	1193 [92.5%]	97 [7.5%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Where do cows generally calve-large pasture/open range?	No	2503 [89.7%]	285 [10.3%]	0.6
	Yes	165 [91.7%]	15 [8.3%]	
Where do heifers generally calve-maternity pens?	No	1523 [89.1%]	187 [10.9%]	0.38
	Yes	1145 [91%]	113 [9%]	
Where do heifers generally calve-common corral?	No	1441 [89%]	177 [11%]	0.51
	Yes	1227 [90.1%]	123 [9.9%]	
Where do heifers generally calve-large pasture/open range?	No	2611 [89.8%]	297 [10.2%]	0.46
	Yes	57 [95%]	3 [5%]	
How long do heifers-cows remain in calving areas after delivery?	≤4 hours	1439 [90.5%]	151 [9.5%]	0.55
	>4 hours	1229 [89.2%]	149 [10.8%]	
Winter housing-barn-heifer calves	No	2558 [89.8%]	290 [10.2%]	0.84
	Yes	110 [91.7%]	10 [9.3%]	
Winter housing-barn-bred heifers	No	2440 [89.4%]	288 [10.6%]	0.07
	Yes	228 [95%]	12 [5%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Winter housing-barn-adult cows	No	2443 [89.6%]	285 [10.4%]	0.21
	Yes	225 [93.8%]	15 [6.3%]	
Winter housing-barn-bulls	No	2584 [89.8%]	294 [10.2%]	0.57
	Yes	84 [93.3%]	6 [6.7%]	
Winter housing-feedlot/pens-heifer calves/open heifers	No	876 [91.4%]	82 [8.6%]	0.44
	Yes	1792 [89.2%]	218 [10.8%]	
Winter housing-feedlot/pens-bred heifers	No	1885 [89.8%]	213 [10.2%]	0.9
	Yes	783 [90.0%]	87 [10.0%]	
Winter housing-feedlot/pens-adult cows	No	2046 [89.8%]	232 [10.2%]	0.87
	Yes	622 [90.1%]	68 [9.9%]	
Winter housing-feedlot/pens-bulls	No	1487 [90.2%]	161 [9.8%]	0.48
	Yes	1181 [89.5%]	139 [10.5%]	
Small winter pasture/loafing areas-heifer calves/open heifers	No	2129 [89.8%]	241 [10.2%]	0.94
	Yes	539 [90.1%]	59 [9.9%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Small winter pasture/loafing areas-bred heifers	No	1288 [89.4%]	152 [10.6%]	0.39
	Yes	1380 [90.3%]	148 [9.7%]	
Small winter pasture/loafing areas-adult cows	No	1138 [90.3%]	122 [9.7%]	0.92
	Yes	1530 [89.6%]	178 [10.4%]	
Small winter pasture/loafing areas-bulls	No	1400 [89.7%]	160 [10.3%]	0.64
	Yes	1268 [90.1%]	140 [9.9%]	
Large winter pasture/open range-heifer calves/open	No	2616 [90.0%]	292 [10.0%]	0.54
	Yes	52 [86.7%]	8 [13.3%]	
Large winter pasture/open range-bred heifers	No	1868 [90.3%]	200 [9.7%]	0.28
	Yes	800 [88.9%]	100 [11.1%]	
Large winter pasture/open range-adult cows	No	1231 [89.3%]	147 [10.7%]	0.95
	Yes	1437 [90.4%]	153 [9.6%]	
Large winter pasture/open range-bulls	No	2320 [90.0%]	258 [10.0%]	0.48
	Yes	348 [89.2%]	42 [10.8%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status		***P*** **-value**[a]
		Frequency [%][b]		
		(-)	(+)	
Summer housing-barn-heifer calves/open heifers	No	2639 [89.8%]	299 [10.2%]	0.41
	Yes	29 [96.7%]	1 [3.3%]	
Summer housing-barn-bred heifers	No	2639 [89.8%]	299 [10.2%]	0.41
	Yes	29 [96.7%]	1 [3.3%]	
Summer housing-barn-adult cows	No	2610 [89.8%]	298 [10.2%]	0.24
	Yes	58 [96.7%]	2 [3.3%]	
Summer housing-barn-bulls	No	2639 [89.8%]	299 [10.2%]	0.41
	Yes	29 [96.7%]	1 [3.3%]	
Summer housing-feedlot/pens-heifer calves/open heifers	No	2525 [90.6%]	263 [9.4%]	0.1
	Yes	143 [79.4%]	37 [20.6%]	
Summer housing-feedlot/pens-bred heifers	No	2614 [89.9%]	294 [10.1%]	0.93
	Yes	54 [90.0%]	6 [10.0%]	
Summer housing-feedlot/pens-adult cows	No	2610 [89.8%]	298 [10.2%]	0.24
	Yes	58 [96.7%]	2 [3.3%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Summer housing-feedlot/pens-bulls	No	2525 [89.6%]	293 [10.4%]	0.17
	Yes	143 [95.3%]	7 [4.7%]	
Summer housing-small pasture/loafing area-heifer calves/open heifers	No	2307 [89.5%]	271 [10.5%]	0.3
	Yes	361 [92.6%]	29 [7.4%]	
Summer housing-small pasture/loafing area-bred heifers	No	2386 [89.4%]	282 [10.6%]	0.14
	Yes	282 [94.0%]	18 [6.0%]	
Summer housing-small pasture/loafing area-adult cows	No	2476 [89.8%]	282 [10.2%]	0.84
	Yes	192 [91.4%]	18 [8.6%]	
Summer housing-small pasture/loafing area-bulls	No	2234 [89.8%]	254 [10.2%]	0.89
	Yes	434 [90.4%]	46 [9.6%]	
Summer housing-large pasture/open range-heifer calves/open heifers	No	983 [88.6%]	127 [11.4%]	0.45
	Yes	1685 [90.7%]	173 [9.3%]	
Summer housing-large pasture/open range-bred heifers	No	468 [91.8%]	42 [8.2%]	0.54
	Yes	2200 [89.5%]	258 [10.5%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Summer housing-large pasture/open range-adult cows	No	52 [86.7%]	8 [13.3%]	0.47
	Yes	2616 [90.0%]	292 [10.0%]	
Summer housing-large pasture/open range-bulls	No	356 [91.3%]	34 [8.7%]	0.65
	Yes	2312 [89.7%]	266 [10.3%]	
How were cattle allowed to graze the pastures-continuous grazing?	No	779 [76.4%]	241 [23.6%]	0.45
	Yes	1025 [79.4%]	266 [20.6%]	
How were cattle allowed to graze the pastures-controlled access grazing?	No	1558 [78.6%]	423 [21.4%]	0.38
	Yes	246 [74.5%]	84 [25.5%]	
Was manure mechanically spread on pastures used by heifers?	No	2210 [91.0%]	218 [9.0%]	0.04
	Yes	458 [84.8%]	82 [15.2%]	
Were these pastures dragged or harrowed this year?	No	1765 [90.2%]	192 [9.8%]	0.49
	Yes	912 [89.4%]	108 [10.6%]	
Were these pastures clipped this year?	No	2530 [89.8%]	288 [10.2%]	0.7
	Yes	138 [92.0%]	12 [8.0%]	
Have you used lime on heifer pastures for reducing soil acidity?	No	2668 [89.9%]	300 [10.1%]	--
	Yes	0 [0]	0 [0]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Have any female beef cattle been purchased in last 5 years?	No	574 [87.2%]	84 [12.8%]	0.41
	Yes	2094 [90.6%]	216 [9.4%]	
Number of replacements purchased in last 5 years?	≤ 30	1090 [88.6%]	140 [11.4%]	0.59
	> 30	1578 [90.8%]	160 [9.2%]	
How many bulls has the farm/ranch purchased in the last 5 years?	≤ 5	1473 [89.3%]	177 [10.7%]	0.83
	> 5	1195 [90.7%]	123 [9.3%]	
Do you transport animals in your own trailer?	No	1351 [90.2%]	147 [9.8%]	0.58
	Yes	1317 [89.6%]	153 [10.4%]	
Do others use your trailer to transport cows?	No	2019 [89.7%]	231 [10.3%]	0.98
	Yes	622 [90.4%]	66 [9.6%]	
Dairy cattle-number on	0	2498 [89.6%]	290 [10.4%]	0.21
	≥ 1	170 [94.4%]	10 [5.6%]	
Dairy cattle-direct contact with beef cattle	No	2497 [89.6%]	291 [10.4%]	0.04
	Yes	117 [97.5%]	3 [2.5%]	
Dairy cattle-contact with feed for beef cattle	No	2500 [89.7%]	288 [10.3%]	0.22
	Yes	114 [95.0%]	6 [5.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Dairy cattle-contact with water for beef cattle	No	2471 [89.6%]	287 [10.4%]	0.14
	Yes	143 [95.3%]	7 [4.7%]	
Sheep-numbers on farm	0	2512 [90.1%]	276 [9.9%]	0.33
	≥ 1	156 [86.7%]	24 [13.3%]	
Sheep-direct contact with beef cattle	No	2541 [90.2%]	277 [9.8%]	0.13
	Yes	73 [81.1%]	17 [18.9%]	
Sheep-contact with feed for beef cattle	No	2561 [89.9%]	287 [10.1%]	0.62
	Yes	53 [88.3%]	7 [11.7%]	
Sheep-contact with water for beef cattle	No	2541 [90.2%]	277 [9.8%]	0.13
	Yes	73 [81.1%]	17 [18.9%]	
Goats-numbers on the farm	0	2567 [90.1%]	281 [9.9%]	0.27
	≥ 1	101 [84.2%]	19 [15.8%]	
Goats-direct animal contact with beef cattle	No	2592 [90.1%]	286 [9.9%]	0.15
	Yes	22 [73.3%]	8 [26.7%]	
Goats-direct contact with feed for beef cattle	No	2592 [90.1%]	286 [9.9%]	0.15
	Yes	22 [73.3%]	8 [26.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Goats-direct contact with water for beef cattle	No	2566 [90.1%]	282 [9.9%]	0.16
	Yes	48 [80.0%]	12 [20.0%]	
Poultry-numbers on farm	0	2425 [89.9%]	273 [10.1%]	0.79
	≥ 1	243 [90.0%]	27 [10.0%]	
Poultry-direct animal contact with beef cattle	No	2614 [89.9%]	294 [10.1%]	--
	Yes	0 [0%]	0 [0%]	
Poultry-contact with feed for beef cattle	No	2614 [89.89]	294 [10.11]	--
	Yes	0 [0%]	0 [0%]	
Poultry-contact with water for beef cattle	No	2614 [89.9%]	294 [10.1%]	--
	Yes	0 [0%]	0 [0%]	
Equine-numbers on farm	0	1031 [88.3%]	137 [11.7%]	0.41
	≥ 1	1637 [90.9%]	163 [9.1%]	
Equine-direct animal contact with beef cattle	No	1471 [89.3%]	177 [10.7%]	0.71
	Yes	1197 [90.7%]	123 [9.3%]	
Equine-contact with feed for beef cattle	No	1773 [89.6%]	205 [10.4%]	0.9
	Yes	895 [90.4%]	95 [9.6%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Equine-contact with water for beef cattle	No	1343	155	0.87
		[89.7%]	[10.3%]	
	Yes	1325	145	
		[90.1%]	[9.9%]	
Pigs-numbers on farm	0	2528	260	0.03
		[90.7%]	[9.3%]	
	≥ 1	140	40	
		[77.8%]	[22.2%]	
Pigs-direct contact with beef cattle	No	2609	269	0.001
		[90.7%]	[9.3%]	
	Yes	5	25	
		[16.7%]	[83.3%]	
Pigs-direct contact with feed for beef cattle	No	2614	294	--
		[89.9%]	[10.1%]	
	Yes	0	0	
		[0%]	[0%]	
Pigs-contact with water for beef cattle	No	2587	291	0.85
		[89.9%]	[10.1%]	
	Yes	27	3	
		[90.0%]	[10.0%]	
Deer or Elk-numbers on farm	0	2641	297	0.86
		[89.9%]	[10.1%]	
	≥ 1	27	3	
		[90.0%]	[10.0%]	
Deer or Elk-direct contact with beef cattle	No	2423	275	0.98
		[89.8%]	[10.2%]	
	Yes	191	19	
		[91.0%]	[9.0%]	
Deer or Elk-contact with feed for beef cattle	No	2423	275	0.98
		[89.8%]	[10.2%]	
	Yes	191	19	
		[91.0%]	[9.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	 (+)	*P* -value[a]
Deer or Elk-contact with water for beef cattle	No	2399 [89.9%]	269 [10.1%]	0.66
	Yes	215 [89.6%]	25 [10.4%]	
Exotics-numbers on farm	0	2374 [90.0%]	264 [10.0%]	0.65
	≥ 1	294 [89.1%]	36 [10.9%]	
Exotics-direct animal contact with beef cattle	No	2503 [89.8%]	285 [10.2%]	0.82
	Yes	138 [92.0%]	12 [8.0%]	
Exotics-contact with water for beef cattle	No	2450 [89.8%]	278 [10.2%]	0.93
	Yes	191 [91.0%]	19 [9.0%]	
Domestic rabbits-numbers on farm	0	2564 [90.0%]	284 [10.0%]	0.5
	≥ 1	104 [86.7%]	16 [13.3%]	
Domestic rabbits-direct animal contact with beef cattle	No	2641 [89.9%]	297 [10.1%]	--
	Yes	0 [0]	0 [0]	
Domestic rabbits-contact with feed for beef cattle	No	2641 [89.9%]	297 [10.1%]	--
	Yes	0 [0]	0 [0]	
Domestic rabbits-contact with water for beef cattle	No	2641 [89.9%]	297 [10.1%]	--
	Yes	0 [0]	0 [0]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Contact with cattle through: shared pasture	No	1669 [89.8%]	189 [10.2%]	0.78
	Yes	999 [90.0%]	111 [10.0%]	
Contact with cattle through: raising young	No	2504 [89.8%]	284 [10.2%]	0.89
	Yes	164 [91.1%]	16 [8.9%]	
Contact with cattle through: fence line	No	385 [91.7%]	35 [8.3%]	0.57
	Yes	2283 [89.6%]	265 [10.4%]	
Contact with cattle through: fairs or exhibitions	No	1903 [89.4%]	225 [10.6%]	0.54
	Yes	765 [91.1%]	75 [8.9%]	
Contact with cattle through: lending cows or bulls	No	2065 [90.6%]	215 [9.4%]	0.12
	Yes	603 [87.6%]	85 [12.4%]	
Contact with cattle through: borrowing cows or bulls	No	2251 [90.5%]	237 [9.5%]	0.11
	Yes	417 [86.9%]	63 [13.1%]	
Total number of dogs on farm	0	239 [88.5%]	31 [11.5%]	0.76
	1-2 dogs	1883 [89.8%]	215 [10.2%]	
	> 2 dogs	546 [91.0%]	54 [9.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Total number of cats on farm	0	212 [88.3%]	28 [11.7%]	0.84
	1-3 cats	609 [88.5%]	79 [11.5%]	
	3-9 cats	1308 [90.8%]	132 [9.2%]	
	> 9 cats	539 [89.8%]	61 [10.2%]	
Dogs: If none present, how long ago were they present?	≤ 2.5 months	104 [86.7%]	16 [13.3%]	0.48
	> 2.5 months	2564 [90.0%]	284 [10.0%]	
Coyotes/wolves seen on farm	1-3 times / year	111 [92.5%]	9 [7.5%]	0.21
	4-6 times / year	144 [96.0%]	6 [4.0%]	
	> 6 times / year	2413 [89.4%]	285 [10.6%]	
Foxes seen on farm	0	482 [89.3%]	58 [10.7%]	0.49
	1-3 times / year	830 [92.2%]	70 [7.8%]	
	4-6 times / year	415 [86.5%]	65 [13.5%]	
	> 6 times / year	921 [90.5%]	97 [9.5%]	
Other dogs seen on farm	0	581 [92.2%]	49 [7.8%]	0.33
	1-3 times / year	945 [90.0%]	105 [10.0%]	
	4-6 times / year	442 [86.7%]	68 [13.3%]	
	> 6 times / year	700 [90.0%]	78 [10.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Stray cats seen on farm	0	299 [90.6%]	31 [9.4%]	0.65
	1-3 times / year	1194 [90.5%]	126 [9.5%]	
	4-6 times / year	487 [90.2%]	53 [9.8%]	
	> 6 times / year	688 [88.4%]	90 [11.6%]	
Raccoons seen on farm	0	2278 [89.4%]	270 [10.6%]	0.08
	1-3 times / year	228 [95.0%]	12 [5.0%]	
	4-6 times / year	29 [96.7%]	1 [3.3%]	
	> 6 times / year	113 [94.2%]	7 [5.8%]	
Skunks seen on farm	0	639 [88.8%]	81 [11.3%]	0.51
	1-3 times / year	1249 [90.6%]	129 [9.4%]	
	4-6 times / year	284 [94.7%]	16 [5.3%]	
	> 6 times / year	476 [88.1%]	64 [11.9%]	
Footbath used in barns	No	2610 [89.8%]	298 [10.2%]	0.24
	Yes	58 [96.7%]	2 [3.3%]	
Times per month change disinfectant in barn	≤ 2 times	58 [96.7%]	2 [3.3%]	0.24
	> 2 times	2610 [89.8%]	298 [10.2%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status		*P* -value[a]
		Frequency [%][b]		
		(-)	(+)	
People entered barn: Beef farmers/ranchers (times / day)	≤ 10 times	848 [85.7%]	142 [14.3%]	0.01
	> 10 times	1820 [92.0%]	158 [8.0%]	
Beef farmers/ranchers vehicles or equipment	No	2015 [89.6%]	233 [10.4%]	0.75
	Yes	653 [90.7%]	67 [9.3%]	
People entered barn: other beef farmers (times / day)	0	2281 [89.5%]	267 [10.5%]	0.39
	≥ 1 time	387 [92.1%]	33 [7.9%]	
People entered barn: Cattle dealer (times / month)	0	1357 [88.8%]	171 [11.2%]	0.49
	≥ 1 time	1311 [91.0%]	129 [9.0%]	
Cattle dealer vehicles or equipment cleaned	No	1990 [89.7%]	228 [10.3%]	0.95
	Yes	678 [90.4%]	72 [9.6%]	
People entered barn: AI tech (times)	≤ 2 times	1957 [89.4%]	231 [10.6%]	0.52
	> 2 times	711 [91.2%]	69 [8.8%]	
AI tech vehicles and equipment cleaned	No	2147 [89.5%]	251 [10.5%]	0.5
	Yes	521 [91.4%]	49 [8.6%]	
People entered barn: Vet (times / month)	≤ 10 times	2206 [89.7%]	252 [10.3%]	0.79
	> 10 times	462 [90.6%]	48 [9.4%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Vet vehicles and equipment cleaned	No	842 [90.5%]	88 [9.5%]	0.77
	Yes	1826 [89.6%]	212 [10.4%]	
People entered barn: nutrition tech (times /	≤ 2 times	1949 [89.1%]	239 [10.9%]	0.23
	> 2 times	719 [92.2%]	61 [7.8%]	
People entered barn: hoof trimmers (times / month)	≤ 1 time	1975 [89.0%]	243 [11.0%]	0.17
	> 1 time	693 [92.4%]	57 [7.6%]	
Hoof trimmers vehicles and equipment cleaned	No	1984 [89.4%]	234 [10.6%]	0.58
	Yes	684 [91.2%]	66 [8.8%]	
People entered barn: dead stock collector (times / month)	≤ 2 times	1683 [89.1%]	205 [10.9%]	0.47
	> 2 times	985 [91.2%]	95 [8.8%]	
Dead stock collector vehicle and equipment cleaned	No	2012 [89.5%]	236 [10.5%]	0.54
	Yes	656 [91.1%]	64 [8.9%]	
People entered barn: contract manure spreader	0	1370 [91.5%]	128 [8.5%]	0.13
	≥ 1 time	1298 [88.3%]	172 [11.7%]	
Manure spreader vehicles and equipment cleaned	No	2349 [90.1%]	259 [9.9%]	0.65
	Yes	319 [88.6%]	41 [11.4%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Borrow equipment with manure contact	No	1080 [87.8%]	150 [12.2%]	0.18
	Yes	1588 [91.4%]	150 [8.6%]	
Always disinfected borrowed equipment	No	2562 [90.0%]	286 [10.0%]	0.64
	Yes	52 [86.7%]	8 [13.3%]	
Lend equipment with manure contact	No	1560 [88.2%]	208 [11.8%]	0.04
	Yes	1108 [92.3%]	92 [7.7%]	
Always disinfect lent equipment	No	2586 [89.9%]	292 [10.1%]	0.8
	Yes	28 [93.3%]	2 [6.7%]	
Calves receive colostrum from: mother	No	86 [95.6%]	4 [4.4%]	0.27
	Yes	2582 [89.7%]	296 [10.3%]	
Calves receive colostrum from: all pooled	No	2609 [89.7%]	299 [10.3%]	0.07
	Yes	59 [98.3%]	1 [1.7%]	
Calves receive colostrum from: dairy cows of unknown status	No	2640 [89.9%]	298 [10.1%]	0.79
	Yes	28 [93.3%]	2 [6.7%]	
Calves receive colostrum from: Johne's negative dairy cows	No	2668 [89.9%]	300 [10.1%]	--
	Yes	0 [0]	0 [0]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Calves receive: fresh colostrum	No	158 [87.8%]	22 [12.2%]	0.68
	Yes	2510 [90.0%]	278 [10.0%]	
Calves receive: frozen colostrum	No	2477 [89.8%]	281 [10.2%]	0.64
	Yes	191 [91.0%]	19 [9.0%]	
Calves receive: fermented colostrum	No	2688 [90.0%]	300 [10.0%]	--
	Yes	0 [0]	0 [0]	
Calves receive: heat treated colostrum	No	2644 [90.0%]	294 [10.0%]	0.3
	Yes	24 [80.0%]	6 [20.0%]	
Was the calving area used as a hospital area in last 12 months?	No	2170 [89.4%]	258 [10.6%]	0.31
	Yes	498 [92.2%]	42 [7.8%]	
Type of bedding used in calving areas: straw?	No	27 [90.0%]	3 [10.0%]	0.86
	Yes	2641 [89.9%]	297 [10.1%]	
Type of bedding used in calving areas: shavings/sawdust?	No	2475 [89.7%]	285 [10.3%]	0.56
	Yes	193 [92.8%]	15 [7.2%]	
Type of bedding used in calving areas: none	No	2668 [89.9%]	300 [10.1%]	--
	Yes	0 [0]	0 [0]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Frequency of adding bedding to calving areas	Every calving	1299 [90.2%]	141 [9.8%]	0.54
	Every 2-4 calvings	795 [91.4%]	75 [8.6%]	
Frequency of removing surface manure from calving areas?	Every calving	759 [90.4%]	81 [9.6%]	0.48
	Every 2-4 calvings	551 [91.8%]	49 [8.2%]	
	Every 5 or more calvings	1330 [88.8%]	168 [11.2%]	
Frequency of removing all manure from calving areas?	Every calving	274 [91.3%]	26 [8.7%]	0.99
	Every 2-4 calvings	316 [87.8%]	44 [12.2%]	
	Every 5 or more calvings	1246 [90.4%]	132 [9.6%]	
What is the usual number of cows in the maternity pens at one time?	None	577 [91.9%]	51 [8.1%]	0.52
	Always one cow	1870 [90.3%]	200 [9.7%]	
How often are placentas eaten by dogs?	Never	637 [88.5%]	83 [11.5%]	0.54
	Sometimes	1654 [90.4%]	176 [9.6%]	
	Often	377 [90.2%]	41 [9.8%]	
How often are placentas eaten by cats?	Never	1285 [91.1%]	125 [8.9%]	0.48
	Sometimes	1084 [88.1%]	146 [11.9%]	
	Often	272 [91.3%]	26 [8.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
How often are placentas eaten by wild animals?	Never	833 [89.8%]	95 [10.2%]	0.99
	Sometimes	1533 [89.6%]	177 [10.4%]	
	Often	216 [90.0%]	24 [10.0%]	
How often are placentas eaten by cows?	Never	58 [96.7%]	2 [3.3%]	0.17
	Sometimes	1269 [88.2%]	169 [11.8%]	
	Often	1341 [91.2%]	129 [8.8%]	
How often are aborted fetuses eaten by dogs?	Never	1823 [90.7%]	187 [9.3%]	0.87
	Sometimes	770 [88.7%]	98 [11.3%]	
	Often	55 [91.7%]	5 [8.3%]	
How often are aborted fetuses eaten by cats?	Never	2041 [90.7%]	209 [9.3%]	0.68
	Sometimes	607 [88.2%]	81 [11.8%]	
How often are aborted fetuses eaten by wild animals?	Never	710 [91.3%]	68 [8.7%]	0.84
	Sometimes	1445 [89.2%]	175 [10.8%]	
	Often	513 [90.0%]	57 [10.0%]	
Percentage of cows bred using artificial insemination	≤ 50	2309 [89.6%]	269 [10.4%]	0.17
	> 50	199 [94.8%]	11 [5.2%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Do you use embryo transfer on your farm?	No	2203 [89.6%]	255 [10.4%]	0.62
	Yes	465 [91.2%]	45 [8.8%]	
Number of embyros purchased outside the herd and implanted?	0	247 [91.5%]	23 [8.5%]	0.7
	≥ 1	2421 [89.7%]	277 [10.3%]	
Number of embryos collected on farm and implanted?	≤ 5	244 [90.4%]	26 [9.6%]	0.92
	> 5	2424 [89.8%]	274 [10.2%]	
Do cows have access to a stream, lake, or pond?	No	0 [0]	0 [0]	--
	Yes	2668 [89.9%]	300 [10.1%]	
Number of days after manure application to grazing?	≤ 90	1087 [90.7%]	111 [9.3%]	0.66
	> 90	1581 [89.3%]	189 [10.7%]	
What % of grains fed to heifers that was homegrown?	≤ 50%	729 [90.0%]	81 [10.0%]	0.62
	> 50%	1864 [90.0%]	206 [10.0%]	
What % of roughages fed to heifers was homegrown?	≤ 50%	231 [85.6%]	39 [14.4%]	0.11
	> 50%	2362 [90.5%]	248 [9.5%]	
What % of grains fed to cows was homegrown?	≤ 50%	749 [89.2%]	91 [10.8%]	0.36
	> 50%	1840 [90.2%]	200 [9.8%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
What % of roughages fed to cows was homegrown?	≤ 50%	303 [77.7%]	87 [22.3%]	0.001
	> 50%	2365 [91.7%]	213 [8.3%]	
Water source-winter, open heifers-surface water	No	2502 [89.7%]	286 [10.3%]	0.72
	Yes	166 [92.2%]	14 [7.8%]	
Water source-winter, open heifers-well water	No	551 [92.1%]	47 [7.9%]	0.46
	Yes	2117 [89.3%]	253 [10.7%]	
Water source-winter, open heifers-municipal water	No	2558 [89.8%]	290 [10.2%]	0.83
	Yes	110 [91.7%]	10 [8.3%]	
Water source-winter, bred heifers-surface water	No	2234 [89.8%]	254 [10.2%]	0.99
	Yes	434 [90.4%]	46 [9.6%]	
Water source-winter, bred heifers-well water	No	520 [91.5%]	48 [8.5%]	0.5
	Yes	2148 [89.5%]	252 [10.5%]	
Water source-winter, bred heifers-municipal water	No	2528 [89.7%]	290 [10.3%]	0.41
	Yes	140 [93.3%]	10 [6.7%]	
Water source-winter, adult cows-surface water	No	2224 [89.4%]	264 [10.6%]	0.31
	Yes	444 [92.5%]	36 [7.5%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Water source-winter, adult cows-well water	No	363 [93.1%]	27 [6.9%]	0.2
	Yes	2305 [89.4%]	273 [10.6%]	
Water source-winter, adult cows-municipal water	No	2528 [89.7%]	290 [10.3%]	0.41
	Yes	140 [93.3%]	10 [6.7%]	
Water source-winter, bulls-surface water	No	2309 [89.6%]	269 [10.4%]	0.5
	Yes	359 [92.1%]	31 [7.9%]	
Water source-winter, bulls-well water	No	377 [94.3%]	23 [5.8%]	0.03
	Yes	2271 [89.1%]	277 [10.9%]	
Water source-winter, bulls-municipal water	No	2581 [89.7%]	297 [10.3%]	0.1
	Yes	87 [96.7%]	3 [3.3%]	
Water source-summer, open heifers-surface water	No	877 [88.8%]	111 [11.2%]	0.67
	Yes	1791 [90.5%]	189 [9.5%]	
Water source-summer, open heifers-well water	No	1712 [90.7%]	176 [9.3%]	0.5
	Yes	956 [88.5%]	124 [11.5%]	
Water source-summer, open heifers-municipal water	No	2610 [89.8%]	298 [10.2%]	0.24
	Yes	58 [96.7%]	2 [3.3%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Water source-summer, bred heifers-surface water	No	635 [88.4%]	83 [11.6%]	0.74
	Yes	2033 [90.4%]	217 [9.6%]	
Water source-summer, bred heifers-well water	No	1550 [90.7%]	158 [9.3%]	0.46
	Yes	1118 [88.7%]	142 [11.3%]	
Water source-summer, bred heifers-municipal water	No	2553 [89.6%]	295 [10.4%]	0.46
	Yes	115 [95.8%]	5 [4.2%]	
Water source-summer, adult cows-surface water	No	380 [84.4%]	70 [15.6%]	0.17
	Yes	2288 [90.9%]	230 [9.1%]	
Water source-summer, adult cows-well water	No	1637 [91.0%]	161 [9.0%]	0.32
	Yes	1031 [88.1%]	139 [11.9%]	
Water source-summer, adult cows-municipal water	No	2563 [90.0%]	285 [10.0%]	0.77
	Yes	105 [87.5%]	15 [12.5%]	
Water source-summer, bulls-surface water	No	1357 [88.7%]	173 [11.3%]	0.48
	Yes	1311 [91.2%]	127 [8.8%]	
Water source-summer, bulls-well water	No	1960 [89.6%]	228 [10.4%]	0.78
	Yes	708 [90.8%]	72 [9.2%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Water source-summer, bulls-municipal water	No	2582 [89.7%]	296 [10.3%]	0.28
	Yes	86 [95.6%]	4 [4.4%]	
Is equipment with manure contact used to handle feed for heifers?	Regularly	399 [95.0%]	21 [5.0%]	0.08
	Occasionally	668 [89.1%]	82 [10.9%]	
	Not a practice	1523 [89.1%]	187 [10.9%]	
Is equipment with manure contact used to handle feed for cows?	Regularly	449 [93.5%]	31 [6.5%]	0.22
	Occasionally	718 [88.9%]	90 [11.1%]	
	Not a practice	1449 [89.4%]	171 [10.6%]	
Do heifers < 12 months of age share feed bunk with adult cattle?	No	2229 [90.6%]	231 [9.4%]	0.19
	Yes	439 [86.4%]	69 [13.6%]	
Do heifers < 12 months of age share water trough with adult cattle?	No	1011 [91.1%]	99 [8.9%]	0.55
	Yes	1657 [89.2%]	201 [10.8%]	
Number of animals with disease problem: retained afterbirth	≤ 2	1467 [90.7%]	151 [9.3%]	0.39
	> 2	1201 [89.0%]	149 [11.0%]	
Number of animals with disease problem: abortion < 4 months	0	1877 [90.8%]	191 [9.2%]	0.33
	≥ 1	791 [87.9%]	109 [12.1%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table A.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Number of animals with disease problem: abortion 4-7 months	0	2668 [89.9%]	300 [10.1%]	--
	≥ 1	0 [0]	0 [0]	
Number of animals with disease problem: abortion > 7 months	0	1930 [90.7%]	198 [9.3%]	0.29
	≥ 1	738 [87.9%]	102 [12.1%]	
Age	36 to < 72 months	1203 [90.4%]	128 [9.6%]	0.31
	72 to < 108 months	877 [90.4%]	93 [9.6%]	
	≥ 108 months	572 [88.1%]	77 [11.9%]	
Herd size	< 70 cattle	580 [88.1%]	78 [11.9%]	0.47
	70 to < 89 cattle	293 [88.8%]	37 [11.2%]	
	89 to < 129 cattle	471 [92.4%]	39 [7.6%]	
	≥ 129 cattle	1324 [90.1%]	146 [9.9%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

APPENDIX B

Table B.1. Bivariate analysis of potential explanatory variables by serological status for antibodies to *Neospora caninum* (NC) for dairy multivariable models. (n = 2311).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Agroecological region	Grassland	495 [82.5%]	105 [17.5%]	0.12
	Montane	227 [84.1%]	43 [15.9%]	
	Parkland	725 [73.2%]	265 [26.8%]	
	Boreal Forrest	357 [79.2%]	94 [20.8%]	
Acreage of Farm	≤ 1500 acres	1217 [78.0%]	344 [22.0%]	0.92
	> 1500 acres	587 [78.3%]	163 [21.7%]	
Acreage of Pasture	≤ 490 acres	1446 [77.7%]	415 [22.3%]	0.75
	> 490 acres	358 [79.6%]	92 [20.4%]	
Acreage of Forage	≤ 350 acres	885 [73.8%]	315 [26.3%]	0.06
	> 350 acres	919 [82.7%]	192 [17.3%]	
Number Culled: Open heifers	0	955 [74.0%]	335 [26.0%]	0.02
	≥ 1	849 [83.2%]	172 [16.8%]	
Number Culled: Bred heifers	0	1467 [77.6%]	423 [22.4%]	0.38
	≥ 1	337 [80.0%]	84 [20.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
How were cattle allowed to graze the pastures-continuous grazing?	No	779 [76.4%]	241 [23.6%]	0.58
	Yes	1025 [79.4%]	266 [20.6%]	
How were cattle allowed to graze the pastures-controlled access grazing?	No	1558 [78.6%]	423 [21.4%]	0.47
	Yes	246 [74.5%]	84 [25.5%]	
Was manure mechanically spread on pastures used by heifers?	No	1439 [79.9%]	362 [20.1%]	0.08
	Yes	365 [71.6%]	145 [28.4%]	
Were these pastures dragged or harrowed this year?	No	1417 [80.0%]	354 [20.0%]	0.11
	Yes	387 [71.7%]	153 [28.3%]	
Were these pastures clipped this year?	No	1532 [78.5%]	419 [21.5%]	0.49
	Yes	272 [75.6%]	88 [24.4%]	
Have you used lime on heifer pastures for reducing soil acidity?	No	1804 [78.1%]	507 [21.9%]	--
	Yes	0 [0%]	0 [0%]	
Have any female beef cattle been purchased in last 5 years?	No	641 [79.1%]	169 [20.9%]	0.79
	Yes	1163 [77.5%]	338 [22.5%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Do you transport animals in your own trailer?	No	796 [78.0%]	225 [22.0%]	0.81
	Yes	1008 [78.1%]	282 [21.9%]	
Do others use your trailer to transport cows?	No	1338 [76.9%]	403 [23.1%]	0.43
	Yes	466 [81.8%]	104 [18.2%]	
Dairy cattle-number on farm	0	893 [78.3%]	248 [21.7%]	0.82
	≥ 1	911 [77.9%]	259 [22.1%]	
Dairy cattle-direct contact with beef cattle	No	1260 [79.2%]	331 [20.8%]	0.39
	Yes	544 [75.6%]	176 [24.4%]	
Dairy cattle-contact with feed for beef cattle	No	1343 [78.5%]	368 [21.5%]	0.59
	Yes	461 [76.8%]	139 [23.2%]	
Dairy cattle-contact with water for beef cattle	No	1273 [78.5%]	348 [21.5%]	0.7
	Yes	531 [77.0%]	159 [23.0%]	
Sheep-numbers on farm	0	1434 [78.3%]	397 [21.7%]	0.87
	≥ 1	370 [77.1%]	110 [22.9%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Sheep-direct contact with beef cattle	No	1687 [78.1%]	474 [21.9%]	0.87
	Yes	117 [78.0%]	33 [22.0%]	
Sheep-contact with feed for beef cattle	No	1715 [78.3%]	476 [21.7%]	0.54
	Yes	89 [74.2%]	31 [25.8%]	
Sheep-contact with water for beef cattle	No	1727 [77.8%]	494 [22.2%]	0.58
	Yes	77 [85.6%]	13 [14.4%]	
Goats-numbers on the farm	0	1713 [78.2%]	478 [21.8%]	0.69
	≥ 1	91 [75.8%]	29 [24.2%]	
Goats-direct animal contact with beef cattle	No	1762 [78.3%]	489 [21.7%]	0.45
	Yes	42 [70.0%]	18 [30.0%]	
Goats-direct contact with feed for beef cattle	No	1781 [78.1%]	500 [21.9%]	0.82
	Yes	23 [76.7%]	7 [23.3%]	
Goats-direct contact with water for beef cattle	No	1762 [78.3%]	489 [21.7%]	0.45
	Yes	42 [70.0%]	18 [30.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Poultry-numbers on farm	0	1052 [76.2%]	329 [23.8%]	0.29
	≥ 1	752 [80.9%]	178 [19.1%]	
Poultry-direct animal contact with beef cattle	No	1779 [78.0%]	502 [22.0%]	0.85
	Yes	25 [83.3%]	5 [16.7%]	
Poultry-contact with feed for beef cattle	No	1804 [78.1%]	507 [21.9%]	--
	Yes	0 [0%]	0 [0%]	
Poultry-contact with water for beef cattle	No	1804 [78.1%]	507 [21.9%]	--
	Yes	0 [0%]	0 [0%]	
Equine-numbers on farm	0	1124 [74.9%]	377 [25.1%]	0.08
	≥ 1	680 [84.0%]	130 [16.0%]	
Equine-direct animal contact with beef cattle	No	1436 [77.2%]	425 [22.8%]	0.61
	Yes	368 [81.8%]	82 [18.2%]	
Equine-contact with feed for beef cattle	No	1660 [77.9%]	471 [22.1%]	0.96
	Yes	144 [80.0%]	36 [20.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Equine-contact with water for beef cattle	No	1478	443	0.41
		[76.9%]	[23.1%]	
	Yes	326	64	
		[83.6%]	[16.4%]	
Pigs-numbers on farm	0	1360	411	0.2
		[76.8%]	[23.2%]	
	≥ 1	444	96	
		[82.2%]	[17.8%]	
Pigs-direct contact with beef cattle	No			
		1804	507	--
	Yes	[78.1%]	[21.9%]	
		0	0	
		[0]	[0]	
Pigs-direct contact with feed for beef cattle	No	1775	506	0.17
		[77.8%]	[22.2%]	
	Yes	29	1	
		[96.7%]	[3.3%]	
Pigs-contact with water for beef cattle	No	1804	507	--
		[78.1%]	[21.9%]	
	Yes	0	0	
		[0]	[0]	
Deer or Elk-numbers on farm	0	1777	504	0.55
		[77.9%]	[22.1%]	
	≥ 1	27	3	
		[90.0%]	[10.0%]	
Deer or Elk-direct contact with beef cattle	No	1788	493	0.92
		[78.4%]	[21.6%]	
	Yes	16	14	
		[53.3%]	[46.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Deer or Elk-contact with feed for beef cattle	No	1741 [78.4%]	480 [21.6%]	0.41
	Yes	63 [70.0%]	27 [30.0%]	
Deer or Elk-contact with water for beef cattle	No	1767 [78.5%]	484 [21.5%]	0.23
	Yes	37 [61.7%]	23 [38.3%]	
Exotics-numbers on farm	0	1715 [78.3%]	476 [21.7%]	0.8
	≥ 1	89 [74.2%]	31 [25.8%]	
Exotics-direct animal contact with beef cattle	No	1788 [78.4%]	493 [21.6%]	0.92
	Yes	16 [53.3%]	14 [46.7%]	
Exotics-contact with water for beef cattle	No	1804 [78.1%]	507 [21.9%]	--
	Yes	0 [0]	0 [0]	
Domestic rabbits-numbers on farm	0	1625 [78.5%]	446 [21.5%]	0.87
	≥ 1	179 [74.6%]	61 [25.4%]	
Domestic rabbits-direct animal contact with beef cattle	No	1750 [77.7%]	501 [22.3%]	0.4
	Yes	54 [90.0%]	6 [10.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Domestic rabbits-contact with feed for beef cattle	No	1721 [77.5%]	500 [22.5%]	0.14
	Yes	83 [92.2%]	7 [7.8%]	
Domestic rabbits-contact with water for beef cattle	No	1775 [77.8%]	506 [22.2%]	0.16
	Yes	29 [96.7%]	1 [3.3%]	
Contact with cattle through: shared pasture	No	1527 [78.3%]	424 [21.7%]	0.69
	Yes	277 [76.9%]	83 [23.1%]	
Contact with cattle through: raising young	No	1627 [78.6%]	444 [21.4%]	0.53
	Yes	177 [73.8%]	63 [26.3%]	
Contact with cattle through: fence line	No	1086 [80.4%]	265 [19.6%]	0.14
	Yes	718 [74.8%]	242 [25.2%]	
Contact with cattle through: fairs or exhibitions	No	1508 [78.5%]	413 [21.5%]	0.44
	Yes	266 [73.9%]	94 [26.1%]	
Contact with cattle through: lending cows or bulls	No	1522 [78.0%]	429 [22.0%]	0.91
	Yes	282 [78.3%]	78 [21.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Contact with cattle through: borrowing cows or bulls	No	1460 [77.2%]	431 [22.8%]	0.47
	Yes	344 [81.9%]	76 [18.1%]	
Total number of dogs on farm	0	275 [83.1%]	56 [16.9%]	0.08
	1-2 dogs	1142 [79.3%]	298 [20.7%]	
	> 2 dogs	387 [71.7%]	153 [28.3%]	
Total number of cats on farm	0	53 [88.3%]	7 [11.7%]	0.14
	1-3 cats	249 [82.7%]	52 [17.3%]	
	3-9 cats	921 [78.7%]	249 [21.3%]	
	> 9 cats	581 [74.5%]	199 [25.5%]	
Dogs: If none present, how long ago were they present?	≤ 2.5 months	90 [75.0%]	30 [25.0%]	0.19
	> 2.5 months	1714 [78.2%]	477 [21.8%]	
Coyotes/wolves seen on farm	1-3 times / year	82 [54.7%]	68 [45.3%]	0.53
	4-6 times / year	398 [82.9%]	82 [17.1%]	
	> 6 times / year	104 [86.7%]	16 [13.3%]	
		1220 [78.2%]	341 [21.8%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Foxes seen on farm	0	738 [76.8%]	223 [23.2%]	0.52
	1-3 times / year	792 [77.6%]	228 [22.4%]	
	4-6 times / year	71 [78.9%]	19 [21.1%]	
	> 6 times / year	203 [84.6%]	37 [15.4%]	
Other dogs seen on farm	0	612 [78.4%]	169 [21.6%]	0.6
	1-3 times / year	728 [78.3%]	202 [21.7%]	
	4-6 times / year	112 [74.7%]	38 [25.3%]	
	> 6 times / year	352 [78.2%]	98 [21.8%]	
Stray cats seen on farm	0	270 [75.0%]	90 [25.0%]	0.44
	1-3 times / year	883 [77.5%]	257 [22.5%]	
	4-6 times / year	235 [78.3%]	65 [21.7%]	
	> 6 times / year	416 [81.4%]	95 [18.6%]	
Raccoons seen on farm	0	1609 [76.6%]	492 [23.4%]	0.05
	1-3 times / year	114 [95.0%]	6 [5.0%]	
	4-6 times / year	54 [90.0%]	6 [10.0%]	
	> 6 times / year	27 [90.0%]	3 [10.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Skunks seen on farm	0	540 [74.9%]	181 [25.1%]	0.53
	1-3 times / year	626 [80.3%]	154 [19.7%]	
	4-6 times / year	242 [73.3%]	88 [26.7%]	
	> 6 times / year	396 [82.5%]	84 [17.5%]	
Footbath used in barns	No	1723 [78.6%]	468 [21.4%]	0.37
	Yes	81 [67.5%]	39 [32.5%]	
Times per month change disinfectant in barn	≤ 2 times	81 [90.0%]	9 [10.0%]	0.22
	> 2 times	1723 [77.6%]	498 [22.4%]	
People entered barn: Beef farmers/ranchers (times / day)	≤ 10 times	1514 [77.6%]	436 [22.4%]	0.67
	> 10 times	290 [80.3%]	71 [19.7%]	
Beef farmers/ranchers vehicles or equipment cleaned	No	1153 [80.0%]	288 [20.0%]	0.42
	Yes	651 [74.8%]	219 [25.2%]	
People entered barn: other beef farmers (times / day)	0	441 [70.0%]	189 [30.0%]	0.1
	≥ 1 time	1363 [81.1%]	318 [18.9%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
People entered barn: Cattle dealer (times / month)	0	918 [78.5%]	252 [21.5%]	0.81
	≥ 1 time	886 [77.7%]	255 [22.3%]	
Cattle dealer vehicles or equipment cleaned	No	1423 [79.0%]	378 [21.0%]	0.41
	Yes	381 [74.7%]	129 [25.3%]	
People entered barn: AI tech (times)	≤ 2 times	358 [79.4%]	93 [20.6%]	0.34
	> 2 times	1446 [77.7%]	414 [22.3%]	
AI tech vehicles and equipment cleaned	No	1026 [79.5%]	265 [20.5%]	0.4
	Yes	778 [76.3%]	242 [23.7%]	
People entered barn: Vet (times / month)	≤ 10 times	407 [79.8%]	103 [20.2%]	0.54
	> 10 times	1397 [77.6%]	404 [22.4%]	
Vet vehicles and equipment cleaned	No	638 [78.8%]	172 [21.2%]	0.94
	Yes	1166 [77.7%]	335 [22.3%]	
People entered barn: nutrition tech (times / month)	≤ 2 times	357 [79.2%]	94 [20.8%]	0.51
	> 2 times	1447 [77.8%]	413 [22.2%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
People entered barn: hoof trimmers (times / month)	≤ 1 time	676 [72.7%]	254 [27.3%]	0.04
	> 1 time	1128 [81.7%]	253 [18.3%]	
Hoof trimmers vehicles and equipment cleaned	No	1007 [76.3%]	313 [23.7%]	0.41
	Yes	797 [80.4%]	194 [19.6%]	
People entered barn: dead stock collector (times / month)	≤ 2 times	804 [74.4%]	277 [25.6%]	0.18
	> 2 times	1000 [81.3%]	230 [18.7%]	
Dead stock collector vehicle and equipment cleaned	No	1432 [76.9%]	429 [23.1%]	0.44
	Yes	372 [82.7%]	78 [17.3%]	
People entered barn: contract manure spreader	0	1013 [76.7%]	307 [23.3%]	0.66
	≥ 1 time	791 [79.8%]	200 [20.2%]	
Manure spreader vehicles and equipment cleaned	No	1567 [76.8%]	473 [23.2%]	0.08
	Yes	237 [87.5%]	34 [12.5%]	
Borrow equipment with manure contact	No	1153 [78.4%]	318 [21.6%]	0.64
	Yes	651 [77.5%]	189 [22.5%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Always disinfected borrowed equipment	No	1777 [77.9%]	504 [22.1%]	0.55
	Yes	27 [90.0%]	3 [10.0%]	
Lend equipment with manure contact	No	1132 [77.0%]	338 [23.0%]	0.65
	Yes	672 [79.9%]	169 [20.1%]	
Always disinfect lent equipment	No	1780 [78.0%]	501 [22.0%]	0.83
	Yes	24 [80.0%]	6 [20.0%]	
Calves receive colostrum from: mother	No	249 [75.2%]	82 [24.8%]	0.56
	Yes	1555 [78.5%]	425 [21.5%]	
Calves receive colostrum from: all pooled	No	1518 [79.1%]	402 [20.9%]	0.34
	Yes	286 [73.1%]	105 [26.9%]	
Calves receive colostrum from: dairy cows of unknown status	No	243 [73.6%]	87 [26.4%]	--
	Yes	0 [0]	0 [0]	
Calves receive colostrum from: Johne's negative dairy cows	No	243 [73.6%]	87 [26.4%]	0.95
	Yes	24 [80.0%]	6 [20.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Calves receive: fresh colostrum	No	79 [87.8%]	11 [12.2%]	0.35
	Yes	1725 [77.7%]	496 [22.3%]	
Calves receive: frozen colostrum	No	1692 [78.3%]	469 [21.7%]	0.53
	Yes	112 [74.7%]	38 [25.3%]	
Calves receive: fermented colostrum	No	1775 [77.8%]	506 [22.2%]	0.16
	Yes	29 [96.7%]	1 [3.3%]	
Calves receive: heat treated colostrum	No	1775 [77.8%]	506 [22.2%]	0.79
	Yes	29 [96.7%]	1 [3.3%]	
Was the calving area used as a hospital area in last 12 months?	No	903 [79.1%]	238 [20.9%]	0.06
	Yes	901 [77.0%]	269 [23.0%]	
Type of bedding used in calving areas: straw?	No	191 [70.7%]	79 [29.3%]	0.02
	Yes	1613 [79.0%]	428 [21.0%]	
Type of bedding used in calving areas: shavings/sawdust?	No	1430 [79.4%]	371 [20.6%]	0.19
	Yes	374 [73.3%]	136 [26.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Type of bedding used in calving areas: none	No	1804 [78.1%]	507 [21.9%]	--
	Yes	0 [0]	0 [0]	
Frequency of adding bedding to calving areas	Every calving	980 [76.0%]	310 [24.0%]	0.37
	Every 2-4 calvings	462 [80.9%]	109 [19.1%]	
	Every 5 or more calvings	266 [80.6%]	64 [19.4%]	
Frequency of removing surface manure from calving areas?	Every calving	469 [74.4%]	161 [25.6%]	0.13
	Every 2-4 calvings	386 [75.7%]	124 [24.3%]	
	Every 5 or more calvings	949 [81.0%]	222 [19.0%]	
Frequency of removing all manure from calving areas?	Every calving	225 [75.0%]	75 [25.0%]	0.75
	Every 2-4 calvings	335 [79.8%]	85 [20.2%]	
	Every 5 or more calvings	1244 [78.2%]	347 [21.8%]	
What is the usual number of cows in the maternity pens at one time?	None	753 [83.6%]	148 [16.4%]	0.04
	Always one cow	845 [76.1%]	265 [23.9%]	
How often are placentas eaten by dogs?	Never	817 [73.5%]	294 [26.5%]	0.13
	Sometimes	876 [74.9%]	294 [25.1%]	
	Often	111 [74.0%]	39 [26.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
How often are placentas eaten by cats?	Never	959 [77.9%]	272 [22.1%]	0.98
	Sometimes	773 [78.1%]	217 [21.9%]	
	Often	72 [80.0%]	18 [20.0%]	
How often are placentas eaten by wild animals?	Never	1280 [79.0%]	341 [21.0%]	0.4
	Sometimes	432 [75.8%]	138 [24.2%]	
	Often	44 [73.3%]	16 [26.7%]	
How often are placentas eaten by cows?	Never	135 [90.0%]	15 [10.0%]	0.31
	Sometimes	1595 [77.0%]	476 [23.0%]	
	Often	74 [82.2%]	16 [17.8%]	
How often are aborted fetuses eaten by dogs?	Never	1484 [79.7%]	377 [20.3%]	0.14
	Sometimes	320 [71.1%]	130 [28.9%]	
	Often	0 [0]	0 [0]	
How often are aborted fetuses eaten by cats?	Never	1506 [78.4%]	415 [21.6%]	0.74
	Sometimes	298 [76.4%]	92 [23.6%]	
	Often	0 [0]	0 [0]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
How often are aborted fetuses eaten by wild animals?	Never	1265 [79.5%]	326 [20.5%]	0.21
	Sometimes	474 [75.2%]	156 [24.8%]	
	Often	65 [72.2%]	25 [27.8%]	
Percentage of cows bred using artificial	≤ 50	438 [76.8%]	132 [23.2%]	0.92
	> 50	1366 [78.5%]	375 [21.5%]	
Do you use embryo transfer on your farm?	No	1536 [77.6%]	444 [22.4%]	0.6
	Yes	268 [81.0%]	63 [19.0%]	
Number of embyros purchased outside the herd and implanted?	0	85 [70.8%]	35 [29.2%]	0.34
	≥ 1	1719 [78.5%]	472 [21.5%]	
Number of embryos collected on farm and implanted?	≤ 5	75 [83.3%]	15 [16.7%]	0.5
	> 5	1729 [77.8%]	492 [22.2%]	
Do cows have access to a stream, lake, or pond?	No	0 [0]	0 [0]	--
	Yes	1804 [78.1%]	507 [21.9%]	
Number of days after manure application to grazing?	≤ 90	581 [74.4%]	200 [25.6%]	0.2
	> 90	1223 [79.9%]	307 [20.1%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
What % of grains fed to heifers that was homegrown?	≤ 50%	807 [74.7%]	273 [25.3%]	0.24
	> 50%	997 [81.0%]	234 [19.0%]	
What % of roughages fed to heifers was homegrown?	≤ 50%	196 [72.6%]	74 [27.4%]	0.48
	> 50%	1608 [78.8%]	433 [21.2%]	
What % of grains fed to cows was homegrown?	≤ 50%	869 [76.2%]	271 [23.8%]	0.46
	> 50%	935 [79.8%]	236 [20.2%]	
What % of roughages fed to cows was homegrown?	≤ 50%	134 [74.4%]	46 [25.6%]	0.76
	> 50%	1646 [78.3%]	455 [21.7%]	
Water source-winter, open heifers-surface water	No	1316 [77.0%]	394 [23.0%]	0.23
	Yes	488 [81.2%]	113 [18.8%]	
Water source-winter, open heifers-well water	No	528 [83.7%]	103 [16.3%]	0.04
	Yes	1276 [76.0%]	404 [24.0%]	
Water source-winter, open heifers-municipal water	No	1720 [77.4%]	501 [22.6%]	0.08
	Yes	84 [93.3%]	6 [6.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Water source-winter, bred heifers-surface water	No	1316 [77.0%]	394 [23.0%]	0.23
	Yes	488 [81.2%]	113 [18.8%]	
Water source-winter, bred heifers-well water	No	528 [83.7%]	103 [16.3%]	0.04
	Yes	1276 [76.0%]	404 [24.0%]	
Water source-winter, bred heifers-municipal water	No	1720 [77.4%]	501 [22.6%]	0.08
	Yes	84 [93.3%]	6 [6.7%]	
Water source-winter, adult cows-surface water	No	1346 [76.0%]	424 [24.0%]	0.06
	Yes	458 [84.7%]	83 [15.3%]	
Water source-winter, adult cows-well water	No	526 [87.5%]	75 [12.5%]	0.02
	Yes	1278 [74.7%]	432 [25.3%]	
Water source-winter, adult cows-municipal water	No	1692 [77.2%]	499 [22.8%]	0.04
	Yes	112 [93.3%]	8 [6.7%]	
Water source-winter, bulls-surface water	No	1375 [76.4%]	425 [23.6%]	0.11
	Yes	429 [84.0%]	82 [16.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Water source-winter, bulls-well water	No	518 [86.2%]	83 [13.8%]	0.01
	Yes	1286 [75.2%]	424 [24.8%]	
Water source-winter, bulls-municipal water	No	1692 [77.2%]	499 [22.8%]	0.05
	Yes	112 [93.3%]	8 [6.7%]	
Water source-summer, open heifers-surface water	No	932 [77.7%]	268 [22.3%]	0.83
	Yes	872 [78.5%]	239 [21.5%]	
Water source-summer, open heifers-well water	No	711 [81.6%]	160 [18.4%]	0.12
	Yes	1093 [75.9%]	347 [24.1%]	
Water source-summer, open heifers-municipal water	No	1720 [77.4%]	501 [22.6%]	0.08
	Yes	84 [93.3%]	6 [6.7%]	
Water source-summer, bred heifers-surface water	No	888 [77.9%]	252 [22.1%]	0.99
	Yes	916 [78.2%]	255 [21.8%]	
Water source-summer, bred heifers-well water	No	712 [81.7%]	159 [18.3%]	0.11
	Yes	1092 [75.8%]	348 [24.2%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Water source-summer, bred heifers-municipal water	No	1720 [77.4%]	501 [22.6%]	0.08
	Yes	84 [93.3%]	6 [6.7%]	
Water source-summer, adult cows-surface water	No	884 [75.6%]	286 [24.4%]	0.26
	Yes	920 [80.6%]	221 [19.4%]	
Water source-summer, adult cows-well water	No	764 [84.8%]	137 [15.2%]	0.005
	Yes	1040 [73.8%]	370 [26.2%]	
Water source-summer, adult cows-municipal water	No	1692 [77.2%]	499 [22.8%]	0.04
	Yes	112 [93.3%]	8 [6.7%]	
Water source-summer, bulls-surface water	No	1248 [77.0%]	372 [23.0%]	0.39
	Yes	556 [80.5%]	135 [19.5%]	
Water source-summer, bulls-well water	No	562 [85.0%]	99 [15.0%]	0.02
	Yes	1242 [75.3%]	408 [24.7%]	
Water source-summer, bulls-municipal water	No	1692 [77.2%]	499 [22.8%]	0.04
	Yes	112 [93.3%]	8 [6.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Is equipment with manure contact used to handle feed for heifers?	Regularly	343 [76.2%]	107 [23.8%]	0.98
	Occasionally	525 [79.5%]	135 [20.5%]	
	Not a practice	936 [77.9%]	265 [22.1%]	
Is equipment with manure contact used to handle feed for cows?	Regularly	335 [74.4%]	115 [25.6%]	0.55
	Occasionally	567 [78.8%]	153 [21.3%]	
	Not a practice	902 [79.1%]	239 [20.9%]	
Do heifers < 12 months of age share feed bunk with adult cattle?	No	1756 [78.0%]	495 [22.0%]	0.99
	Yes	48 [80.0%]	12 [20.0%]	
Do heifers < 12 months of age share water trough with adult cattle?	No	1290 [78.1%]	361 [21.9%]	0.77
	Yes	514 [77.9%]	146 [22.1%]	
Number of animals with disease problem: retained afterbirth	≤ 2	237 [79.0%]	63 [21.0%]	0.83
	> 2	1567 [77.9%]	444 [22.1%]	
Number of animals with disease problem: abortion < 4 months	0	543 [82.3%]	117 [17.7%]	0.13
	≥ 1	1261 [76.4%]	390 [23.6%]	
Number of animals with disease problem: abortion 4-7 months	0	1804 [78.1%]	507 [21.9%]	--
	≥ 1	0 [0]	0 [0]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table B.1. (Continued).

Factor	**Factor Level**	**NC Serological Status Frequency [%][b] (-)**	**(+)**	***P*-value[a]**
Number of animals with disease problem: abortion > 7 months	0	889 [82.3%]	191 [17.7%]	0.13
	≥ 1	915 [74.3%]	316 [25.7%]	
Age	36 to < 72 months	1208 [78.3%]	334 [21.7%]	0.31
	72 to < 108 months	494 [77.1%]	147 [22.9%]	
	≥ 108 months	77 [77.8%]	22 [22.2%]	
Herd size	< 70 cattle	458 [80.4%]	112 [19.6%]	0.81
	70 to < 89 cattle	429 [75.3%]	141 [24.7%]	
	89 to < 129 cattle	435 [76.3%]	135 [23.7%]	
	≥ 129 cattle	482 [80.2%]	119 [19.8%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

APPENDIX C

Table C.1. Bivariate analysis of potential explanatory variables by serological status for antibodies to *Neospora caninum* (NC) for combined beef and dairy multivariable models (n = 5279 cattle).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Agroecological	Grassland	1038 [88.7%]	132 [11.3%]	0.02
	Montane	395 [87.8%]	55 [12.2%]	
	Parkland	1893 [83.0%]	387 [17.0%]	
	Boreal Forrest	1146 [83.1%]	233 [16.9%]	
Acreage of Farm	≤ 1500 acres	2330 [81.8%]	519 [18.2%]	0.02
	> 1500 acres	2142 [88.1%]	288 [11.9%]	
Acreage of Pasture	≤ 490 acres	2133 [79.9%]	536 [20.1%]	0.001
	> 490 acres	2339 [89.6%]	271 [10.4%]	
Acreage of Forage	≤ 350 acres	2150 [81.5%]	488 [18.5%]	0.01
	> 350 acres	2322 [43.99]	319 [6.04]	
Number Culled: Open heifers	0	2289 [82.1%]	499 [17.9%]	0.04
	≥1	2183 [87.6%]	308 [12.4%]	
Number Culled: Bred heifers	0	3746 [84.4%]	692 [15.6%]	0.39
	≥1	726 [86.3%]	115 [13.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status		*P* -value[a]
		Frequency [%][b]		
		(-)	(+)	
Number died last year: Pre-weaned calves	≤4	2506 [84.4%]	462 [15.6%]	0.63
	>4	1966 [85.1%]	345 [14.9%]	
Number died last year: open heifers	0	3575 [85.1%]	624 [14.9%]	0.48
	≥1	897 [83.1%]	183 [16.9%]	
Number died last year: bred heifers	0	3862 [85.8%]	637 [14.2%]	0.1
	≥1	610 [78.2%]	170 [21.8%]	
Number died last year: Bulls	0	4025 [84.4%]	744 [15.6%]	0.49
	≥1	447 [87.6%]	63 [12.4%]	
Number purchased last year: open heifers	0	3987 [84.1%]	752 [15.9%]	0.11
	≥1	485 [89.8%]	55 [10.2%]	
Number purchased last year: bred heifers	0	3402 [84.0%]	647 [16.0%]	0.19
	≥1	1070 [87.0%]	160 [13.0%]	
Number purchased last year: adult bulls	0	3004 [86.3%]	475 [13.7%]	0.1
	≥1	1468 [81.6%]	332 [18.4%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Was manure mechanically spread on pastures used by heifers?	No	3649 [86.3%]	580 [13.7%]	0.01
	Yes	823 [78.4%]	227 [21.6%]	
Were these pastures dragged or harrowed this year?	No	3173 [85.3%]	546 [14.7%]	0.37
	Yes	1299 [83.3%]	261 [16.7%]	
Were these pastures clipped this year?	No	3173 [85.3%]	546 [14.7%]	0.37
	Yes	1299 [83.3%]	261 [16.7%]	
Have you used lime on heifer pastures for reducing soil acidity?	No	4472 [84.7%]	807 [15.3%]	--
	Yes	0 [0]	0 [0]	
Have any female beef cattle been purchased in last 5 years?	No	1215 [82.8%]	253 [17.2%]	0.33
	Yes	3257 [85.5%]	554 [14.5%]	
Do you transport animals in your own trailer?	No	2147 [85.2%]	372 [14.8%]	0.66
	Yes	2325 [84.2%]	435 [15.8%]	
Do others use your trailer to transport cows?	No	3357 [84.1%]	634 [15.9%]	0.65
	Yes	1088 [86.5%]	170 [13.5%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Dairy cattle-number on farm	0	3391 [86.3%]	538 [13.7%]	0.06
	≥ 1	1081 [80.1%]	269 [19.9%]	
Dairy cattle-direct contact with beef cattle	No	3757 [85.8%]	622 [14.2%]	0.04
	Yes	661 [78.7%]	179 [21.3%]	
Dairy cattle-contact with feed for beef cattle	No	3843 [85.4%]	656 [14.6%]	0.09
	Yes	575 [79.9%]	145 [20.1%]	
Dairy cattle-contact with water for beef cattle	No	3744 [85.5%]	635 [14.5%]	0.12
	Yes	674 [80.2%]	166 [19.8%]	
Sheep-numbers on farm	0	3946 [85.4%]	673 [14.6%]	0.09
	≥ 1	526 [79.7%]	134 [20.3%]	
Sheep-direct contact with beef cattle	No	4228 [84.9%]	751 [15.1%]	0.19
	Yes	190 [79.2%]	50 [20.8%]	
Sheep-contact with feed for beef cattle	No	4276 [84.9%]	763 [15.1%]	0.23
	Yes	142 [78.9%]	38 [21.1%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Sheep-contact with water for beef cattle	No	4268 [84.7%]	771 [15.3%]	0.56
	Yes	150 [83.3%]	30 [16.7%]	
Goats-numbers on the farm	0	4280 [84.9%]	759 [15.1%]	0.3
	≥ 1	192 [80.0%]	48 [20.0%]	
Goats-direct animal contact with beef cattle	No	4354 [84.9%]	775 [15.1%]	0.11
	Yes	64 [71.1%]	26 [28.9%]	
Goats-direct contact with feed for beef cattle	No	4373 [84.8%]	786 [15.2%]	0.28
	Yes	45 [75.0%]	15 [25.0%]	
Goats-direct contact with water for beef cattle	No	4328 [84.9%]	771 [15.1%]	0.14
	Yes	90 [75.0%]	30 [25.0%]	
Poultry-numbers on farm	0	3477 [85.2%]	602 [14.8%]	0.26
	≥ 1	995 [82.9%]	205 [17.1%]	
Poultry-direct animal contact with beef cattle	No	4393 [84.7%]	796 [15.3%]	0.73
	Yes	25 [83.3%]	5 [16.7%]	
Poultry-contact with feed for beef cattle	No	4418 [84.7%]	801 [15.3%]	--
	Yes	0 [0]	0 [0]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status		*P* -value[a]
		Frequency [%][b]		
		(-)	(+)	
Poultry-contact with water for beef cattle	No	4418 [84.7%]	801 [15.3%]	--
	Yes	0 [0]	0 [0]	
Equine-numbers on farm	0	2155 [80.7%]	514 [19.3%]	0.003
	≥ 1	2317 [88.8%]	293 [11.2%]	
Equine-direct animal contact with beef cattle	No	2907 [82.8%]	602 [17.2%]	0.06
	Yes	1565 [88.4%]	205 [11.6%]	
Equine-contact with feed for beef cattle	No	3433 [83.5%]	676 [16.5%]	0.1
	Yes	1039 [88.8%]	131 [11.2%]	
Equine-contact with water for beef cattle	No	2821 [82.5%]	598 [17.5%]	0.03
	Yes	1651 [88.8%]	209 [11.2%]	
Pigs-numbers on farm	0	3888 [85.3%]	671 [14.7%]	0.31
	≥ 1	584 [81.1%]	136 [18.9%]	
Pigs-direct contact with beef cattle	No	4413 [85.0%]	776 [15.0%]	0.002
	Yes	5 [16.7%]	25 [83.3%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Pigs-direct contact with feed for beef cattle	No	4389 [84.6%]	800 [15.4%]	0.31
	Yes	29 [96.7%]	1 [3.3%]	
Pigs-contact with water for beef cattle	No	4391 [84.6%]	798 [15.4%]	0.84
	Yes	27 [90.0%]	3 [10.0%]	
Deer or Elk-numbers on farm	0	4418 [84.7%]	801 [15.3%]	0.77
	≥ 1	54 [90.0%]	6 [10.0%]	
Deer or Elk-direct contact with beef cattle	No	4211 [84.6%]	768 [15.4%]	0.86
	Yes	207 [86.3%]	33 [13.8%]	
Deer or Elk-contact with feed for beef cattle	No	4164 [84.7%]	755 [15.3%]	0.83
	Yes	254 [84.7%]	46 [15.3%]	
Deer or Elk-contact with water for beef cattle	No	4166 [84.7%]	753 [15.3%]	0.72
	Yes	252 [84.0%]	48 [16.0%]	
Exotics-numbers on farm	0	4089 [84.7%]	740 [15.3%]	0.93
	≥ 1	383 [85.1%]	67 [14.9%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Exotics-direct animal contact with beef cattle	No	4291 [84.7%]	778 [15.3%]	0.92
	Yes	154 [85.6%]	26 [14.4%]	
Exotics-contact with water for beef cattle	No	4264 [84.6%]	775 [15.4%]	0.87
	Yes	181 [86.2%]	29 [13.8%]	
Domestic rabbits-numbers on farm	0	4189 [85.2%]	730 [14.8%]	0.3
	≥ 1	283 [78.6%]	77 [21.4%]	
Domestic rabbits-direct animal contact with beef cattle	No	4391 [84.6%]	798 [15.4%]	0.77
	Yes	54 [90.0%]	6 [10.0%]	
Domestic rabbits-contact with feed for beef cattle	No	4362 [84.6%]	797 [15.4%]	0.45
	Yes	83 [92.2%]	7 [7.8%]	
Domestic rabbits-contact with water for beef cattle	No	4416 [84.6%]	803 [15.4%]	0.31
	Yes	29 [96.7%]	1 [3.3%]	
Contact with cattle through: shared pasture	No	3196 [83.9%]	613 [16.1%]	0.42
	Yes	1276 [86.8%]	194 [13.2%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Contact with cattle through: raising	No	4131 [85.0%]	728 [15.0%]	0.4
	Yes	341 [81.2%]	79 [18.8%]	
Contact with cattle through: fence line	No	1471 [83.1%]	300 [16.9%]	0.31
	Yes	3001 [85.5%]	507 [14.5%]	
Contact with cattle through: fairs or exhibitions	No	3441 [84.4%]	638 [15.6%]	0.5
	Yes	1031 [85.9%]	169 [14.1%]	
Contact with cattle through: lending cows or bulls	No	3587 [84.8%]	644 [15.2%]	0.54
	Yes	885 [84.4%]	163 [15.6%]	
Contact with cattle through: borrowing cows or bulls	No	3711 [84.7%]	668 [15.3%]	0.56
	Yes	761 [84.6%]	139 [15.4%]	
Total number of dogs on farm	0	514 [85.5%]	87 [14.5%]	0.48
	1-2 dogs	3025 [85.5%]	513 [14.5%]	
	> 2 dogs	933 [81.8%]	207 [18.2%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Total number of cats on farm	0	265 [88.3%]	35 [11.7%]	0.29
	1-3 cats	858 [86.8%]	131 [13.2%]	
	3-9 cats	2229 [85.4%]	381 [14.6%]	
	> 9 cats	1120 [81.2%]	260 [18.8%]	
Dogs: If none present, how long ago were they present?	≤ 2.5 months	194 [80.8%]	46 [19.2%]	0.87
	> 2.5 months	4278 [84.9%]	761 [15.1%]	
Coyotes/wolves seen on farm	0	82 [54.7%]	68 [45.3%]	0.07
	1-3 times / year	509 [84.8%]	91 [15.2%]	
	4-6 times / year	248 [91.9%]	22 [8.1%]	
	> 6 times / year	3633 [85.3%]	626 [14.7%]	
Foxes seen on farm	0	1220 [81.3%]	281 [18.7%]	0.03
	1-3 times / year	1622 [84.5%]	298 [15.5%]	
	4-6 times / year	486 [85.3%]	84 [14.7%]	
	> 6 times / year	1124 [89.3%]	134 [10.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Other dogs seen on farm	0	1193 [84.5%]	218 [15.5%]	0.87
	1-3 times / year	1673 [84.5%]	307 [15.5%]	
	4-6 times / year	554 [83.9%]	106 [16.1%]	
	> 6 times / year	1052 [85.7%]	176 [14.3%]	
Stray cats seen on farm	0	569 [82.5%]	121 [17.5%]	0.47
	1-3 times / year	2077 [84.4%]	383 [15.6%]	
	4-6 times / year	722 [86.0%]	118 [14.0%]	
	> 6 times / year	1104 [85.6%]	185 [14.4%]	
Raccoons seen on farm	0	3887 [83.6%]	762 [16.4%]	0.01
	1-3 times / year	342 [95.0%]	18 [5.0%]	
	4-6 times / year	83 [92.2%]	7 [7.8%]	
	> 6 times / year	140 [93.3%]	10 [6.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status		*P* -value[a]
		Frequency [%][b]		
		(-)	(+)	
Skunks seen on farm	0	1179 [81.8%]	262 [18.2%]	0.44
	1-3 times / year	1875 [86.9%]	283 [13.1%]	
	4-6 times / year	526 [83.5%]	104 [16.5%]	
	> 6 times / year	872 [85.5%]	148 [14.5%]	
Footbath used in barns	No	4333 [85.0%]	766 [15.0%]	0.5
	Yes	139 [77.2%]	41 [22.8%]	
Times per month change disinfectant in barn	≤ 2 times	139 [92.7%]	11 [7.3%]	0.2
	> 2 times	4333 [84.5%]	796 [15.5%]	
People entered barn: Beef farmers/ranchers (times / day)	≤ 10 times	2362 [80.3%]	578 [19.7%]	0.001
	> 10 times	2110 [90.2%]	229 [9.8%]	
Beef farmers/ranchers vehicles or equipment cleaned	No	3855 [85.1%]	674 [14.9%]	0.22
	Yes	590 [81.9%]	130 [18.1%]	
People entered barn: other beef farmers (times / day)	0	2722 [85.7%]	456 [14.3%]	0.09
	≥ 1 time	1750 [83.3%]	351 [16.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
People entered barn: Cattle dealer (times / month)	0	2275 [84.3%]	423 [15.7%]	0.76
	≥ 1 time	2197 [85.1%]	384 [14.9%]	
Cattle dealer vehicles or equipment cleaned	No	3413 [84.9%]	606 [15.1%]	0.64
	Yes	1059 [84.0%]	201 [16.0%]	
People entered barn: AI tech (times)	≤ 2 times	2315 [87.7%]	324 [12.3%]	0.002
	> 2 times	2157 [81.7%]	483 [18.3%]	
AI tech vehicles and equipment cleaned	No	3173 [86.0%]	516 [14.0%]	0.09
	Yes	1299 [81.7%]	291 [18.3%]	
People entered barn: Vet (times / month)	≤ 10 times	2613 [88.0%]	355 [12.0%]	0.005
	> 10 times	1859 [80.4%]	452 [19.6%]	
Vet vehicles and equipment cleaned	No	1480 [85.1%]	260 [14.9%]	0.98
	Yes	2992 [84.5%]	547 [15.5%]	
People entered barn: nutrition tech (times / month)	≤ 2 times	2306 [87.4%]	333 [12.6%]	0.008
	> 2 times	2166 [82.0%]	474 [18.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status		*P* -value[a]
		Frequency [%][b]		
		(-)	(+)	
People entered barn: hoof trimmers (times / month)	≤ 1 time	2651 [84.2%]	497 [15.8%]	0.71
	> 1 time	1821 [85.5%]	310 [14.5%]	
Hoof trimmers vehicles and equipment cleaned	No	2991 [84.5%]	547 [15.5%]	0.95
	Yes	1481 [85.1%]	260 [14.9%]	
People entered barn: dead stock collector (times / month)	≤ 2 times	2487 [83.8%]	482 [16.2%]	0.66
	> 2 times	1985 [85.9%]	325 [14.1%]	
Dead stock collector vehicle and equipment cleaned	No	3444 [83.8%]	665 [16.2%]	0.24
	Yes	1028 [87.9%]	142 [12.1%]	
People entered barn: contract manure spreader	0	2383 [84.6%]	435 [15.4%]	0.79
	≥ 1 time	2089 [84.9%]	372 [15.1%]	
Manure spreader vehicles and equipment cleaned	No	3916 [84.3%]	732 [15.7%]	0.32
	Yes	556 [88.1%]	75 [11.9%]	
Borrow equipment with manure contact	No	2233 [82.7%]	468 [17.3%]	0.13
	Yes	2239 [86.9%]	339 [13.1%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Always disinfected borrowed equipment	No	4339 [84.6%]	790 [15.4%]	0.84
	Yes	79 [87.8%]	11 [12.2%]	
Lend equipment with manure contact	No	2692 [83.1%]	546 [16.9%]	0.09
	Yes	1780 [87.2%]	261 [12.8%]	
Always disinfect lent equipment	No	4366 [84.6%]	793 [15.4%]	0.98
	Yes	52 [86.7%]	8 [13.3%]	
Calves receive colostrum from: mother	No	335 [79.6%]	86 [20.4%]	0.23
	Yes	4137 [85.2%]	721 [14.8%]	
Calves receive colostrum from: all pooled	No	4127 [85.5%]	701 [14.5%]	0.07
	Yes	345 [76.5%]	106 [23.5%]	
colostrum from: dairy cows of unknown status	No	2883 [88.2%]	385 [11.8%]	0.75
	Yes	28 [93.3%]	2 [6.7%]	
colostrum from: Johne's negative dairy cows	No	2911 [88.3%]	387 [11.7%]	0.36
	Yes	24 [80.0%]	6 [20.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Calves receive: fresh colostrum	No	237 [87.8%]	33 [12.2%]	0.56
	Yes	4235 [84.5%]	774 [15.5%]	
Calves receive: frozen colostrum	No	4169 [84.8%]	750 [15.2%]	0.88
	Yes	303 [84.2%]	57 [15.8%]	
Calves receive: fermented colostrum	No	4443 [84.6%]	806 [15.4%]	0.34
	Yes	29 [96.7%]	1 [3.3%]	
Calves receive: heat treated colostrum	No	4419 [84.7%]	800 [15.3%]	0.79
	Yes	53 [88.3%]	7 [11.7%]	
Was the calving area used as a hospital area in last 12 months?	No	3073 [86.1%]	496 [13.9%]	0.06
	Yes	1399 [81.8%]	311 [18.2%]	
Type of bedding used in calving areas: straw?	No	218 [72.7%]	82 [27.3%]	0.02
	Yes	4254 [85.4%]	725 [14.6%]	
Type of bedding used in calving areas: shavings/sawdust?	No	3905 [85.6%]	656 [14.4%]	0.05
	Yes	567 [79.0%]	151 [21.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Type of bedding used in calving areas: none	No	4472 [84.7%]	807 [15.3%]	--
	Yes	0 [0]	0 [0]	
Frequency of adding bedding to calving areas	Every calving	2279 [83.5%]	451 [16.5%]	0.79
	Every 2-4 calvings	1257 [87.2%]	184 [12.8%]	
	Every 5 or more calvings	266 [80.6%]	64 [19.4%]	
Frequency of removing surface manure from calving areas?	Every calving	1228 [83.5%]	242 [16.5%]	0.54
	Every 2-4 calvings	937 [84.4%]	173 [15.6%]	
	Every 5 or more calvings	2279 [85.4%]	390 [14.6%]	
Frequency of removing all manure from calving areas?	Every calving	499 [83.2%]	101 [16.8%]	0.9
	Every 2-4 calvings	651 [83.5%]	129 [16.5%]	
	Every 5 or more calvings	2490 [83.9%]	479 [16.1%]	
How often are placentas eaten by dogs?	Never	1454 [85.0%]	257 [15.0%]	0.66
	Sometimes	2530 [84.3%]	470 [15.7%]	
	Often	488 [85.9%]	80 [14.1%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status		***P*-value**[a]
		Frequency [%][b]		
		(-)	(+)	
How often are placentas eaten by cats?	Never	2244 [85.0%]	397 [15.0%]	0.91
	Sometimes	1857 [83.6%]	363 [16.4%]	
	Often	344 [88.7%]	44 [11.3%]	
How often are placentas eaten by wild animals?	Never	2113 [82.9%]	436 [17.1%]	0.2
	Sometimes	1965 [86.2%]	315 [13.8%]	
	Often	260 [86.7%]	40 [13.3%]	
How often are placentas eaten by cows?	Never	193 [91.9%]	17 [8.1%]	0.01
	Sometimes	2864 [81.6%]	645 [18.4%]	
	Often	1415 [90.7%]	145 [9.3%]	
How often are aborted fetuses eaten by dogs?	Never	3307 [85.4%]	564 [14.6%]	0.68
	Sometimes	1090 [82.7%]	228 [17.3%]	
	Often	55 [91.7%]	5 [8.3%]	
How often are aborted fetuses eaten by cats?	Never	3547 [85.0%]	624 [15.0%]	0.98
	Sometimes	905 [84.0%]	173 [16.0%]	
	Often	0 [0]	0 [0]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
How often are aborted fetuses eaten by wild animals?	Never	1975 [83.4%]	394 [16.6%]	0.27
	Sometimes	1919 [85.3%]	331 [14.7%]	
	Often	578 [87.6%]	82 [12.4%]	
Percentage of cows bred using artificial insemination	≤ 50	2747 [87.3%]	401 [12.7%]	0.002
	> 50	1565 [80.2%]	386 [19.8%]	
Do you use embryo transfer on your farm?	No	3739 [84.2%]	699 [15.8%]	0.39
	Yes	733 [87.2%]	108 [12.8%]	
Number of embyros purchased outside the herd and implanted?	0	332 [85.1%]	58 [14.9%]	0.99
	≥ 1	4140 [84.7%]	749 [15.3%]	
Number of embryos collected on farm and implanted?	≤ 5	319 [88.6%]	41 [11.4%]	0.37
	> 5	4153 [84.4%]	766 [15.6%]	
Do cows have access to a stream, lake, or pond?	No	0 [0]	0 [0]	--
	Yes	4472 [84.7%]	807 [15.3%]	
Number of days after manure application to grazing?	≤ 90	1668 [84.3%]	311 [15.7%]	0.74
	> 90	2804 [85.0%]	496 [15.0%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
What % of grains fed to heifers that was homegrown?	≤ 50%	1536 [81.3%]	354 [18.7%]	0.03
	> 50%	2861 [86.7%]	440 [13.3%]	
What % of roughages fed to heifers was homegrown?	≤ 50%	427 [79.1%]	113 [20.9%]	0.1
	> 50%	3970 [85.4%]	681 [14.6%]	
What % of grains fed to cows was homegrown?	≤ 50%	1618 [81.7%]	362 [18.3%]	0.03
	> 50%	2775 [86.4%]	436 [13.6%]	
What % of roughages fed to cows was homegrown?	≤ 50%	437 [76.7%]	133 [23.3%]	0.02
	> 50%	4011 [85.7%]	668 [14.3%]	
Water source-winter, open heifers-surface water	No	3818 [84.9%]	680 [15.1%]	0.81
	Yes	654 [83.7%]	127 [16.3%]	
Water source-winter, open heifers-well water	No	1079 [87.8%]	150 [12.2%]	0.13
	Yes	3393 [83.8%]	657 [16.2%]	
Water source-winter, open heifers-municipal water	No	4278 [84.4%]	791 [15.6%]	0.17
	Yes	194 [92.4%]	16 [7.6%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	**Factor Level**	**NC Serological Status**		***P*-value**[a]
		Frequency [%][b]		
		(-)	(+)	
Water source-winter, bred heifers-surface water	No	3550 [84.6%]	648 [15.4%]	0.75
	Yes	922 [85.3%]	159 [14.7%]	
Water source-winter, bred heifers-well water	No	1048 [87.4%]	151 [12.6%]	0.14
	Yes	3424 [83.9%]	656 [16.1%]	
Water source-winter, bred heifers-municipal water	No	4248 [84.3%]	791 [15.7%]	0.07
	Yes	224 [93.3%]	16 [6.7%]	
Water source-winter, adult cows-surface water	No	3570 [83.8%]	688 [16.2%]	0.12
	Yes	902 [88.3%]	119 [11.7%]	
Water source-winter, adult cows-well water	No	889 [89.7%]	102 [10.3%]	0.03
	Yes	3583 [83.6%]	705 [16.4%]	
Water source-winter, adult cows-municipal water	No	4220 [84.2%]	789 [15.8%]	0.06
	Yes	252 [93.3%]	18 [6.7%]	
Water source-winter, bulls-surface water	No	3684 [84.1%]	694 [15.9%]	0.32
	Yes	788 [87.5%]	113 [12.5%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status		*P*-value[a]
		Frequency [%][b]		
		(-)	(+)	
Water source-winter, bulls-well water	No	915 [89.6%]	106 [10.4%]	0.02
	Yes	3557 [83.5%]	701 [16.5%]	
Water source-winter, bulls-municipal water	No	4273 [84.3%]	796 [15.7%]	0.03
	Yes	199 [94.8%]	11 [5.2%]	
Water source-summer, open heifers-surface water	No	1809 [82.7%]	379 [17.3%]	0.18
	Yes	2663 [86.2%]	428 [13.8%]	
Water source-summer, open heifers-well water	No	2423 [87.8%]	336 [12.2%]	0.005
	Yes	2049 [81.3%]	471 [18.7%]	
Water source-summer, open heifers-municipal water	No	4330 [84.4%]	799 [15.6%]	0.09
	Yes	142 [94.7%]	8 [5.3%]	
Water source-summer, bred heifers-surface water	No	1523 [82.0%]	335 [18.0%]	0.13
	Yes	2949 [86.2%]	472 [13.8%]	
Water source-summer, bred heifers-well water	No	2262 [87.7%]	317 [12.3%]	0.01
	Yes	2210 [81.9%]	490 [18.1%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P*-value[a]
Water source-summer, bred heifers-municipal water	No	4273 [84.3%]	796 [15.7%]	0.04
	Yes	199 [94.8%]	11 [5.2%]	
Water source-summer, adult cows-surface water	No	1264 [78.0%]	356 [22.0%]	0.001
	Yes	3208 [87.7%]	451 [12.3%]	
Water source-summer, adult cows-well water	No	2401 [89.0%]	298 [11.0%]	0.001
	Yes	2071 [80.3%]	509 [19.7%]	
Water source-summer, adult cows-municipal water	No	4255 [84.4%]	784 [15.6%]	0.23
	Yes	217 [90.4%]	23 [9.6%]	
Water source-summer, bulls-surface water	No	2605 [82.7%]	545 [17.3%]	0.06
	Yes	1867 [87.7%]	262 [12.3%]	
Water source-summer, bulls-well water	No	2522 [88.5%]	327 [11.5%]	0.001
	Yes	1950 [80.2%]	480 [19.8%]	
Water source-summer, bulls-municipal water	No	4274 [84.3%]	795 [15.7%]	0.06
	Yes	198 [94.3%]	12 [5.7%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Is equipment with manure contact used to handle feed for heifers?	Regularly	742 [85.3%]	128 [14.7%]	0.63
	Occasionally	1193 [84.6%]	217 [15.4%]	
	Not a practice	2459 [84.5%]	452 [15.5%]	
Is equipment with manure contact used to handle feed for cows?	Regularly	784 [84.3%]	146 [15.7%]	0.83
	Occasionally	1285 [84.1%]	243 [15.9%]	
	Not a practice	2351 [85.2%]	410 [14.8%]	
Do heifers < 12 months of age share feed bunk with adult cattle?	No	3985 [84.6%]	726 [15.4%]	0.81
	Yes	487 [85.7%]	81 [14.3%]	
Do heifers < 12 months of age share water trough with adult cattle?	No	2301 [83.3%]	460 [16.7%]	0.22
	Yes	2171 [86.2%]	347 [13.8%]	
Number of animals with disease problem: retained afterbirth	≤ 2	1704 [88.8%]	214 [11.2%]	0.003
	> 2	2768 [82.4%]	593 [17.6%]	
Number of animals with disease problem: abortion < 4 months	0	2420 [88.7%]	308 [11.3%]	0.002
	≥ 1	2052 [80.4%]	499 [19.6%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.

[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

Table C.1. (Continued).

Factor	Factor Level	NC Serological Status Frequency [%][b] (-)	(+)	*P* -value[a]
Number of animals with disease problem: abortion 4-7 months	0	4472 [84.7%]	807 [15.3%]	--
	≥ 1	0 [0]	0 [0]	
Number of animals with disease problem: abortion > 7 months	0	2819 [87.9%]	389 [12.1%]	0.002
	≥ 1	1653 [79.8%]	418 [20.2%]	
Cow type / Operation	Dairy	1804 [78.1%]	507 [21.9%]	0.001
	Beef	2668 [89.9%]	300 [10.1%]	
Age	36 to < 72 months	2411 [83.9%]	462 [16.1%]	0.41
	72 to < 108 months	1371 [85.2%]	240 [14.8%]	
	≥ 108 months	649 [86.8%]	99 [13.2%]	
Herd size	< 70 cattle	1038 [84.5%]	190 [15.5%]	0.15
	70 to < 89 cattle	722 [80.2%]	178 [19.8%]	
	89 to < 129 cattle	906 [83.9%]	174 [16.1%]	
	≥ 129 cattle	1806 [87.2%]	265 [16.8%]	

[a] The p-value is derived from bivariate analysis using the likelihood ratio test of significance.
[b] This value represents the percentage of cattle in each designation (NC + or -) by category of potential explanatory factor.

APPENDIX D

Survey of Risk Factors for Johne's Disease and Neospora in Alberta Beef Cow-calf Herds (2002)

Part A:

Herd Code and Geographical Location

DO NOT COMPLETE SHADED AREAS: STUDY PERSONNEL ONLY!

Herd Identifier Page:

Please return this page to Dr. H. Morgan Scott, College of Veterinary Medicine, Texas A&M University, in the pre-addressed, stamped envelope.

***Note: This information is only used to link to databases reflecting soil type, major climatic, and landscape features. These databases will never include herd owner or farm name.

A. Primary farm/ranch location (i.e., calving grounds and/or home quarter) and identification

Item	**Enter Data Here**	**Field #**	**Entered**
Alberta Johne's Control Program Herd Identifier *(Accr, Vet #/Year/Herd #):*		001	
Date of Sampling:		002	
County:		003	
Postal Code:		004	
Legal Subdivision (if applicable):		005	
Quarter:		006	
Section:		007	
Township:		008	
Range:		009	
Meridian (West of ...):		010	

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Survey of Risk Factors for Johne's Disease and Neospora in Alberta Beef Cow-calf Herds (2002)

Part B:

Herd Code and Herd Management Data

DO NOT COMPLETE SHADED AREAS: STUDY PERSONNEL ONLY!

Herd Management Data:

Please return this survey to Annette Visser, Food Safety Division, Alberta Agriculture, Food and Rural Development, in the pre-addressed, stamped envelope provided.

*****Note:** This information will be kept confidential and will never be linked directly to databases reflecting the owner or farm name. In addition, reports arising from this study will not refer to specific geographical locations that could be used to identify herds.

A. Identification (Field # 001-002; *Field #'s 003-010 are located in Part A of this survey***)**

Item	**Enter Data Here**	**Field #**	**Entered**
Alberta Johne's Control Program Herd <u>Identifier (Accr, Vet #/Year/Herd #):</u>		001	
Date of Sampling:		002	

B. Farm/Ranch (Field #'s 011–014)

Item	**Enter Data Here**	**Field #**	**Entered**
Total area of the farm/ranch (in acres), both owned and leased/rented, in the last summer:		011	
Area of pasture (grazing) (in acres), both owned and leased/rented, in the last summer:		012	
Area of forage production (in acres), both owned and leased/rented, in the last summer:		013	
Area of land used for other purposes (in acres), both owned and leased/rented, in the last summer:		014	

C. Herd population (Field #'s 015-059)

Item	**Enter Data Here**	**Field #**	**Entered**
Type of herd operation	▯ [1] Purebred ▯ [2] Commercial ▯ [3] Both of above % Purebred ______________ % Commercial ______________	015	

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Type of farm enterprise	☐ 1 Beef cattle only ☐ 2 Mixed operation % Beef cattle ____________ % Other ____________	016	
Primary breed (major influence) of your beef cows (check one):	☐ 1 Angus - Black ☐ 2 Angus - Red ☐ 3 Blonde D'Aquitane ☐ 4 Charolais ☐ 5 Gelbvieh ☐ 6 Hereford - Horned ☐ 7 Hereford - Polled ☐ 8 Limousin ☐ 9 Maine Anjou ☐ 10 Salers ☐ 11 Simmental ☐ 12 Shorthorn ☐ 13 Other (specify): ____________________	017	
Secondary breed **(second major influence) of your beef cows** (check one):	☐ 1 Angus - Black ☐ 2 Angus - Red ☐ 3 Blonde D'Aquitane ☐ 4 Charolais ☐ 5 Gelbvieh ☐ 6 Hereford - Horned ☐ 7 Hereford - Polled ☐ 8 Limousin ☐ 9 Maine Anjou ☐ 10 Salers ☐ 11 Simmental ☐ 12 Shorthorn ☐ 13 Other (specify): ____________________	018	
Primary breed (major influence) of your **bulls used on adult cows** (check one):	☐ 1 Angus - Black ☐ 2 Angus - Red ☐ 3 Blonde D'Aquitane	019	

	[] 4 Charolais [] 5 Gelbvieh [] 6 Hereford - Horned [] 7 Hereford - Polled [] 8 Limousin [] 9 Maine Anjou [] 10 Salers [] 11 Simmental [] 12 Shorthorn [] 13 Other (specify): ________________		
Primary breed (major influence) of your **bulls used on heifers** (check one):	[] 1 Angus - Black [] 2 Angus - Red [] 3 Blonde D'Aquitane [] 4 Charolais [] 5 Gelbvieh [] 6 Hereford - Horned [] 7 Hereford - Polled [] 8 Limousin [] 9 Maine Anjou [] 10 Salers [] 11 Simmental [] 12 Shorthorn [] 13 Other (specify): ________________	020	
Number of animals present in herd on the day of blood sampling:			
• Pre-weaned calves		021	
• Post-weaned bull/steer calves		022	
• Post-weaned heifer calves		023	
• Open heifers		024	
• Yearling bulls		025	
• Bred heifers		026	
• Adult cows		027	
• Adult bulls		028	

Number of animals in herd that were sold for beef herd 'replacement' purposes in the last 12 months (i.e., not sold for feeding or slaughter):			
• Post-weaned heifer calves		029	
• Post-weaned bull calves		030	
• Open heifers		031	
• Bred heifers		032	
• Adult cows only (no pre-weaned calf)		033	
• Adult cow-calf pairs (number of pairs: includes the pre-weaned calf)		034	
• Yearling bulls		035	
• Adult bulls		036	
Number of animals in herd that were culled in the last 12 months:			
• Open heifers		037	
• Bred heifers		038	
• Adult cows		039	
• Bulls		040	
Number of animals in herd that were sold as feeders in the last 12 months:			
• Pre-weaned calves		041	
• Post-weaned calves		042	
• Yearling heifers		043	
• Yearling steers/bulls		044	
Number of animals in herd that died in the last 12 months:			
• Pre-weaned calves		045	
• Post-weaned calves		046	
• Open heifers		047	
• Bred heifers		048	
• Adult cows		049	
• Bulls		050	
Number of animals purchased into the herd during the last 12 months:			
• Post-weaned heifer calves		051	
• Post-weaned bull calves		052	
• Open heifers		053	
• Bred heifers		054	
• Adult cows		055	
• Adult cow-calf pairs (number of		056	

pairs: includes the pre-weaned calf)			
• Yearling bulls		057	
• Adult bulls		058	

D. Pasture and Housing (Field #'s 059-115)

Item	Enter Data Here	Field #	Entered
Calving area:			
Major calving season (please check one)	☐ Winter	059	
	☐ Spring	060	
	☐ Summer	061	
	☐ Fall	062	
Are cows and heifers housed separately pre-calving?	☐ Yes	063	
	☐ No	064	
Are cows and heifers housed separately post-calving?	☐ Yes	065	
	☐ No	066	
Where do cows generally calve?	☐ Maternity pen(s):	067	
	How many are available? ________	068	
	☐ Common corral / feedlot	069	
	☐ Small pasture	070	
	☐ Large pasture / open range	071	
Where do heifers generally calve?	☐ Maternity pen(s):	072	
	How many are available? ________	073	
	☐ Common corral / feedlot	074	
	☐ Small pasture	075	
	☐ Large pasture / open range	076	
How long do heifers and cows generally remain in the calving area(s) after delivering the calf?	☐ _________________(days)	077	
Winter housing. Please, check all that apply for each group of animals on your farm:			
Barn:	☐ Heifer calves / open heifers	078	
	☐ Bred heifers	079	
	☐ Adult cows	080	
	☐ Bulls	081	
Feedlot / pens:	☐ Heifer calves / open heifers	082	
	☐ Bred heifers	083	
	☐ Adult cows	084	

	▯ Bulls	085	
Small winter pasture / loafing area:	▯ Heifer calves / open heifers	086	
	▯ Bred heifers	087	
	▯ Adult cows	088	
	▯ Bulls	089	
Large winter pasture / open range:	▯ Heifer calves / open heifers	090	
	▯ Bred heifers	091	
	▯ Adult cows	092	
	▯ Bulls	093	
Summer housing. Please, check all that apply for each group of animals on your farm:			
Barn:	▯ Heifer calves / open heifers	094	
	▯ Bred heifers	095	
	▯ Adult cows	096	
	▯ Bulls	097	
Feedlot / pens:	▯ Heifer calves / open heifers	098	
	▯ Bred heifers	099	
	▯ Adult cows	100	
	▯ Bulls	101	
Small summer pasture / loafing area:	▯ Heifer calves / open heifers	102	
	▯ Bred heifers	103	
	▯ Adult cows	104	
	▯ Bulls	105	
Large summer pasture / open range:	▯ Heifer calves / open heifers	106	
	▯ Bred heifers	107	
	▯ Adult cows	108	
	▯ Bulls	109	

If your heifers (open/bred) have access to pasture then answer the rest of the questions in this section (otherwise, please skip to Field #116)

How did you manage the pastures that were used by heifers in the most recent grazing season:	▯ [1] continuous grazing (continuous access to the same pasture for the whole pasture season) ▯ [2] controlled access grazing (rotational or strip grazing)	110	
Was any cattle manure mechanically spread on pastures that were used for grazing by heifers?	▯ [0] No ▯ [1] Yes	111	
Were these pastures dragged or harrowed this year?	▯ [0] No ▯ [1] Yes	112	

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Were these pastures clipped this year?	▯ ^{0} No ▯ ^{1} Yes	113	
Have you used lime on heifer pastures for reducing soil acidity during the past 5 years?	▯ ^{0} No ▯ ^{1} Yes	114	
If YES to Field # 114, how often do the pasture fields receive lime If no, skip to Field # 116)?	▯ ^{1} every year ▯ ^{2} every 2-3 years ▯ ^{3} every 4-5 years ▯ ^{4} every 6-10 years ▯ ^{5} never	115	

E. Biosecurity – Purchase (Field #'s 116-130)

Item	**Enter Data Here**	**Field #**	**Entered**
Has the farm purchased any female beef cattle replacements (heifer calves, open or bred heifers or adult cows) in the last 5 years?	▯ ^{0} No ▯ ^{1} Yes	116	
If yes to Field #116, number of replacements purchased in the last 5 years.		117	
If yes to Field #116, percentage of beef animals purchased <u>directly</u> from other producers:	________ %	118	
If yes to Field #116, percentage of beef animals purchased from private dealers:	________ %	119	
If yes to Field #116, percentage of beef animals purchased through an auction mart:	________ %	120	
How many bulls has the farm/ranch purchased in the last 5 years?		121	
Percentage of bulls purchased <u>directly</u> from other producers:	________ %	122	
Percentage of bulls purchased from private dealers:	________ %	123	
Percentage of bulls purchased through an auction mart:	________ %	124	
When animals are transported to your farm, do you only use your own trailer?	▯ ^{0} No ▯ ^{1} Yes	125	
If YES to Field # 125 do others use your trailer to transport cows?	▯ ^{0} No ▯ ^{1} Yes	126	

Before bringing cattle (either female or male) on your farm/ranch, does the farm normally require:				
• a negative test for Neosporosis from the animal(s)?	☐ ⁰ No	☐ ¹ Yes	127	
• a negative test for Johne's disease from the animal(s)?	☐ ⁰ No	☐ ¹ Yes	128	
• a negative HERD test for Johne's disease?	☐ ⁰ No	☐ ¹ Yes	129	
• a negative HERD HISTORY for Johne's clinical disease?	☐ ⁰ No	☐ ¹ Yes	130	

F. Biosecurity – Contact (Field #'s 131-221)

Item	Enter Data Here	Field #	Entered
Please, fill in the table below to describe contact between your beef animals and other animal types/species that are on your farm/ranch:			
Dairy cattle	Numbers on farm: ___________	131	
	Direct animal contact with beef cattle ☐ ⁰ No ☐ ¹ Yes	132	
	Contact with feed for beef animals ☐ ⁰ No ☐ ¹ Yes	133	
	Contact with water for beef animals ☐ ⁰ No ☐ ¹ Yes	134	
Sheep	Numbers on farm: ___________	135	
	Direct animal contact with beef cattle ☐ ⁰ No ☐ ¹ Yes	136	
	Contact with feed for beef animals ☐ ⁰ No ☐ ¹ Yes	137	
	Contact with water for beef animals ☐ ⁰ No ☐ ¹ Yes	138	
Goats	Numbers on farm: ___________	139	
	Direct animal contact with beef cattle ☐ ⁰ No ☐ ¹ Yes	140	
	Contact with feed for beef animals ☐ ⁰ No ☐ ¹ Yes	141	
	Contact with water for beef animals ☐ ⁰ No ☐ ¹ Yes	142	
Chicken or poultry	Numbers on farm: ___________	143	
	Direct animal contact with beef cattle		

	[] ^{0} No [] ^{1} Yes Contact with feed for beef animals [] ^{0} No [] ^{1} Yes Contact with water for beef animals [] ^{0} No [] ^{1} Yes	144 145 146	
Horses and other equines	Numbers on farm: ___________ Direct animal contact with beef cattle [] ^{0} No [] ^{1} Yes Contact with feed for beef animals [] ^{0} No [] ^{1} Yes Contact with water for beef animals [] ^{0} No [] ^{1} Yes	147 148 149 150	
Pigs	Numbers on farm: ___________ Direct animal contact with beef cattle [] ^{0} No [] ^{1} Yes Contact with feed for beef animals [] ^{0} No [] ^{1} Yes Contact with water for beef animals [] ^{0} No [] ^{1} Yes	151 152 153 154	
Deer or elk	Numbers on farm: ___________ Direct animal contact with beef cattle [] ^{0} No [] ^{1} Yes Contact with feed for beef animals [] ^{0} No [] ^{1} Yes Contact with water for beef animals [] ^{0} No [] ^{1} Yes	155 156 157 158	
Exotic ruminants (alpacas, llamas)	Numbers on farm: ___________ Direct animal contact with beef cattle [] ^{0} No [] ^{1} Yes Contact with feed for beef animals [] ^{0} No [] ^{1} Yes Contact with water for beef animals [] ^{0} No [] ^{1} Yes	159 160 161 162	
Domestic rabbits	Numbers on farm: ___________ Direct animal contact with beef cattle	163	

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	☐ ^{0} No ☐ ^{1} Yes	164	
	Contact with feed for beef animals ☐ ^{0} No ☐ ^{1} Yes	165	
	Contact with water for beef animals ☐ ^{0} No ☐ ^{1} Yes	166	
In the past 5 years have any of your beef cattle had contact with cattle (dairy or beef) from other herds through any of the following routes:			
• shared pasture	☐ ^{0} No ☐ ^{1} Yes	167	
• contract raising of young stock	☐ ^{0} No ☐ ^{1} Yes	168	
• fence line contact while on pasture	☐ ^{0} No ☐ ^{1} Yes	169	
• contact at fairs/exhibitions	☐ ^{0} No ☐ ^{1} Yes	170	
• lending cows or bulls	☐ ^{0} No ☐ ^{1} Yes	171	
• borrowing cows or bulls	☐ ^{0} No ☐ ^{1} Yes	172	
Please fill in the table below to describe any dogs and cats that live on your farm:			
Dogs			
• number of males (intact & neutered)		173	
• number of females (spayed)		174	
• number of females (intact)		175	
• number of litters in last 12 months		176	
• usual birthing location	☐ 1 – Barn ☐ 2 – Feed Storage areas ☐ 3 – House ☐ 4 – Other specify:____________	177	
Cats			
• number of males (intact & neutered)		178	
• number of females (spayed)		179	
• number of females (intact)		180	
• number of litters in last 12 months		181	
• usual birthing location	☐ 1 – Barn ☐ 2 – Feed Storage areas ☐ 3 – House ☐ 4 – Other specify:____________	182	
Compared with the previous years, **has the number of litters of dogs in the last 12 months:**	☐ ^{1} increased ☐ ^{2} decreased ☐ ^{3} continued to be the same	183	
Compared with the previous years, **has the number of litters of cats in**	☐ ^{1} increased	184	

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the last 12 months:	▯ ² decreased ▯ ³ continued to be the same		
If there are NO dogs on the farm, how long ago (years) did one reside on the farm?		185	
In the last 12 months how often have the following animals been seen on the farm?			
Coyotes/wolves	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	186	
Foxes	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	187	
Other dogs	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	188	
Stray cats	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	189	
Raccoons	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	190	
Skunks	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	191	
Does the farm use a footbath for disinfecting visitor's boots before entering the cow and/or heifer areas? If YES for Field 175, how many times is disinfectant changed each month:	▯ ⁰ No ▯ ¹ Yes _______________	192 193	
During the past 12 months, list the number of times the following categories of people **actually entered your farm** and whether you felt their vehicle/equipment was properly cleaned.			
Other beef farmer/ranchers	Number of times: _________	194	

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	Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	195	
Other dairy farmers	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	196 197	
Cattle dealers	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	198 199	
AI technicians + sales reps	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	200 201	
Veterinarians	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	202 203	
Nutrition technicians/advisors + sales reps	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	204 205	
Other health advisers	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	206 207	
Hoof trimmers	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	208 209	
Dead stock collection	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	210 211	
Contract manure spreaders	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	212 213	
Farm equipment technicians	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	214 215	
Others (specify)	Number of times: _________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	216 217	
During the past 12 months, did you borrow equipment from other farmers	[] ⁰ No [] ¹ Yes	218	

that could have manure contact (e.g. foot trimming chute, manure spreader, tractor, cattle trailer)?	If YES, did you always disinfect it before using it? ▯ ^{0} No ▯ ^{1} Yes	219	
During the past year, did you lend equipment to other farmers that could have manure contact?	▯ ^{0} No ▯ ^{1} Yes If YES, did you always disinfect it before using it again? ▯ ^{0} No ▯ ^{1} Yes	220 221	

F. Calving and calf management (Field #'s 222-247)

What percentage of your newborn calves receive colostrum as follows?	^{1} only from their mother [%] ^{2} pooled from other beef cows on your farm [%] ^{3} from dairy cows / dairy herd of unknown status [%] ^{4} from Johne's disease negative dairy cows [%]	222 223 224 225	
What percentage of your newborn calves receive:	^{1} fresh colostrum [%] ^{2} frozen colostrum [%] ^{3} fermented colostrum [%] ^{4} heat treated colostrum [%]	226 227 228 229	
The following questions pertain to calving areas:			
Was the calving area used as a hospital area for sick cows in the last 12 months?	▯ ^{0} No ▯ ^{1} Yes	230	
Type of bedding used in calving areas.	▯ ^{1} straw ▯ ^{2} shavings/sawdust ▯ ^{3} other ▯ ^{4} none	231	
Frequency of adding bedding to calving areas:	▯ ^{1} each calving ▯ ^{2} every 2-4 calvings ▯ ^{3} every 5 or more calvings	232	
Frequency of removing surface manure from calving areas:	▯ ^{1} each calving ▯ ^{2} every 2-4 calvings ▯ ^{3} every 5 or more calvings	233	
Frequency of removing ALL manure from calving areas:	▯ ^{1} each calving ▯ ^{2} every 2-4 calvings ▯ ^{3} every 5 or more calvings	234	
If maternity pens are used, what is the usual number of cows in the pens at one time.	▯ ^{1} always just a single cow in pen ▯ ^{2} sometimes multiple cows in the pen	235	

	If multiple cows are in the calving pen at a time, what is the percentage of **calvings** when multiple cows present: [%]	236	
Note how often placentas are partially or fully eaten by:			
Dogs	[] 1 never [] 2 sometimes [] 3 often	237	
Cats	[] 1 never [] 2 sometimes [] 3 often	238	
Cows	[] 1 never [] 2 sometimes [] 3 often	239	
Wild animals	[] 1 never [] 2 sometimes [] 3 often	240	
Note how often aborted fetuses are partially or fully eaten by:			
Dogs	[] 1 never [] 2 sometimes [] 3 often	241	
Cats	[] 1 never [] 2 sometimes [] 3 often	242	
Wild animals	[] 1 never [] 2 sometimes [] 3 often	243	
Percentage of heifers/cows bred using artificial insemination:	[%]	244	
Do you use embryo transfer on your farm?	[] 0 No [] 1 Yes If YES, number of embryos purchased outside the herd and implanted in last 12 months: _____ If YES, number of embryos collected on farm and implanted in last 12 months: ___________________	245 246 247	

J. Feed, Water and Manure (Field #'s 248-268)

Do cows have access to a stream, lake	[] 0 No [] 1 Yes	248	

or pond?			
Which methods are used to dispose of manure on owned or rented land? (check all that apply)	[] 1 injection [] 2 spread with surface incorporation (e.g. plowing, disking) [] 3 spread without surface incorporation (e.g. plowing, disking)	249 250 251	
How many days do you wait after applying manure to a field before heifers are allowed to graze the field?	____________ days	252	
In the last 12 months, what percentage of the grains you fed to heifers was homegrown?	%	253	
In the last 12 months, what percentage of the roughages you fed to heifers was homegrown?	%	254	
In the last 12 months, what percentage of the grains you fed to cows was homegrown?	%	255	
In the last 12 months, what percentage of the roughages you fed to cows was homegrown?	%	256	
Origin of drinking water by season; fill in for each group of animals on your farm: **Choices:** **1 – Surface water (stream, pond or lake)** **2 – Well water** **3 – Municipal water**			
WINTER - Open heifers		257	
- Bred heifers		258	
- Adult cows		259	
- Bulls		260	
SUMMER - Open heifers		261	
- Bred heifers		262	
- Adult cows		263	
- Bulls		264	
How often is equipment that holds manure (e.g. bucket, spreader) also used to handle feed fed to heifers?	[] 1 regularly (at least weekly) [] 2 occasionally (less than once a week) [] 3 not a practice	265	
How often is equipment that holds manure (e.g. bucket, spreader) also used to handle feed fed to cows?	[] 1 regularly (at least weekly) [] 2 occasionally (less than once a	266	

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	week) [] [3] not a practice		
Do heifers less than 12 months of age share a feed bunk with adult cattle?	[] [0] No [] [1] Yes	267	
Do heifers less than 12 months of age share a water trough with adult cattle?	[] [0] No [] [1] Yes	268	

K. Prevalence of disease (Field #'s 269-287)

Please fill in the table based on the last 12 months. Give your best estimate (for disease monitoring, do not include animals tested as part of this research project)			
Johne's Disease Number of animals with the disease problem:		269	
Number of animals tested (blood or fecal test):		270	
Number of animals with positive test results:		271	
Neosporosis Number of animals with the disease problem:		272	
Number of animals tested (blood, milk or fecal test):		273	
Number of animals with positive test results:		274	
Retained afterbirth (> 24 hrs) Number of animals with the disease problem:		275	
Abortion less than 4 months Number of animals with the disease problem:		276	
Abortion 4 to 7 months Number of animals with the disease problem:		277	
Abortion greater than 7 months Number of animals with the disease problem:		278	
In the LAST 5 YEARS, how many cattle have been diagnosed with Johne's disease by:			
Fecal test: Number of animals tested		279	
Number of positives		280	

Blood test: Number of animals tested		281	
Number of positives		282	
Veterinary diagnosis Number of animals tested		283	
Number of positives		284	
In the LAST 12 MONTHS, how many of your CULLED COWS showed chronic diarrhea, normal appetite and weight loss that didn't respond to treatment?	____________	285	
What is done with apparently healthy cows that have a positive Johne's disease test?	[] 1 immediately shipped [] 2 slaughtered at end of lactation [] 3 kept on farm but handled differently [] 4 nothing	286	
Are there any other Johne's disease control procedures employed on the farm? Please describe.		287	

APPENDIX E

Survey of Risk Factors for Johne's Disease, Neospora, BVD and Leukosis in Alberta Dairy Herds (2002)

Part A:

Herd Code, DHI Number, and Location

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Herd Identifier Page:

Please return this page to Dr. H. Morgan Scott, College of Veterinary Medicine, Texas A&M University, in the pre-addressed, stamped envelope.

*****Note: This information is only used to link to databases reflecting soil type, major climatic, and landscape features. DHI production data are used in a national initiative to assess the potential production and economic impact of these diseases. These databases will never include herd owner or farm name.**

A. Location and identification

Item	**Enter Data Here**	**Field #**	**Entered**
Alberta Johne's Control Program Herd Identifier *(Accr, Vet #/Year/Herd #):*		001	
DHI Number (if available):		002	
County:		003	
Postal Code:		004	
Legal Subdivision (if applicable):		005	
Quarter:		006	
Section:		007	
Township:		008	
Range:		009	
Meridian (West of ...):		010	

Survey of Risk Factors

for Johne's Disease,

Neospora,

BVD

and Leukosis

in Alberta Dairy Herds (2002)

Part B:

DHI Data Access Consent Form

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DHI Data Access Consent Form Page:

Please return this page (4) and the next page (5) directly to Mike Slomp, Western Canadian DHI Services, Edmonton, in the pre-addressed, stamped envelope. This form will be maintained solely by DHI for their records.

If the herd is not enrolled in DHI, please ignore this section of the survey, but be sure to indicate "Not Applicable (N/A)" in Field # 002 of Section A in this package.

*****Note: DHI production data are used in a national initiative to assess the potential production and economic impact of these diseases. These databases will never include herd owner or farm name. DHI data will be provided to the researchers without any references to herd or herd owner name.**

Serological Survey for Neosporosis, Johne's Disease, Bovine Viral Diarrhea (BVD), and Enzootic Bovine Leukosis (EBL).

The producer named below hereby agrees to participate in Alberta Agriculture, Food, and Rural Development's (AAFRD) survey of the four diseases listed above, in accordance with the following terms and conditions:

1. The producer agrees that their veterinarian will come to the producer's farm in order to take blood and manure samples from a number of the producer's animals, selected at random by the veterinarian.

2. The samples will be used by AAFRD for the purpose of testing for the four diseases listed above. The samples will be submitted to a laboratory or laboratories chosen by AAFRD for the purpose of conducting laboratory tests and/or contributing to a national serum bank on a non-identifying basis. The latter may be used in the future to test, on an as-needed basis, for diseases known and unknown, on an anonymous basis.

3. The samples will become the property of AAFRD, to be retained or destroyed at the sole discretion of AAFRD.

4. AAFRD will bear the costs of veterinarian farm visits, sample collection and laboratory analysis, and will provide the producer with the results of the testing (via their herd veterinarian) for the four diseases listed above.

5. AAFRD will hold the test results and any other personal or herd information provided by the producer in connection with this disease survey in confidence, and will not disclose such results or information to anyone without the producer's consent, except as may be required by law or as may be necessary for the administration of this Agreement. Notwithstanding the foregoing, AAFRD may

publish the results of the survey, and may share any test results or information provided by the producer with third parties as part of the national Production Limiting Diseases Survey, provided it is in a form which does not identify the farm of origin. AAFRD will not have access to any information through the administration of this survey that would identify the herd owner by name. Any such information will be maintained solely by the herd veterinarian.

6. **The producer authorizes AAFRD to obtain Dairy Herd Improvement (DHI) information respecting the producer's operation from Western Canadian DHI Services, provided that such information will be subject to the provisions of section 5. Such information is to be provided to the researchers without any data fields referring to either herd or herd owner name, address, phone, or other personal identifier except for the DHI herd number.**

7. The producer acknowledges that this is a research project, designed to gather information about the extent of certain diseases in Alberta. Alberta does not guarantee to the producer or anyone else that the producer's herd is disease free.

8. The producer may withdraw from the survey at any time by notifying AAFRD in writing. AAFRD may discontinue the survey, or the producer's participation in the survey, at any time by notifying the producer in writing. In such event, no further samples or information would be collected regarding that producer pursuant to sections 1 and 6; however, AAFRD would still be able to use any samples and information collected prior to the withdrawal or discontinuance, in accordance with this Agreement.

Name ____

Address ____

Telephone _______________________ **DHI #**_________________

Signature ____

Date ____

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Survey of Risk Factors

for Johne's Disease,

Neospora,

BVD

and Leukosis

in Alberta Dairy Herds (2002)

Part C:

Herd Management Data

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Herd Management Data:

Please return this survey to Annette Visser, Food Safety Division, Alberta Agriculture, Food and Rural Development, in the pre-addressed, stamped envelope provided.

*****Note:** This information will be kept confidential and will never be linked directly to databases reflecting the owner or farm name. In addition, reports arising from this study will not refer to specific geographical locations that could be used to identify herds.

9. Identification (Field # 001; *Field #'s 002-010 are located in Part A of this survey***)**

Item	**Enter Data Here**	**Field #**	**Entered**
Alberta Johne's Control Program Herd <u>Identifier (Accr, Vet #/Year/Herd #):</u>		001	

10.Farm and Farmer (Field #'s 011–020)

Item	**Enter Data Here**	**Field #**	**Entered**
Age (in years) of the primary person making day-to-day management decisions on the farm:		011	
Province of the farm:	[] 1 Alberta [] 2 British Columbia [] 3 Manitoba [] 4 New Brunswick [] 5 Newfoundland [] 6 Nova Scotia [] 7 Ontario [] 8 Prince Edward Island [] 9 Quebec [] 10 Saskatchewan	012	
Area of the farm (in acres), both owned and rented, in the last summer:		013	
Area of pasture (grazing) (in acres), both owned and rented, in the last summer:		014	
Area of forage production (in acres), both owned and rented, in the last summer:		015	

Area of land used for other purposes (in acres), both owned and rented, in the last summer:		016	
Number of full-time employees, including family members, working directly in dairy production:		017	
Number of part-time employees, including family members, working directly in dairy production:		018	
Percentage of the total family income derived from dairy production:	___________ %	019	
Primary breed of your dairy cows (check one):	[] 1 Holstein [] 2 Jersey [] 3 Ayrshire [] 4 Brown Swiss [] 5 Guernsey [] 6 Shorthorn [] 7 Other (specify): ___________	020	

C. Herd population (Field #'s 021-052)

Item	**Enter Data Here** (use an estimate, if exact numbers are unavailable)	**Field #**	**Entered**
Number of animals present in herd on the day of blood sampling:			
• Pre-weaned calves		021	
• Open heifers		022	
• Bred heifers		023	
• Milk cows		024	
• Dry cows		025	
• Bulls		026	
Number of animals in herd that were sold for dairy purposes in the last 12 months:			
• Pre-weaned calves		027	
• Open heifers		028	
• Bred heifers		029	
• Milk cows		030	
• Dry cows		031	
• Bulls		032	

Number of animals in herd that were culled in the last 12 months:			
• Pre-weaned calves		033	
• Open heifers		034	
• Bred heifers		035	
• Milk cows		036	
• Dry cows		037	
• Bulls		038	
Number of animals in herd that died in the last 12 months:			
• Pre-weaned calves		039	
• Open heifers		040	
• Bred heifers		041	
• Milk cows		042	
• Dry cows		043	
• Bulls		044	
Number of animals purchased into the herd during the last 12 months:			
• Pre-weaned calves		045	
• Open heifers		046	
• Bred heifers		047	
• Milk cows		048	
• Dry cows		049	
• Bulls		050	
How many of the cows (milking and dry) were raised on your farm:		051	
How many of the cows (milking and dry) are registered:		052	

D. Housing (Field #'s 053-099)

Item	Enter Data Here	Field #	Entered
Pre-weaned calf housing. Please, check all that apply for each season:			
Barn type: Group pens	☐ Winter ☐ Summer	053 054	
Barn type: Individual pens	☐ Winter ☐ Summer	055 056	
Barn type: Hutches	☐ Winter ☐ Summer	057 058	

Winter housing. Please, check all that apply for each group of animals on your farm:			
Barn type: Tie-stall or stanchion	▯ Open heifers	059	
	▯ Bred heifers	060	
	▯ Milk cows	061	
	▯ Dry cows	062	
	▯ Bulls	063	
Barn type: Freestall	▯ Open heifers	064	
	▯ Bred heifers	065	
	▯ Milk cows	066	
	▯ Dry cows	067	
	▯ Bulls	068	
Barn type: Loose housing	▯ Open heifers	069	
	▯ Bred heifers	070	
	▯ Milk cows	071	
	▯ Dry cows	072	
	▯ Bulls	073	
Summer housing. Please, check all that apply for each group of animals on your farm:			
Totally confined (in barn) 24 hrs/day	▯ Open heifers	074	
	▯ Bred heifers	075	
	▯ Milk cows	076	
	▯ Dry cows	077	
	▯ Bulls	078	
Spent some time grazing and met some of their nutritional requirements from pasture	▯ Open heifers	079	
	▯ Bred heifers	080	
	▯ Milk cows	081	
	▯ Dry cows	082	
	▯ Bulls	083	
Given access to a concrete or dirt (non-turf) surface exercise yard (outdoor) some time each day	▯ Open heifers	084	
	▯ Bred heifers	085	
	▯ Milk cows	086	
	▯ Dry cows	087	
	▯ Bulls	088	

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Given access to a small field for the propose of exercise (not primarily for grazing)	☐ Open heifers	089	
	☐ Bred heifers	090	
	☐ Milk cows	091	
	☐ Dry cows	092	
	☐ Bulls	093	

If your heifers (open/bred) have access to pasture then answer the rest of the questions in this section (otherwise, please skip to Field #100)

How did you manage the pastures that were used by heifers in the most recent grazing season:	☐ ¹ continuous grazing (continuous access to the same pasture for the whole pasture season) ☐ ² controlled access grazing (rotational or strip grazing)	094	
Was any cattle manure mechanically spread on pastures that were used for grazing by heifers?	☐ ⁰ No ☐ ¹ Yes	095	
Were these pastures dragged or harrowed this year?	☐ ⁰ No ☐ ¹ Yes	096	
Were these pastures clipped this year?	☐ ⁰ No ☐ ¹ Yes	097	
Have you used lime on heifer pastures for reducing soil acidity during the past 5 years?	☐ ⁰ No ☐ ¹ Yes	098	
If YES to Field # 098, how often do the pasture fields receive lime If no, skip to Field # 100)?	☐ ¹ every year ☐ ² every 2-3 years ☐ ³ every 4-5 years ☐ ⁴ every 6-10 years ☐ ⁵ never	099	

E. Biosecurity – Purchase (Field #'s 100-113)

Item	**Enter Data Here**	**Field #**	**Entered**
Has the farm purchased any dairy animals in the last 5 years?	☐ ⁰ No ☐ ¹ Yes	100	
If yes to Field #100, percentage of dairy animals purchased directly from other producers:	_______ %	101	
If yes to Field #100, percentage of dairy animals purchased from private dealers:	_______ %	102	
If yes to Field #100, percentage of dairy animals purchased through an auction:	_______ %	103	

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When animals are transported to your farm, do you only use your own trailer?	[] [0] No [] [1] Yes	104	
If YES to Field # 104, do others use your trailer to transport cows?	[] [0] No [] [1] Yes	105	
Before bringing cattle (either beef or dairy) on your farm, the farm normally requires:			
• a negative test for BVDV from the animal(s)	[] [0] No [] [1] Yes	106	
• a negative test for Leukosis from animal(s)	[] [0] No [] [1] Yes	107	
• a negative test for Neosporosis from the animal(s)	[] [0] No [] [1] Yes	108	
• a negative test for Johne's disease from the animal(s)	[] [0] No [] [1] Yes	109	
• a negative HERD test for Johne's disease	[] [0] No [] [1] Yes	110	
• a negative HERD HISTORY for Johne's clinical disease	[] [0] No [] [1] Yes	111	
• a low somatic cell count from the animal(s)	[] [0] No [] [1] Yes	112	
• a low bulk tank somatic cell count for the herd(s)	[] [0] No [] [1] Yes	113	

F. Biosecurity – Contact (Field #'s 114-204)

Item	Enter Data Here	Field #	Entered
Please, fill in the table below to describe contact between your dairy animals and other animal types/species that are on your farm:			
Beef cattle	Numbers on farm: ___________	114	
	Direct animal contact with dairy cattle [] [0] No [] [1] Yes	115	
	Contact with feed for dairy animals [] [0] No [] [1] Yes	116	
	Contact with water for dairy animals [] [0] No [] [1] Yes	117	
Sheep	Numbers on farm: ___________	118	
	Direct animal contact with dairy cattle [] [0] No [] [1] Yes	119	
	Contact with feed for dairy animals [] [0] No [] [1] Yes	120	
	Contact with water for dairy animals [] [0] No [] [1] Yes	121	

Goats	Numbers on farm: ___________	122	
	Direct animal contact with dairy cattle ▯ ^{0} No ▯ ^{1} Yes	123	
	Contact with feed for dairy animals ▯ ^{0} No ▯ ^{1} Yes	124	
	Contact with water for dairy animals ▯ ^{0} No ▯ ^{1} Yes	125	
Chicken or poultry	Numbers on farm: ___________	126	
	Direct animal contact with dairy cattle ▯ ^{0} No ▯ ^{1} Yes	127	
	Contact with feed for dairy animals ▯ ^{0} No ▯ ^{1} Yes	128	
	Contact with water for dairy animals ▯ ^{0} No ▯ ^{1} Yes	129	
Horses and other equines	Numbers on farm: ___________	130	
	Direct animal contact with dairy cattle ▯ ^{0} No ▯ ^{1} Yes	131	
	Contact with feed for dairy animals ▯ ^{0} No ▯ ^{1} Yes	132	
	Contact with water for dairy animals ▯ ^{0} No ▯ ^{1} Yes	133	
Pigs	Numbers on farm: ___________	134	
	Direct animal contact with dairy cattle ▯ ^{0} No ▯ ^{1} Yes	135	
	Contact with feed for dairy animals ▯ ^{0} No ▯ ^{1} Yes	136	
	Contact with water for dairy animals ▯ ^{0} No ▯ ^{1} Yes	137	
Deer or elk	Numbers on farm: ___________	138	
	Direct animal contact with dairy cattle ▯ ^{0} No ▯ ^{1} Yes	139	
	Contact with feed for dairy animals ▯ ^{0} No ▯ ^{1} Yes	140	
	Contact with water for dairy animals ▯ ^{0} No ▯ ^{1} Yes	141	

Exotic ruminants (alpacas, llamas)	Numbers on farm: ___________	142	
	Direct animal contact with dairy cattle ▯ 0 No ▯ 1 Yes	143	
	Contact with feed for dairy animals ▯ 0 No ▯ 1 Yes	144	
	Contact with water for dairy animals ▯ 0 No ▯ 1 Yes	145	
Domestic rabbits	Numbers on farm: ___________	146	
	Direct animal contact with dairy cattle ▯ 0 No ▯ 1 Yes	147	
	Contact with feed for dairy animals ▯ 0 No ▯ 1 Yes	148	
	Contact with water for dairy animals ▯ 0 No ▯ 1 Yes	149	
In the past 5 years have any of your dairy cattle had contact with cattle (dairy or beef) from other herds through any of the following routes:			
• shared pasture	▯ 0 No ▯ 1 Yes	150	
• contract raising of young stock	▯ 0 No ▯ 1 Yes	151	
• fence line contact while on pasture	▯ 0 No ▯ 1 Yes	152	
• contact at fairs/exhibitions	▯ 0 No ▯ 1 Yes	153	
• lending cows or bulls	▯ 0 No ▯ 1 Yes	154	
• borrowing cows or bulls	▯ 0 No ▯ 1 Yes	155	
Please fill in the table below to describe any dogs and cats that live on your farm:			
Dogs			
• number of males (intact & neutered)		156	
• number of females (spayed)		157	
• number of females (intact)		158	
• number of litters in last 12 months		159	
• usual birthing location	▯ 1 – Dairy Barn ▯ 2 – Feed Storage areas ▯ 3 – House ▯ 4 – Other specify:_____________	160	
Cats			
• number of males (intact & neutered)		161	
• number of females (spayed)		162	

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• number of females (intact)		163	
• number of litters in last 12 months		164	
• usual birthing location	▯ 1 – Dairy Barn ▯ 2 – Feed Storage areas ▯ 3 – House ▯ 4 – Other specify:____________	165	
Compared with the previous years, **has the number of litters of dogs in the last 12 months:**	▯ [1] increased ▯ [2] decreased ▯ [3] continued to be the same	166	
Compared with the previous years, **has the number of litters of cats in the last 12 months:**	▯ [1] increased ▯ [2] decreased ▯ [3] continued to be the same	167	
If there are NO dogs on the farm, how long ago (years) did one reside on the farm?		168	
In the last 12 months how often have the following animals been seen on the farm?			
Coyotes/wolves	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	169	
Foxes	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	170	
Other dogs	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	171	
Stray cats	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	172	
Raccoons	▯ Never ▯ 1 – 3 times/year ▯ 4 – 6 times/year ▯ More than 6 times/year	173	

Skunk	[] Never [] 1 – 3 times/year [] 4 – 6 times/year [] More than 6 times/year	174	
Does the farm use a footbath for disinfecting visitor's boots before entering the cow and/or heifer barns? If YES for Field 175, how many times is disinfectant changed each month:	[] ⁰ No [] ¹ Yes _______________	175 176	
During the past 12 months, list the number of times the following categories of people **actually entered your barn** and whether you felt their vehicle/equipment was properly cleaned.			
Other dairy farmers	Number of times: ________ Vehicles or equipment cleaned [] 0 No [] 1 Yes	177 178	
Other beef farmers	Number of times: ________ Vehicles or equipment cleaned [] 0 No [] 1 Yes	179 180	
Cattle dealers	Number of times: ________ Vehicles or equipment cleaned [] 0 No [] 1 Yes	181 182	
AI technicians + sales reps	Number of times: ________ Vehicles or equipment cleaned [] 0 No [] 1 Yes	183 184	
Veterinarians	Number of times: ________ Vehicles or equipment cleaned [] 0 No [] 1 Yes	185 186	
Nutrition technicians/advisors + sales reps	Number of times: ________ Vehicles or equipment cleaned [] 0 No [] 1 Yes	187 188	
Udder health advisers	Number of times: ________ Vehicles or equipment cleaned [] 0 No [] 1 Yes	189 190	
Hoof trimmers	Number of times: ________ Vehicles or equipment cleaned [] 0 No [] 1 Yes	191 192	
Dead stock collection	Number of times: ________ Vehicles or equipment cleaned [] 0 No [] 1 Yes	193 194	

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Contract manure spreaders	Number of times: ________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	195 196	
DHI technicians	Number of times: ________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	197 198	
Others (specify)	Number of times: ________ Vehicles or equipment cleaned [] ⁰ No [] ¹ Yes	199 200	
During the past 12 months, did you borrow equipment from other farmers that could have manure contact (e.g. foot trimming chute, manure spreader, tractor, cattle trailer)?	[] ⁰ No [] ¹ Yes If YES, did you always disinfect it before using it? [] ⁰ No [] ¹ Yes	201 202	
During the past year, did you lend equipment to other farmers that could have manure contact?	[] ⁰ No [] ¹ Yes If YES, did you always disinfect it before using it again? [] ⁰ No [] ¹ Yes	203 204	

G. Biosecurity – Injection practices (Field #'s 205-216)

Do you use a new needle for every injection?	[] ⁰ No [] ¹ Yes If NOT, do you use a disinfected needle for every injection? [] ⁰ No [] ¹ Yes	205 206	
Do you use a new syringe for every injection?	[] ⁰ No [] ¹ Yes If NOT, do you use a disinfected syringe for every injection? [] ⁰ No [] ¹ Yes	207 208	
Usual method of dehorning:	[] ¹ Paste [] ² Cutting (gougers, wire, etc) [] ³ Burning (electric, butane, etc)	209	
If you use cutting equipment for dehorning, do you disinfect the equipment between animals?	[] ⁰ No [] ¹ Yes	210	
Are the instruments used for extra teat removal disinfected between animals?	[] ⁰ No [] ¹ Yes	211	
Do people who artificially inseminate cows/heifers on your farm change rectal gloves between animals?	[] ⁰ No [] ¹ Yes	212	
Do people who do other rectal exams (e.g. pregnancy check) change rectal gloves between animals?	[] ⁰ No [] ¹ Yes	213	

Estimate the level of rodent infestation on your farm?	[] 1 Low [] 2 Medium [] 3 High	214	
What is the primary method you use for insect control?	[] 1 Spray [] 2 Bait [] 3 Adhesive tape [] 4 Other [] 5 None	215	
Is the equipment used for hoof trimming disinfected between animals?	[] 0 No [] 1 Yes	216	

11.Biosecurity – Vaccination and medication practices (Field #'s 217-300)

Do you use coccidiostats/ionophores in calves/heifers/cows?	[] 0 No [] 1 Yes	217	
If YES to Field # 217, please fill in the table below (check all that apply), otherwise, please skip to Field #234			
Pre-weaned calves	[] Decoquinate in feed (Deccox)	218	
	[] Lasalocid in feed (Bovatec)	219	
	[] Monensin in feed (Rumensin)	220	
	[] Premix Monensin in bolus (Rumensin CRC)	221	
Heifers	[] Decoquinate in feed (Deccox)	222	
	[] Lasalocid in feed (Bovatec)	223	
	[] Monensin in feed (Rumensin)	224	
	[] Premix Monensin in bolus (Rumensin CRC)	225	
Dry cows	[] Decoquinate in feed (Deccox)	226	
	[] Lasalocid in feed (Bovatec)	227	
	[] Monensin in feed (Rumensin)	228	
	[] Premix Monensin in bolus (Rumensin CRC)	229	
Milk cows	[] Decoquinate in feed (Deccox)	230	
	[] Lasalocid in feed (Bovatec)	231	
	[] Monensin in feed (Rumensin)	232	
	[] Premix Monensin in bolus (Rumensin CRC)	233	
Did you vaccinate **any dairy animals** on your farm **for any disease** in the last 12 months?	[] 0 No [] 1 Yes	234	
Did you vaccinate **any dairy animals** on your farm **for BVD** in the last 12 months?	[] 0 No [] 1 Yes [] Don't know	235	

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If YES for BVD, in their 1st year of vaccination, are animals boostered 2-4 weeks after their 1st shot?	▯ 0 No ▯ 1 Yes	236	
If YES for boostered, are these 2 injections given after the animals are 6 months of age?	▯ 0 No ▯ 1 Yes	237	
If you vaccinated your animals with a BVD vaccine, indicate the major brand of vaccine you usually use in each group of animals in the table below (check all categories of animals vaccinated that apply per brand, ignoring fields for brands you do not use):			
Barvac (e.g., Barvac 3, Barvac 3-BRSV, Barvac 3-Somnugen, Barvac 3-somnugen-BRSV)	▯ Cows	238	
	▯ Heifers (+ 6 mo.)	239	
	▯ Calves	240	
Bovishield (e.g., Bovishield 3, Bovishield 4, Bovishield 4+L5)	▯ Cows	241	
	▯ Heifers (+ 6 mo.)	242	
	▯ Calves	243	
Breed Back (e.g., Breed Back 9/Somnugen)	▯ Cows	244	
	▯ Heifers (+ 6 mo.)	245	
	▯ Calves	246	
BRSV Vac (e.g., BRSV Vac 4, BRSV Vac 9)	▯ Cows	247	
	▯ Heifers (+ 6 mo.)	248	
	▯ Calves	249	
Cattlemaster (e.g., Cattlemaster BVD-K, Cattlemaster 3, Cattlemaster 4, Cattlemaster 4+L5, Cattlemaster 4+VL5)	▯ Cows	250	
	▯ Heifers (+ 6 mo.)	251	
	▯ Calves	252	
Express (e.g., Express 5, Express 5 Somnugen, Express 10, Express 10 Somnugen)	▯ Cows	253	
	▯ Heifers (+ 6 mo.)	254	
	▯ Calves	255	
Herd-vac (e.g., Herd-vac 3)	▯ Cows	256	
	▯ Heifers (+ 6 mo.)	257	
	▯ Calves	258	
Horizon (e.g., Horizon 1+vac3, Horizon 4, Horizon 9)	▯ Cows	259	
	▯ Heifers (+ 6 mo.)	260	
	▯ Calves	261	
IBR Plus (e.g., IBR Plus 4)	▯ Cows	262	
	▯ Heifers (+ 6 mo.)	263	
	▯ Calves	264	
Journey (e.g., Journey 4)	▯ Cows	265	
	▯ Heifers (+ 6 mo.)	266	
	▯ Calves	267	

Preg-guard (e.g., Preg-guard 9)	▯ Cows	268	
	▯ Heifers (+ 6 mo.)	269	
	▯ Calves	270	
Prism (e.g., Prism 4)	▯ Cows	271	
	▯ Heifers (+ 6 mo.)	272	
	▯ Calves	273	
Pyramid (e.g., Pyramid MVL3, Pyramid MVL4, Pyramid 4+ presponse, Pyramid 9)	▯ Cows	274	
	▯ Heifers (+ 6 mo.)	275	
	▯ Calves	276	
Reliant (e.g., Reliant 3, Reliant 4, Reliant 8)	▯ Cows	277	
	▯ Heifers (+ 6 mo.)	278	
	▯ Calves	279	
Respishield (e.g., Respishield 4, Respishield 4L5)	▯ Cows	280	
	▯ Heifers (+ 6 mo.)	281	
	▯ Calves	282	
Resvac (e.g., Resvac 3/Somnuvac, Resvac 4/Somnuvac)	▯ Cows	283	
	▯ Heifers (+ 6 mo.)	284	
	▯ Calves	285	
Sentry (e.g., Sentry 4, Sentry 4/Somnugen, Sentry 9, Sentry 9/Somnugen)	▯ Cows	286	
	▯ Heifers (+ 6 mo.)	287	
	▯ Calves	288	
Starvac (e.g., Starvac 3 plus, Starvac 4 plus)	▯ Cows	289	
	▯ Heifers (+ 6 mo.)	290	
	▯ Calves	291	
Triangle (e.g., Triangle 1, Triangle 3, Triangle 4, Triangle 4+HS, Triangle 8, Triangle 9 (OR ANY OF THESE WITH TYPE II BVD))	▯ Cows	292	
	▯ Heifers (+ 6 mo.)	293	
	▯ Calves	294	
Virabos (e.g., Virabos 3, Virabos 4, Virabos 4+H. Somnus, Virabos 4 + VL5)	▯ Cows	295	
	▯ Heifers (+ 6 mo.)	296	
	▯ Calves	297	
OTHER (Specify): ____________________	▯ Cows	298	
	▯ Heifers (+ 6 mo.)	299	
	▯ Calves	300	

12.Calving and calf management (Field #'s 301-342)

What is the usual amount of time after which your newborn heifer dairy calves are usually separated from their mothers (in hours)?	___________ Hours	301	
What percentage of heifer calves born on the farm remained with their dams for more than 24 hours?	___________ **%**	302	
What percentage of your newborn heifer dairy calves suckle their dam?	___________ **%**	303	
Are teats usually washed before the newborn heifer dairy calves nurse?	▯ [0] No ▯ [1] Yes	304	
Are teats usually washed before colostrum is collected?	▯ [0] No ▯ [1] Yes	305	
What percentage of your newborn heifer dairy calves receive colostrum as follows?	[1] only from their mother [%]	306	
	[2] pooled from all cows [%]	307	
	[3] pooled from BLV negative cows [%]	308	
	[4] pooled from Johne's disease negative cows [%]	309	
What percentage of your newborn heifer calves receive:	[1] fresh colostrum [%]	310	
	[2] frozen colostrum [%]	311	
	[3] fermented colostrum [%]	312	
	[4] heat treated colostrum [%]	313	
With regard to the primary source of milk given to calves, what percentage of milk fed to your heifer dairy calves is:	[1] milk replacer [%]	314	
	[2] pooled milk from all cows [%]	315	
	[3] pooled milk from negative for BLV cows [%]	316	
	[4] pooled from negative for Johne's disease cows [%]	317	
	[5] milk from mastitic (clinic or high SCC) cows or with antibiotic residue [%]	318	
Was the calving area used as a hospital area for sick cows in the last 12 months?	▯ [0] No ▯ [1] Yes	319	
Type of bedding used in calving areas.	▯ [1] straw ▯ [2] shavings/sawdust ▯ [3] other ▯ [4] none	320	
The following questions pertain to indoor calving, if calving occurs outdoor, please use code −999:			
Frequency of adding bedding to calving areas:	▯ [1] each calving ▯ [2] every 2-4 calvings ▯ [3] every 5 or more calvings	321	

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Frequency of removing surface manure from calving areas:	☐ 1 each calving ☐ 2 every 2-4 calvings ☐ 3 every 5 or more calvings	322	
Frequency of removing ALL manure from calving areas:	☐ 1 each calving ☐ 2 every 2-4 calvings ☐ 3 every 5 or more calvings	323	
After separation from the mother, but before weaning, do dairy heifer calves have physical contact (nose to nose) with other pre-weaned calves?	☐ 0 No ☐ 1 Yes	324	
After separation from the mother, but before weaning, do dairy heifer calves have physical contact (nose to nose) with heifers?	☐ 0 No ☐ 1 Yes	325	
After separation from the mother, but before weaning, do dairy heifer calves have physical contact (nose to nose) with adult cows?	☐ 0 No ☐ 1 Yes	326	
What percentages of pre-weaned dairy heifer calves are uniquely identified (e.g ear tags)?	[%]	327	
Primary location of calving in the summer:	☐ 1 freestall ☐ 2 tie-stall/stanchion ☐ 3 loose housing ☐ 4 maternity pen ☐ 5 pasture	328	
Primary location of calving in the winter:	☐ 1 freestall ☐ 2 tie-stall/stanchion ☐ 3 loose housing ☐ 4 maternity pen ☐ 5 pasture	329	
If maternity pens are used, what is the usual number of cows in the pens at one time.	☐ 1 always just a single cow in pen ☐ 2 sometimes multiple cows in the pen	330	
	If multiple cows are in the calving pen at a time, what is the percentage of **calvings** when multiple cows present: [%]	331	
Note how often placentas are partially or fully eaten by:			
Dogs	☐ 1 never ☐ 2 sometimes ☐ 3 often	332	

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Cats	[] 1 never [] 2 sometimes [] 3 often	333	
Cows	[] 1 never [] 2 sometimes [] 3 often	334	
Wild animals	[] 1 never [] 2 sometimes [] 3 often	335	
Note how often aborted fetuses are partially or fully eaten by:			
Dogs	[] 1 never [] 2 sometimes [] 3 often	336	
Cats	[] 1 never [] 2 sometimes [] 3 often	337	
Wild animals	[] 1 never [] 2 sometimes [] 3 often	338	
Percentage of cows bred using artificial insemination:	%	339	
Do you use embryo transfer on your farm?	[] 0 No [] 1 Yes If YES, number of embryos purchased outside the herd and implanted in last 12 months: _____ If YES, number of embryos collected on farm and implanted in last 12 months: ____________________	340 341 342	

J. Feed, Water and Manure (Field #'s 343-374)

Do you feed a TMR?	[] 0 No [] 1 Yes	343	
Do you feed greenchop?	[] 0 No [] 1 Yes	344	
How do you store your silage?	[] 1 tower silo [] 2 bunker silo [] 3 plastic bags/wrap [] 4 none	345	
Do dogs, cats or wildlife have access to stored grain?	[] 0 No [] 1 Yes	346	
Do you have an outdoor feed bunk or manger built for heifers?	[] 0 No [] 1 Yes	347	

Do you have an outdoor feed bunk or manger built for milk cows?	▯ 0 No ▯ 1 Yes	348	
Do you have an outdoor feed bunk or manger built for dry cows?	▯ 0 No ▯ 1 Yes	349	
Method of manure removal from milk cow barn.	▯ 1 gutter cleaner ▯ 2 alley scraper (mechanical or tractor) ▯ 3 slatted floor ▯ 4 removed (with bucket, bulldozer, etc.) as bedded pack ▯ 5 alley flushed with water ▯ 6 other (specify) ____________	350	
Method of storage of manure from milk cow barn:	▯ 1 pit (under barn) ▯ 2 open pile ▯ 3 earth lagoon ▯ 4 concrete lagoon ▯ 5 other (specify) ____________	351	
Distance (in feet) from milk cow manure storage area to nearest farm well?		352	
Distance (in feet) from milk cow manure storage area to stream, lake or pond?		353	
Do cows have access to a stream, lake or pond?	▯ 0 No ▯ 1 Yes	354	
Which methods are used to dispose of manure on owned or rented land? (check all that apply)	▯ 1 injection ▯ 2 spread with surface incorporation (e.g. plowing, disking) ▯ 3 spread without surface incorporation (e.g. plowing, disking)	355 356 357	
How many days do you wait after applying manure to a field before heifers are allowed to graze the field or get fed green chop from the field?	____________ days	358	
In the last 12 months, what percentage of the grains you fed to heifers was homegrown?	%	359	
In the last 12 months, what percentage of the roughages you fed to heifers was homegrown?	%	360	
In the last 12 months, what percentage of the grains you fed to cows was homegrown?	%	361	

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In the last 12 months, what percentage of the roughages you fed to cows was homegrown?	%	362	
Origin of drinking water by season; fill in for each group of animals on your farm: **Choices:** **1 – Surface water (stream, pond or lake)** **2 – Well water** **3 – Municipal water**			
WINTER - Open heifers		363	
- Bred heifers		364	
- Dry cows		365	
- Milking cows		366	
SUMMER - Open heifers		367	
- Bred heifers		368	
- Dry cows		369	
- Milking cows		370	
How often is equipment that holds manure (e.g. bucket, spreader) also used to handle feed fed to heifers?	[] 1 regularly (at least weekly) [] 2 occasionally (less than once a week) [] 3 not a practice	371	
How often is equipment that holds manure (e.g. bucket, spreader) also used to handle feed fed to cows?	[] 1 regularly (at least weekly) [] 2 occasionally (less than once a week) [] 3 not a practice	372	
Do heifers less than 12 months of age share a feed bunk with adult cattle?	[] 0 No [] 1 Yes	373	
Do heifers less than 12 months of age share a water trough with adult cattle?	[] 0 No [] 1 Yes	374	

K. Prevalence of disease (Field #'s 375-399)

Please fill in the table based on the last 12 months. Give your best estimate (for disease monitoring, do not include animals tested as part of this research project)			
BVD Number of animals with the disease problem:		375	
Number of animals tested (blood, milk or fecal test):		376	
Number of animals with positive test results:		377	
Leukosis Number of animals with the disease problem:		378	
Number of animals tested (blood, milk or fecal test):		379	
Number of animals with positive test results:		380	
Johne's Disease Number of animals with the disease problem:		381	
Number of animals tested (blood, milk or fecal test):		382	
Number of animals with positive test results:		383	
Neosporosis Number of animals with the disease problem:		384	
Number of animals tested (blood, milk or fecal test):		385	
Number of animals with positive test results:		386	
Retained afterbirth (> 24 hrs) Number of animals with the disease problem:		387	
Abortion less than 4 months Number of animals with the disease problem:		388	
Abortion 4 to 7 months Number of animals with the disease problem:		389	

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Abortion greater than 7 months Number of animals with the disease problem:		390	
In the LAST 5 YEARS, how many cattle have been diagnosed with Johne's disease by:			
Fecal test: Number of animals tested		391	
Number of positives		392	
Blood test: Number of animals tested		393	
Number of positives		394	
Veterinary diagnosis Number of animals tested		395	
Number of positives		396	
In the LAST 12 MONTHS, how many of your CULLED COWS showed chronic diarrhea, normal appetite and weight loss that didn't respond to treatment?	______________	397	
What is done with apparently healthy cows that have a positive Johne's disease test?	[] 1 immediately shipped [] 2 slaughtered at end of lactation [] 3 kept on farm but handled differently [] 4 nothing	398	
Are there any other Johne's disease control procedures employed on the farm? Please describe.		399	

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EDUCATION

2005 Bachelor of Science in Biology (Microbiology), The University of Texas at Austin

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2011 Doctorate of Veterinary Medicine, Oklahoma State University (expected)

PRESENTATIONS

A Comparison of Host-, Herd- and Environmental-Factors Associated with Seropositivity to *Neospora caninum* Infection Among Adult Dairy and Beef Cattle in Alberta. 2007 CAVEPM Conference. Edmonton, Canada. June 8, 2007.

LAB EXPERIENCE

▪ Experience with genotypic / phenotypic characterization of commensal bacteria isolated from bovine and swine fecal samples