PROGRAM OUTCOMES OF A VOLUNTARY JOHNE'S DISEASE CONTROL PROGRAM WITH A FOCUS ON ADHERENCE TO MANAGEMENT PLAN RECOMMENDATIONS AND VETERINARY COMMUNICATION SKILLS

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ABSTRACT

The Atlantic Johne's Disease Initiative (AJDI) was a voluntary Johne's disease (JD) control program with the goal of reducing the prevalence and impact of *Mycobacterium avium* subspecies *paratuberculosis* (MAP) infection in dairy cattle in Atlantic Canada. The aim of this research was to enhance JD prevention and management.

The AJDI was launched in 2011 as a 3-year risk assessment-based program. Four hundred and sixty-three of the region's 664 herds (70%) enrolled in the AJDI. Environmental cultures (EC) were conducted annually for AJDI herds. The overall herd apparent prevalence of MAP infection was 26.5%. The mean apparent within-herd prevalence of MAP infection for the 42 EC-positive herds which conducted cow-level testing was 5.5%.

Evaluation of factors associated with MAP infection revealed that herd risk of being EC-positive was significantly higher as the number of lactating cows, the number of bull calves, and the percentage of pneumonia in heifers increased. The herd risk was also significantly higher if the herd planned to purchase cattle in the next year and if the herd had more than 5% mortality in heifers that were one to four months of age. Furthermore, the herd risk was significantly higher in summer and was significantly higher if the herd was in Newfoundland and Labrador but significantly lower if the herd was in Nova Scotia.

In this study, 894 RAMPs were conducted by AJDI-certified veterinarians on 457 dairy herds. JD risk assessment indicated that on average, existing management practices

had moderate potential to spread MAP between and within farms. After one year of participation in the AJDI, JD risk assessment showed improvements in management practices that were statistically significant. However, producers' self-assessed adherence rating indicated fair adherence to first RAMPs and certified veterinarians' adherence rating indicated slight adherence. RAMP-specific satisfaction was high among 133 AJDI producers surveyed using a satisfaction questionnaire.

This study used theory of planned behaviour framework to design a questionnaire to elicit and measure behavioural intent of cow managers. A total of 68 cow managers completed in-person questionnaires from June 2012 to September 2013. On average, cow managers had moderate positive intent to utilize strategies to prevent and control JD. Strengthening either behavioural beliefs or control beliefs towards JD were associated with increased likelihood that cow managers intended to utilize strategies to prevent and control JD.

A communication training workshop was developed as an intervention to support the AJDI. Seventeen food animal production medicine (FAPM) veterinarians and three FAPM senior veterinary students participated in a pre-post intervention design. Study results showed that prior to training, communication skills of participants had significant limitations, including skill deficits in communication tasks associated with adherence to veterinary recommendations. Communication skills of participants significantly improved with the training provided. Rater training and experience was important to facilitate fair assessment of communication skills.

This research, through evaluation of the AJDI, exploration of factors potentially affecting adherence to JD control measures, and implementation of communication skills training and assessment for FAPM veterinarians, offered new information to assist in JD prevention and control.

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A huge thank you to technical staff and summer students in the AJDI, AVC, and MQM laboratory for your hard work in performing the many tasks required for MAP diagnostic testing (e.g., sample collection, processing, and testing, entering data, and relaying results to certified veterinarians) and completing questionnaires with producers. Special thanks to Norman Wiebe, Jane Saunders-Jewell, Theresa Andrews, Natasha Robinson, and Ricky Milton for going above and beyond for this work and for all the laughs and happiness you added.

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I thank Atlantic Canadian dairy producers for voluntarily participating in the AJDI and their involvement in Johne's disease control and this study. I commend the dedication of AJDI certified veterinarians for recruiting herds, communicating diagnostic MAP results, conducting RAMPs, advising on cow MAP testing strategies, and collecting samples for cow MAP diagnostics. I also thank DHI milk testers for their role in milk sample collection for cow MAP diagnostics. I thank the regional DHI database for providing cow production and management data for the study as well.

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I am very fortunate to be working in epidemiology in the PEI Chief Public Health Office. To have the opportunity to put my training and education to practice in my home province, to support and promote the health of Islanders, with a great team of dedicated professionals is an honor. Thank you to my colleagues for your understanding and encouragement to complete this thesis and attain my PhD.

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DEDICATION

This thesis is dedicated to my family. Your support and your love are my greatest source of strength. These I treasure above all else.

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LIST OF ABBREVIATIONS

ACA	available case analysis
AJDI	Atlantic Johne’s Disease Initiative
ALOBA	agenda-led outcome-based analysis
AR-self	producer self-assessment of adherence to management plan
AR-vet	veterinary assessment of adherence to management plan
AVC	Atlantic Veterinary College
aWHP	apparent within-herd prevalence
BLV	Bovine Leukosis Virus
BMP	best management practice
BVD	Bovine Viral Diarrhea
CCG	Calgary-Cambridge-Guides
CCIA	Canadian Cattle Identification Agency
CI	confidence interval
CSQ	client satisfaction questionnaire
DHI	dairy herd improvement
DVM	Doctor of Veterinary Medicine
EC	environmental culture
EC-6	set of 6 mixed manure samples collected for herd environmental culture
EC-neg	environmental culture test negative
EC-pos	environmental culture test positive
ELISA	enzyme-linked immunosorbent assay
$E\rho^2$	generalizability coefficient
FAPM	food animal production medicine

GEE	generalized estimating equation
HBM	Health Belief Model
JD	Johne’s disease
MAP	*Mycobacterium avium* subspecies *paratuberculosis*
MCAR	missing completely at random
MP	management plan
MQM	maritime quality milk
NB	New Brunswick
NL	Newfoundland and Labrador
NS	Nova Scotia
OR	odds ratio
OSCE	objective structured clinical exam
PBC	perceived behavioural control
PE	Prince Edward Island
PCR	polymerase chain reaction
PMRS	proportion of maximum risk score
qPCR	real-time polymerase chain reaction
RA	risk assessment
RAMP	risk assessment and management plan
RAMP1	first year risk assessment and management plan
RAMP2	second year risk assessment and management plan
RAMP3	third year risk assessment and management plan
ROC	receiver operating characteristic
SC	standardized client
SD	standard deviation

Se	sensitivity
Sp	specificity
TPB	theory of planned behaviour
UCVM	University of Calgary Faculty of Veterinary Medicine
USCA	United States Department of Agriculture
VSSQ	Veterinary Service Satisfaction Questionnaire
WHP	within-herd prevalence

CHAPTER 1: GENERAL INTRODUCTION

Johne's disease, also known as paratuberculosis, is an important production limiting disease in dairy cattle. It is an incurable, chronic, infectious enteritis caused by *Mycobacterium avium* subspecies *paratuberculosis* (MAP). In the clinical stage, Johne's disease causes progressive weight loss, severe watery diarrhea and diffuse edema (Whitlock and Buergelt, 1996). Johne's disease has global distribution (Barkema et al., 2010) and causes substantial economic losses worldwide (Chi et al., 2002; McKenna et al., 2006a; Barkema et al., 2010; Wolf et al., 2014a; Rasmussen et al. 2020). There are also alleged public health concerns related to possible association between MAP and Crohn's disease (Naser et al., 2004; Abubakar et al., 2008; Barkema et al., 2011; Chiodini et al., 2012; Atreya et al., 2014; Serraino et al., 2014). Johne's disease has been identified as one of the top disease priorities of Canadian dairy farmers, university researchers and practicing veterinarians (Bauman et al., 2016).

1.1 MAP infection in dairy cows

Johne's disease is caused by MAP, an aerobic, obligate intracellular, Gram-positive, acid fast rod from the *Mycobacterium avian* complex (He and DeBuck, 2010). Unlike other mycobacteria within this complex, MAP is fastidious and slow-growing, does not produce iron-chelating mycobactin, and has specific, detectable genes (Green et al., 1989; Clarke, 1997; Ellingson et al., 1998). Traditionally, infection with MAP was divided into four stages, depending upon the severity of clinical signs, the potential for shedding MAP into the environment and the ease of detection using diagnostic tests (Whitlock and Buergelt, 1996; Tiwari et al., 2006; Fecteau and Whitlock, 2010). The four stages were silent infection, subclinical infection, clinical infection and advanced clinical infection. Cattle in the first two stages had no clinical signs of infection, were difficult to detect with diagnostic tests but may shed infectious organisms into the farm environment (Tiwari et al., 2006). Subclinically infected animals were thought to be normal clinically but already had impaired productivity. Following a prolonged incubation period of 2 to 10 years, cattle in the next two stages had overt clinical signs and were usually detectable through demonstration of either the MAP organism or an immune response (Larsen et al., 1975; Tiwari et al., 2006; Fecteau and Whitlock, 2010). Most had high bacterial shedding (Larsen et al., 1975; Tiwari et al., 2006; Fecteau and Whitlock, 2010). Advanced clinical cases had severe clinical signs, including low body condition and chronic diarrhea (Tiwari et al., 2006). More recently, stages of Johne's disease were divided into three categories; infected, infectious and affected (Nielsen and Toft, 2008), based on detectable MAP shedding and obvious clinical impacts of infection. Cows infected with MAP without detectable shedding were considered to be in the infected category (Laurin, 2015). The infectious category combines cows that have detectable shedding that were traditionally considered to be in stages two or three; whereas, the affected category combines cows that have clinical signs of Johne's disease that were traditionally placed in stages three or four (Laurin, 2015).

1.2 Diagnosis of MAP infection in dairy cows

1.2.1 Animal-level diagnostic tests

Diagnosis of MAP infection can be a challenge, particularly among cows within the infected stage of infection (Nielsen and Toft, 2008). No single assay can detect all cows infected with MAP in a herd at a single point in time (Kalis, 2003). For every diagnosed affected cow within a herd, the potential number of undiagnosed infected cows could be as high as 25 and undiagnosed cows within stage two could be as high as eight (Whitlock, 1992; Fecteau and Whitlock, 2010). Ante-mortem diagnostic assays used to test for MAP infection are based on either detection of the MAP organism [culture and polymerase chain reaction (PCR)], or detection of an immune response (interferon gammon or immunoglobulin G (IgG)) (Lavers, 2013). Each diagnostic assay has advantages and limitations, such as cost, efficiency and the trade-off between test sensitivity (Se) and specificity (Sp) (Collins, 2011).

Fecal culture is considered the best practical test for detection of MAP infection and is considered the most sensitive and specific diagnostic assay (Whitlock et al., 2000; Bölske and Herthnek, 2010; Arango-Sabogal et al., 2018). However, fecal culture is the most costly test and takes the longest time to complete (12 to 16 weeks) (Tiwari et al., 2006; Lavers, 2013). More recently, real time PCR (qPCR) has improved detection of MAP bacteria compared to culture methods (Laurin et al., 2015). PCR is more time efficient than culture, taking less than 24 hours to 4 days to complete (Tiwari et al., 2006; Laurin, 2015).

The most time efficient diagnostic assay for MAP infection is ELISA for MAP IgG, taking only a few hours to process (Laurin, 2015). The ELISA is widely used and cost-effective but its Se is generally poor, depending on the reference standard, target condition, herd MAP prevalence, and ELISA kit and methodology (Nielsen et al., 2002; Collins et al., 2005; Lombard et al., 2006; Tiwari et al., 2006; Lavers, 2013; Laurin, 2015). Performance of all diagnostic assays improves as MAP infection becomes more advanced (Tiwari et al., 2006).

1.2.2 Herd-level diagnostic tests

Sampling and testing of individual animals can be used to identify herds infected with MAP but has limitations including cost, labour required, and variable test Se and Sp (Donat et al., 2016). To decrease costs of identifying MAP-positive herds, testing pools of individual fecal samples (pools of up to five cows) and environmental fecal samples have become common practices (van Schaik et al., 2003; Laurin, 2015). Environmental fecal sampling does not require sample collection from individual animals. Instead, samples are collected from areas containing mixed mature cow manure; such as, manure storage areas (pits, lagoons, manure piles, or manure spreaders), manure concentration areas (alleyways, gutters, adjacent to waterers or feeders) and maternity and sick cow pens (Lavers et al., 2013; Wolf et al., 2015b). Even in low-prevalence herds, environmental fecal culture is an acceptable tool for herd diagnosis of MAP infection (Lavers et al., 2013), which is important for control programs.

1.3 Prevalence of MAP infection in dairy cows

Johne's disease has become endemic in most of Europe and North America. The majority of prevalence estimates have used serum ELISA testing for antibodies against MAP. Due to low sensitivity, ELISA testing underestimates the true prevalence of MAP infection (McKenna et al., 2005). Estimates of apparent herd-level seroprevalence of MAP infection in dairy herds among Canadian provinces vary between 9.8% and 43.1% (herds with at least 2 seropositive cows) (Tiwari et al., 2006). In the province of Ontario, 26% of herds had at least 1 ELISA-positive cow (apparent herd-level seroprevalence) (Ontario Johne's Education and Management Assistance Program, 2014). In Atlantic Canada, cow-level seroprevalence has been reported at 2.6% and herd-level seroprevalence has been reported at 17% (herds with at least 2 seropositive cows) (VanLeeuwen et al., 2001). Using environmental fecal testing and an approximate Baysian computation model, true herd-level prevalence was estimated to be 68% for Alberta and 76% for Saskatchewan (Wolf et al., 2014a). In U.S. herds, environmental fecal testing isolated MAP on more than 68% of operations (apparent herd-level prevalence) (USDA-APHIS-VS-CEAH, 2008). Prevalence studies across Europe indicate that more than 50% of cattle herds appear to have MAP infection (Nielsen and Toft, 2009).

1.4 Transmission of MAP in dairy cows

Horizontal transmission of MAP can occur through MAP-containing colostrum and milk, fecal contamination of water and feed, or other environmental elements such as dust or soil (Sweeney, 1996; Eisenberg et al., 2010; Eisenberg et al., 2011). Contact of calves with adult feces (e.g., on the dam, in the maternity pen, and in foodstuffs) has been shown to be the most important risk factor in MAP transmission (McKenna et al., 2006a; Fecteau and Whitlock, 2010; Sweeney, 2011; Arango-Sabogal et al., 2017). Susceptibility to MAP infection decreases with age. Higher susceptibility has been reported for calves younger than one year of age (Windsor and Whittington, 2010; Mortier et al., 2013), with the highest risk for calves less than one month old (Sweeney, 2011). Infection studies have suggested that experimental infection with MAP is expected to be successful in 75% of calves less than 6 months of age, in 50% of calves 6 to 12 months of age, and in 20% of cattle over 12 months of age (Windsor and Whittington, 2010). The mechanisms of age-related susceptibility to MAP infection remain elusive (Mortier et al., 2015). Cows can also become infected as adults, especially those who are immune-supressed and/or exposed to a high burden of MAP (Chiodini et al., 1984). The earliest infection can begin *in utero* and is most likely with pregnant dams in a clinical infection stage of Johne's disease (Sweeney et al., 1992; Fecteau and Whitlock, 2010).

A number of studies have shown that MAP infection and progression to clinical Johne's disease is related to the rate and concentration of MAP exposure. More frequent exposure to MAP decreases the likelihood that a calf's immune system can mount an adequate response to resist infection (Begg and Whittington, 2008). Furthermore, exposures with higher concentrations of MAP result in shorter time periods between infection and observed immunological responses (O'Brien et al., 2006) and produce more severe tissue lesions (Begg and Whittington, 2008; Mortier et al., 2013). The exact frequency and concentration of MAP exposure required to produce Johne's disease have varied greatly in infection studies (Begg and Whittington, 2008), due to interaction of host susceptibility, agent factors and environmental factors (Ott et al., 1999; McKenna et al., 2006a).

1.5 Impacts of MAP infection on the dairy industry

It has been estimated that1% of gross milk revenue is lost in MAP-positive dairy herds annually (Rasmussen et al., 2020). This economic impact has been equated to losses of US$33 per cow per year on infected farms, with greater losses associated with regions that had higher farm-gate milk prices and production per cow (Rasmussen et al., 2020). In the Canadian Maritime Provinces, estimates of annual losses per cow range from US$28.48 in Prince Edward Island to US$53.16 in Newfoundland and Labrador (with 10% within-herd MAP prevalence and 50% herd MAP prevalence assumed) (Rasmussen et al., 2020). Projected to the Canadian dairy industry, economic impact has been estimated to be CA$15 million (approximately US$12 million) annually (McKenna et al., 2006a) and between US$17-28 million annually (Rasmussen et al., 2020). Costs for economic losses in the United States dairy industry have been estimated to be US$198 million annually (Rasmussen et al., 2020) and between US$200-250 million annually (Wells and Wagner, 2000). Economic losses that have been associated with Johne's disease have been largely attributed to decreased milk production and slaughter value, increased culling risk, mortality, treatment costs, and reproductive loss (Benedictus et al., 1987; Chi et al., 2002; McKenna et al., 2006a; Barkema et al., 2010; Wolf et al., 2014b; Rasmussen et al., 2020).

There are alleged public health concerns and research into possible associations between MAP and Crohn's disease in humans is ongoing. Perceived consumer risk and the prospect of a zoonotic link between Johne's disease and Crohn's disease can affect dairy consumer behaviour and could have devastating economic implications for the dairy industry (Barkema et al., 2011; Laurin, 2015). Continued research for improved efficacy in MAP diagnostic testing and Johne's disease prevention and control programs would be essential if these alleged concerns prove to be legitimate.

1.6 Johne's disease control in dairy cows

Infectious disease control typically requires a combination of key components, including: 1) reducing the reservoirs of infection; 2) reducing transmission between reservoirs and susceptible animals; 3) bolstering resistance to the infection; and 4) monitoring the infection status to determine the impact of control measures and need for further actions. Currently there is no cost-effective method to eliminate Johne's disease from a herd (de Lisle, 2010), but control measures can lower prevalence and impacts of infection. These control measures are briefly discussed here.

There is not an approved vaccine for Johne's disease in Canada and there is only one approved vaccine in the United States, which is available only on a limited basis (Patton, 2011; Fecteau and Whitlock, 2011). While the vaccine has been shown to decrease clinical disease and fecal shedding, it does not prevent infection and has the potential to cause a granuloma at the injection site and interfere with diagnostic testing for bovine tuberculosis (TB) and Johne's disease (Patton, 2011). Even with those limitations, cost-benefit analysis has estimated MAP vaccination to be economically attractive on farms in regions without a high frequency of TB testing (Groenendaal et al., 2015). Vaccination is considered a useful tool for controlling Johne's disease and research is ongoing to develop a quality vaccine (Shippy et al., 2017).

There is no definitive cure for MAP infection and no medications approved for treatment of MAP in food-producing animals (Fecteau and Whitlock, 2011). Several therapeutic agents are used as extra-label prescriptions to prolong lives of cattle that have significant economic, genetic, or sentimental value, but require lifelong therapy (Fecteau and Whitlock, 2011). Another potential aid that has been suggested for the prevention and control of MAP is monensin, an antimicrobial agent licenced for use in cattle (Fecteau and Whitlock, 2011). It has been shown that monensin can decrease the pathologic lesions associated with JD (Brumbaugh et al., 2000) but its impact on infection prevention in calves and MAP transmission requires further investigation (Hendrick et al., 2006).

Two fundamental approaches are used by effective Johne's disease control programs to reduce MAP transmission. First, the implementation of best management practices to target infection routes and decrease calf exposure to all manure, and second, the reduction of prevalent infections to limit the quantity of MAP shed into the environment (McKenna et al., 2006a; Whitlock, 2010; Arango-Sabogal et al., 2017). Given the diagnostic challenges within cattle infected with MAP, control plans focused on testing and culling of infected animals will have limited success due to many infected animals producing false negative test results. Therefore, prevention and management of Johne's disease is most commonly based on reducing MAP transmission (Pieper et al., 2015; Arango-Sabogal et al., 2017).

The risk assessment and management plan (RAMP) approach to control Johne's disease has been adopted around the world as the most appropriate method of controlling the disease (Kennedy, 2011; Geraghty et al., 2014; McAloon et al., 2015; Pieper et al., 2015). Many countries, including Canada, have implemented voluntary control and surveillance programs based on this approach. Most programs utilize veterinarian-administered risk assessment (RA) to identify high risk management practices to prompt changes in management behaviour. The focus is to close transmission routes within a farm and to reduce risk of Johne's disease introduction to a farm (Kennedy and Allworth, 2000; Groenendaal et al., 2003; Nielsen, 2007; Collins et al., 2010; Barker et al., 2012).

Through adoption of farm-specific management protocols, risk of MAP transmission within the herd, and eventually, the prevalence of infection within the herd and between herds will be decreased (Groenendaal et al., 2002; McKenna et al., 2006b; Kudahl et al., 2007; Wells et al., 2008; Collins et al., 2010; Sorge et al., 2011). In addition, improving management practices to minimize calf exposure to manure will also reduce the impacts of other fecal-orally transmitted diseases of cattle (*Escherichia coli, Campylobacter* spp., *Salmonella* spp., and *Cryptosporidium* spp.) (McKenna et al., 2006a). To decrease time required to reduce prevalence of MAP within a herd, testing and culling of infected animals may be beneficial in combination with the RAMP-based approach. This will depend on the reproductive management of the herd and price of replacement animals (Lu et al., 2010; Kudahl et al., 2011). In the absence of control measures (e.g., when no plan is in place or there is no adherence to a plan), MAP infection prevalence typically increases, spreading within and between herds (Robins et al., 2015; Barkema et al., 2018).

1.7 Adherence to best management practices for Johne's disease control

The ultimate success of a RAMP-based control program depends on implementation and adherence to best management practices to reduce the risk of MAP introduction and spread on-farm. Unfortunately, previous studies have indicated that management practice changes are not being made as recommended, particularly with increasing duration of participation in a control program (Wraight et al., 2000; Ridge et al., 2010; Sorge, U. et al., 2010; Wolf et al., 2015a). These studies propose that additional research will be required to better understand the reasons for the lack of adherence and that future efforts to improve adherence should likely include better veterinary communication, improved educational efforts to increase producer knowledge, and linking Johne's disease control programs to programs targeting other infectious diseases or pathogens (Wraight et al., 2000; Ridge et al., 2010; Sorge, U. et al., 2010; Wolf et al., 2015a).

Nonadherence has been recognized as a considerable challenge within veterinary medicine and has become an important area of research. In veterinary medicine, adherence implies the consistency and accuracy with which a client follows through with an agreed-upon treatment or management plan (Wayner and Heinke, 2006; Silverman et al., 2013). Adherence is similar to the concept of compliance, except health professionals are moving away from the use of that term. "Compliance" does not fit well with modern approaches to planning and shared decision making, as it invokes negative connotations about the client and their commitment to their animal's health (Talamonti et al., 2015; Adams and Kurtz, 2017).

A landmark veterinary medicine adherence study in 2003 estimated that the adherence to six basic health care recommendations was 64% overall (range of 21% to 87%), and proposed that incomplete or ineffective communication was a contributing factor to not achieving higher adherence (American Animal Hospital Association, 2003). Similar results were seen in a review of research on adherence in human medicine. It was reported that average patient adherence to treatment recommendations was 60%, but fell to 30% when treatment was complex or required lifestyle changes (Martin et al., 2005). There is extensive literature on adherence in human medicine from research over the past 40 years and over 200 different variables have been studied as possible predictors of patient nonadherence (Vermeire et al., 2001; Martin et al., 2005; Jin et al., 2008). Factors found to be associated with nonadherence can be broadly grouped into one of four categories, those related to: a) communication between the doctor and the patient (e.g., poor communication and lack of patient involvement in decision making); b) the treatment program (e.g., complexity of treatment and degree of behavioural change required); c) factors associated with the doctor (e.g., doctor's attitude and empathy toward the patient); and d) factors associated with the patient (e.g., patient attitudes, beliefs, and group norms) (Vermeire et al., 2001; Martin et al., 2005; Jin et al., 2008; Lamb et al., 2018).

Literature on potential factors that affect client adherence in veterinary medicine is growing. An instrument has been developed for assessing whether factors previously identified in human health studies were also associated with pet owner adherence (Lamb et al., 2018). In both companion animal and food animal veterinary medicine, evidence is clear that adherence is connected to good communication (Adams and Kurtz, 2017). Several food animal studies have investigated and described barriers to the adoption of disease control behaviours (Jansen, 2010; Lam et al., 2011; Lind et al., 2012; Alarcon et al., 2014; Vande Velde et al., 2015; Ritter et al., 2017), biosecurity practices more broadly (Gunn et al., 2008; Garforth et al., 2013; Brennan et al., 2016), and veterinary advice after herd health visits (Ritter et al., 2019). To date, three studies have investigated reasons for nonadherence with on-farm recommendations to control Johne's disease. One used quantitative research methods (Sorge et al., 2010) and two used qualitative research methods (Roche, 2014; Ritter et al., 2016). Sorge et al. (2010) reported that one of the main reasons for nonadherence was because respondents did not believe a change was necessary. Roche (2014) reported that there were both physical resource barriers (i.e., time, money, and infrastructure) and intrinsic barriers (i.e., perceived priority of Johne's disease, motivation, and perceived practicality of Johne's disease control recommendations) to adoption of on-farm management practices. The exploratory study by Ritter et al. (2016) distinguished farmers' perceptions according to their beliefs in the importance of Johne’s disease and in recommended prevention and control strategies for Johne’s disease, resulting in the categorization of farmers into one of four groups: proactivists, disillusionists, deniers, and unconcerned. Little is known about which factors may be affecting adherence to Johne’s disease best management practices among dairy producers in the Atlantic provinces of Canada; specifically, New Brunswick (NB), Newfoundland and Labrador (NL), Nova Scotia (NS), and Prince Edward Island (PE).

1.8 Knowledge, attitudes, beliefs and behaviour related to Johne’s disease control

Socio-psychological research has established relationships between a person’s knowledge, attitudes, beliefs and their behaviour. Understanding a producer’s mindset and the specific factors that combine to influence that mindset is crucial for motivating them to adopt or change management behaviour (Ritter et al., 2017). Ensuring that producers have sufficient knowledge about Johne’s disease, its prevention and control, and their herd’s Johne’s disease status is an additional important factor influencing management behaviour (Roche, 2014; Wolf et al., 2015a).

Studies have described attitudes and perceptions of dairy and beef farmers towards impacts of Johne’s disease, participation in Johne’s disease control programs, and RAMP-based Johne’s disease control strategies (Sorge et al., 2010; Benjamin et al., 2010; Hop et al., 2011; Nielsen, 2011; Bhattarai et al., 2013; Ritter et al., 2015; Roche et al., 2015; Ritter et al., 2016). However, research has shown that attitudes don’t always predict behaviour, at least not on their own, nor does knowledge. While knowledge is necessary for behaviour change, studies have shown that it is not sufficient to result in adoption or change of control practices (Kuiper et al., 2005; Jansen, 2010; Ellis-Iversen et al., 2010; Kristensen and Jakobsen, 2011; Lam et al., 2011; Garforth et al., 2013; Roche

2014; Wolf et al., 2015a; Ritter et al., 2017). Socio-psychological theories suggest that behaviour is influenced by a complex set of factors, including both internal (e.g., attitude, personality, perception, beliefs, knowledge, learning preferences, skills), and external (e.g., policy, economics, penalties, incentives, input from social referents) factors (Janz and Becker, 1984; Roche et al., 2015; Ritter et al., 2015).

Theoretical models have been developed to understand the determinants of behaviour and to describe and predict behaviour. Many of the socio-psychological studies carried out in food animal settings have used or adapted one or both of two frameworks widely utilized in research on human behaviour, the theory of planned behaviour (TPB) (Ajzen, 1991) and the health belief model (HBM) (Janz and Becker, 1984). The TPB is a general model of human behaviour that suggests a bridge between one’s attitudes and beliefs and their behaviour (Vande Velde et al., 2015). According to the TPB, when people have the time to plan how they are going to behave, the best predictor for that behaviour is one’s intention, which in turn is determined by three things: attitude, subjective norms, and perceived control (Ajzen, 2020). In general, with more favorable attitudes and subjective norms, and greater perceived control, a person’s intention to perform the behaviour in question should be stronger. Appropriately designed questionnaires can elicit and measure the three behavioural intention determinants, to aid in understanding behaviour and to design intervention strategies to help increase the uptake of recommendations (Francis et al., 2004).

The HBM was specifically developed to understand health-related behaviour and to predict behaviour change in health-related areas (Vande Velde et al., 2015). According to HBM, the tendency to adopt or change health behaviour(s) is influenced by four dimensions: perceived susceptibility, perceived severity, perceived benefits, and perceived barriers (Janz and Becker, 1984). In a study that applied HBM to therapies for multiple sclerosis in people, adherence was consistently predicted by only one of four dimensions, perceived benefits (Turner et al., 2007). It was suggested that patients who had unrealistically positive expectations regarding treatment outcomes may have discontinued treatment because of frustration and disappointment, which was not captured by all the HBM constructs (Klauer and Zettl, 2008). This nonadherence could also be the case if HBM assessment was applied to RAMP-based control strategies for Johne's disease; dairy producers may discontinue the management changes if they became frustrated or disappointed at the length of time required to reduce the prevalence of Johne's disease on-farm. In that scenario, much of the HBM framework may not reliably predict adherence to the recommended best management practices; instead, use of items from the perceived benefits dimension may uniquely predict adherence across points in time.

A recent study in the Canadian province of Ontario (Roche et al., 2015) used questionnaires that included TPB assessment to evaluate dairy producers' knowledge, attitudes, and behaviour with regard to Johne's disease control. Roche et al. (2015) reported that dairy producers exhibited a moderate knowledge score, held strong positive attitudes toward the control of Johne's disease, felt a moderate amount of social pressure to make on-farm changes, but questioned their ability to effectively control Johne's disease on their farm. For future studies, it was suggested that TPB assessment within a Johne's disease control program should be done on different dairy populations and aim to address as many pertinent factors as possible in TPB instruments (Roche et al., 2015).

Interestingly, the mechanisms behind the HBM have similarities with the behavioural determinants of the TPB, and studies in food animal settings have developed frameworks that combined items from both the TPB and the HBM to better understand and predict behaviour (Garforth et al., 2013; Vande Velde et al., 2015).

1.9 Client satisfaction related to Johne's disease control

Satisfaction is an important outcome in veterinary medicine and there is burgeoning research in this area (Woodcock and Barleggs, 2005; Coe et al., 2010; Shaw et al., 2012; Shaw et al., 2016). Measuring satisfaction in human and veterinary medicine is important for several reasons: to evaluate the quality of health care provided (Haya et al., 1993; Sitzia and Wood, 1997; Jackson et al., 2001; Bragadóttir and Reed, 2002; Loomans et al., 2009), to isolate problem areas in service delivery and generate ideas for solutions (Locker and Dunt, 1978; Jackson et al., 2001; Wassink et al., 2010; Derks et al., 2012; Chand et al., 2014), and to improve adherence with treatment and management recommendations and changes (Larsen and Rootman, 1976; Bartlett et al., 1984; Bell et al., 2002; Wassink et al., 2010; Kanji et al., 2012; Ritter et al., 2019).

To measure client satisfaction in companion animal practice, two questionnaires have been developed and validated, the Veterinary Service Satisfaction Questionnaire (VSSQ) (Woodcock and Barleggs, 2005) and the Client Satisfaction Questionnaire (CSQ) (Coe et al., 2010). The VSSQ is intended to assess clients' overall satisfaction with small animal veterinary services and the CSQ is to measure appointment-specific client satisfaction with veterinary care in companion animal practice (Woodcock and Barleggs, 2005; Coe et al., 2010). Coe et al. (2010) demonstrated that the CSQ could be used as an outcome measure of appointment-specific client satisfaction in companion-animal practice however, continued evaluation of the CSQ in different contexts was recommended.

A recent study applied a slightly modified CSQ to dairy farmers [e.g., by exchanging the word "pet(s)" for "animals(s)] to elicit their satisfaction with veterinary advisors after herd health and production management farm visits (Ritter et al., 2019). Overall, Ritter et al. (2019) reported that farmers were satisfied with their veterinarian's communication and their satisfaction was positively associated with their preparedness to adopt veterinary advice. Client satisfaction has also been linked to adherence with treatment and management plans in a number of veterinary studies (Wassink et al., 2010; Kanji et al., 2012; Ritter et al., 2019). Formal research into client satisfaction in food animal production medicine is limited, particularly for how it relates to adherence to infectious disease control programs. Therefore, additional research into producer satisfaction in the context of a Johne's disease control program is warranted.

1.10 Communication related to Johne's disease control

Skilled communication is a requisite to the practice of excellent and compassionate veterinary medicine (Adams and Kurtz, 2017). Evidence from studies conducted over the past 40 years in human medicine clearly indicates that effective communication between physicians and patients has a positive impact on patient health, increases adherence to medical recommendations, and improves patient and physician satisfaction (Silverman et al., 2013). Research on, and teaching of, communication as an essential clinical skill in veterinary medicine is a growing discipline (Kurtz, 2006; Silverman et al., 2013; Adams and Kurtz, 2017).

Today, communication is considered a core clinical competency by the American Veterinary Medical Association Council on Education (American Veterinary Medical Association, 2020) as well as the Association of American Veterinary Medical Colleges (Association of American Veterinary Medical Colleges, 2018) and the World Organization for Animal Health (OIE) (World Organization for Animal Health, 2012). There is also a growing body of evidence in companion and food animal veterinary medicine literature to demonstrate that skilled communication is related to more efficient and satisfying consultations for both clients and veterinarians and improved outcomes of care, specifically satisfaction and adherence (American Animal Hospital Association, 2009; Coe et al., 2010; Kanji et al., 2012; Shaw et al., 2012; Adams and Kurtz, 2017; Ritter et al., 2019).

Unfortunately, various studies have suggested that communication deficiencies are evident during veterinary school (Shaw et al., 2004) and that following graduation, learning communication skills "on the job" is not sufficient to fully master the necessary skills (Humphries, 2002; Mullan and Kothe, 2010). Studies in food animal veterinary medicine have confirmed that communication skills of practitioners are suboptimal (Jansen, 2010; Cipolla and Zecconi, 2015; Ritter et al., 2018; Ritter et al., 2019). Fortunately, training in communication has led to skill acquisition and increased mastery of communication in veterinary students and companion animal practitioners (American Animal Hospital Association, 2009; Shaw et al., 2010; Adams and Kurtz, 2017). Veterinary schools around the globe are incorporating communication skills education into their curriculum by training faculty and developing programs that use lectures, small-group interactive sessions, video feedback, assigned readings, role-play, simulated clients and Web-based programs (Gray et al., 2006; Mills et al., 2006; Radford et al., 2006; Shaw and Ihle, 2006; Latham and Morris, 2007; Chun et al., 2009; Hargie et al., 2010; Artemiou et al., 2013; Shaw, 2019). However, little research has been conducted on methods to improve the communication skills of practicing food animal production medicine veterinarians.

Recently, an article described a few communication steps to facilitate veterinary-client consultations in bovine medicine, both at the individual animal and population level (Petrovski and McArthur, 2015). The recommendations by Petrovski and McArthur (2015) were based on the modified Calgary-Cambridge-Guides (CCG), a comprehensive set of communication skills initially developed for human medicine (Silverman et al., 2013) and then modified for veterinary medicine (Adams and Kurtz, 2006; Radford et al., 2006; Adams and Kurtz, 2017). The CCG comprises 73 highly evidence-based communication process skills that are applicable to routine and complex cases (Adams and Kurtz, 2012). Teaching instruments have also been developed to enhance teaching and learning of CCG skills through training in veterinary practice settings, including food animal medicine practice settings (Adams and Kurtz, 2012). Adoption of the CCG for use in bovine medicine along with CCG teaching instruments will be valuable resources for food animal medicine practitioners to improve their communication skills.

1.11 Limitations in research

Prevention and control of Johne's disease is one of the top health priorities in the Canadian dairy industry, and Johne's disease control programs are being implemented in Canada and around the world. As part of the effort in Canada, a voluntary Johne's disease surveillance and control program based on herd MAP categorization and veterinary-administered RAMPs has been implemented in the Atlantic provinces; specifically, NB, NL, NS, and PE. Research is required to estimate the burden of Johne's disease in Atlantic Canada and to evaluate the program outcomes, including herd participation, assessment of Johne's disease risk and management plan recommendations on-farm, and adherence to the recommended best management practices.

Due to the lack of adherence reported in other voluntary RAMP-based control programs, additional research is required to better understand nonadherence to Johne's disease control measures in Canada, and to further investigate factors that have been associated with nonadherence, particularly in different dairy populations. Detailed information about factors that could be relevant to the implementation and adherence of Johne's disease control measures in Atlantic Canada is required to understand and predict behaviour of dairy producers on-farm, to address adherence barriers, and to optimise efforts and investment within the Atlantic Johne's Disease Initiative (AJDI).

1.12 Thesis objectives

The aim of this research was to enhance Johne's disease prevention and management through program outcome evaluation, increased understanding of adherence to management plan recommendations, investigation into dairy producer intention toward best management strategy implementation, measurement of producer satisfaction with veterinary-administered RAMP and the AJDI, and assessment of communication effectiveness and training in the AJDI. Specific objectives, by the chapter in which they are most fully addressed, are:

- Chapter 2: The Atlantic Johne's Disease Initiative – Program Description, Prevalence and Impacts on Productivity

    - estimate herd and within-herd apparent prevalence of Johne's disease in the AJDI;
    - analyse herd demographic, production, and management data in relation to herd Johne's disease categorization in the AJDI;
- Chapter 3: Risk Assessment and Adherence to Management Plan Recommendations on Dairy Farms Participating in a Voluntary Johne's Disease Control Program
    - describe risk assessments and management plan recommendations in the AJDI;
    - evaluate adherence to management plan recommendations in the AJDI;
    - assess perceptions of dairy producers in the AJDI about recommended management practices that had less than ideal adherence;
- Chapter 4: Johne's Disease Knowledge, Attitudes, Beliefs and Behaviours of Dairy Cow Herd Managers Participating in a Voluntary Johne's Disease Control Program
    - explore the intentions of cow managers towards utilizing and implementing strategies to prevent and control Johne's disease on farm;
    - measure knowledge of cow managers in the AJDI about Johne's disease;
- Chapter 5: Dairy Producer Satisfaction with the Veterinary-Administered Risk Assessment and Management Plan in a Voluntary Johne's Disease Control Program
    - evaluate dairy producer satisfaction with veterinary-administered RAMPs and the AJDI;
    - measure knowledge translation from veterinarians to dairy producers during RAMPs;

- Chapter 6: Communication Skills Training and Assessment of Food Animal Production Medicine Veterinarians as a Component of a Voluntary Johne's Disease Control Program
    - assess and teach communication skills to food animal production medicine veterinarians in the AJDI.

The chapters in this thesis were structured to be stand-alone and paper-based. This means there is inherently some repetition between chapters.

1.13 References

Abubakar, I., D. Myhill, S. H. Aliyu and P. R. Hunter. 2008. Detection of *Mycobacterium avium* subspecies *paratuberculosis* from patients with Crohn's disease using nucleic acid-based techniques: A systematic review and meta-analysis. Inflamm. Bowel Dis. 14(3):401-410.

Adams, C. L. and S. Kurtz. 2012. Coaching and feedback: Enhancing communication teaching and learning in veterinary practice settings. J. Vet. Med. Educ. 39:217-228.

Adams, C. L. and S. M. Kurtz. 2006. Building on existing models from human medical education to develop a communication curriculum in veterinary medicine. J. Vet. Med. Educ. 33:28-37.

Adams, C. L. and S. M. Kurtz. 2017. Skills for Communicating in Veterinary Medicine. Dewpoint Publishing, Parsippany, NJ, USA.

Ajzen, I. 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50:179-211.

Ajzen, I. 2020. The theory of planned behavior: Frequently asked questions. Hum. Behav. Emerg. Technol. 2:314-324.

Alarcon, P., B. Wieland, A. L. P. Mateus and C. Dewberry. 2014. Pig farmers' perceptions, attitudes, influences and management of information in the decision-making process for disease control. Prev. Vet. Med. 116:223-242.

American Animal Hospital Association. 2009. Compliance: Taking Quality Care to the Next Level: A Report of the 2009 AAHA Compliance Follow-Up Study. AAHA Press, Lakewood, Colorado, USA.

American Animal Hospital Association. 2003. The Path to High-Quality Care: Practical Tips for Improving Compliance. AAHA Press, Lakewood, Colorado, USA.

American Veterinary Medical Association. 2020. Council on Education (COE) Accreditation Policies and Procedures: Requirements. Accessed March 13, 2021. https://www-avma-org.proxy.library.upei.ca/education/accreditation/colleges/coe-accreditation-policies-and-procedures-requirements.

Arango-Sabogal, J., J. Pare, O. Labrecque, G. Cote, J. P. Roy, S. Buczinski, V. Wellemans and G. Fecteau. 2017. Incidence of fecal excretion of *Mycobacterium avium* subspecies *paratuberculosis* in dairy cows before and after the enrolment in the Quebec voluntary program. Prev. Vet. Med. 148:94-105

Arango-Sabogal, J., G. Fecteau, J. Pare, J. Roy, O. Labrecque, G. Cote, V. Wellemans, I. Schiller, N. Dendukuri and S. Buczinski. 2018. Estimating diagnostic accuracy of fecal culture in liquid media for the detection of *Mycobacterium avium* subspecies *paratuberculosis* infections in Quebec dairy cows: A latent class model. Prev. Vet. Med. 160:26-34.

Artemiou, E., C. L. Adams, A. Vallevand, C. Violato and K. G. Hecker. 2013. Measuring the effectiveness of small-group and web-based training methods in teaching clinical communication: A case comparison study. J. Vet. Med. Educ. 40:242-251.

Association of American Veterinary Medical Colleges. 2018. Competency-Based Veterinary Education: Part 1 - CBVE framework. Association of American Veterinary Medical Colleges, Washington, DC, USA.

Atreya, R., M. Bülte, G. Gerlach, R. Goethe, M. W. Hornef, H. Köhler, J. Meens, P. Möbius, E. Roeb and S. Weiss. 2014. Mini review: Facts, myths and hypotheses on the zoonotic nature of *Mycobacterium avium* subspecies *paratuberculosis*. Int. J. Med. Microbiol. 304:858-867.

Barkema, H. W., S. Hendrick, J. M. Buck, S. Ghosh, G. G. Kaplan and K. P. Rioux. 2011. Crohn's disease in humans and Johne's disease in cattle - linked diseases?. Zoonotic Pathogens in the Food Chain. D. O. Krause and S. Hendrick eds. CAB International, Cambridge, MA, USA.

Barkema, H. W., J. W. Hesselink, S. L. B. McKenna, G. Benedictus and H. Groenendaal. 2010. Global prevalence and economics of infection with *Mycobacterium avium* subspecies *paratuberculosis* in ruminants. Paratuberculosis: Organism, Disease, Control. M. Behr and D. M. Collins eds. CAB International, Boston, MA, USA.

Barkema, H. W., K. Orsel, S. S. Nielsen, A. P. Koets, V. P. M. G. Rutten, J. P. Bannantine, G. P. Keefe, D. F. Kelton, S. J. Wells, R. J. Whittington, C. G. Mackintosh, E. J. Manning, M. F. Weber, C. Heuer, T. L. Forde, C. Ritter, S. Roche, C. S. Corbett, R. Wolf and P. J. Griebel. 2018. Knowledge gaps that hamper prevention and control of *Mycobacterium avium* subspecies *paratuberculosis* infection. Transbound. Emerg. Dis. 65:125-148.

Barker, R. A., H. W. Barkema, G. Fecteau, G. K. Keefe and D. F. Kelton. 2012. Johne's Disease Control in Canada - Coordinated Nationally - Delivered Provincially. Proc. 3rd ParaTB Forum, Sydney, Australia. 45-51.

Bartlett, E. E., M. Grayson, R. Barker, D. M. Levine, A. Golden and S. Libber. 1984. The effects of physician communications skills on patient satisfaction; recall, and adherence. J. Chronic Dis. 37:755-764.

Bauman, C. A., H. W. Barkema, J. Dubuc, G. P. Keefe and D. F. Kelton. 2016. Identifying management and disease priorities of Canadian dairy industry stakeholders. J. Dairy Sci. 99:10194-10203.

Begg, D. J. and R. J. Whittington. 2008. Experimental animal infection models for Johne's disease, an infectious enteropathy caused by *Mycobacterium avium* subspecies *paratuberculosis*. Vet. J. 176:129-145.

Bell, R. A., R. L. Kravitz, D. Thom, E. Krupat and R. Azari. 2002. Unmet expectations for care and the patient-physician relationship. J. Gen. Intern. Med. 17(11):817-24.

Benedictus, G., A. A. Dijkhuizen and J. Stelwagen. 1987. Economic losses due to paratuberculosis in dairy cattle. Vet. Rec. 121:142-146.

Benjamin, L. A., G. T. Fosgate, M. P. Ward, A. J. Roussel, R. A. Feagin and A. L. Schwartz. 2010. Attitudes towards biosecurity practices relevant to Johne's disease control on beef cattle farms. Prev. Vet. Med. 94:222-230.

Bhattarai, B., G. T. Fosgate, J. B. Osterstock, C. P. Fossler, S. C. Park and A. J. Roussel. 2013. Perceptions of veterinarians in bovine practice and producers with beef cow-calf operations enrolled in the US voluntary bovine Johne's disease control program concerning economic losses associated with Johne's disease. Prev. Vet. Med. 112:330-337.

Bölske, G. and D. Herthnek. 2010. Diagnosis of paratuberculosis by PCR. Paratuberculosis: Organism, Disease, Control. M. Behr and D. M. Collins eds. CAB International, Boston, MA, USA.

Bragadóttir, H. and D. Reed. 2002. Psychometric instrument evaluation: The pediatric family satisfaction questionnaire. Pediatr. Nurs. 28:475-484.

Brennan, M. L., N. Wright, W. Wapenaar, S. Jarratt, P. Hobson-West, I. F. Richens, J. Kaler, H. Buchanan, J. N. Huxley and H. M. O'Connor. 2016. Exploring attitudes and beliefs towards implementing cattle disease prevention and control measures: A qualitative study with dairy farmers in Great Britain. Animals (Basel). 6:61-61.

Brumbaugh, G. W., J. F. Edwards, A. J. Roussel, Jr and T. D. Thomson. 2000. Effect of monensin sodium on histological lesions of naturally occurring bovine paratuberculosis. J. Comp. Path. 123:22-28.

Chand, S., B. S. Meena and H. C. Verma. 2014. A study on farmers' satisfaction with delivery of veterinary services. Indian J. Anim. Res. 48:67-70.

Chi, J., J. A. VanLeeuwen, A. Weersink and G. P. Keefe. 2002. Direct production losses and treatment costs from bovine viral diarrhoea virus, bovine leukosis virus, *Mycobacterium avium* subspecies *paratuberculosis*, and Neospora caninum. Prev. Vet. Med. 55:137-153.

Chiodini, R. J., H. J. Kruiningen and R. S. Merkal. 1984. Ruminant paratuberculosis (Johne's disease): The current status and future prospects. Cornell Vet. 74:218-262.

Chiodini, R. J., W. M. Chamberlin, J. Sarosiek and R. W. McCallum. 2012. Crohn's disease and the mycobacterioses: A quarter century later. causation or simple association?. Crit. Rev. Microbiol. 38:52-93.

Chun, R., S. Schaefer, C. C. Lotta, J. A. Banning and S. E. Skochelak. 2009. Didactic and experiential training to teach communication skills: The University of Wisconsin-Madison School of Veterinary Medicine collaborative experience. J. Vet. Med. Educ. 36:196-201.

Cipolla, M. and A. Zecconi. 2015. Short communication: Study on veterinarian communication skills preferred and perceived by dairy farmers. Res. Vet. Sci. 99:60-62.

Clarke, C. J. 1997. The pathology and pathogenesis of paratuberculosis in ruminants and other species. J. Comp. Pathol. 116(3):217-261.

Click, R. E. 2011. A 60-day probiotic protocol with *Dietzia* subspecies C79793-74 prevents development of Johne's disease parameters after in utero and/or neonatal MAP infection. Virulence. 2(4):337-347.

Coe, J. B., C. L. Adams, K. Eva, S. Desmarais and B. N. Bonnett. 2010. Development and validation of an instrument for measuring appointment-specific client satisfaction in companion-animal practice. Prev. Vet. Med. 93:201-210.

Collins, M. T., V. Eggleston and E. J. B. Manning. 2010. Successful control of Johne's disease in nine dairy herds: Results of a six-year field trial. J. Dairy Sci. 93:1638-1643.

Collins, M. T., S. J. Wells, K. R. Petrini, J. E. Collins, R. D. Schultz and R. H. Whitlock. 2005. Evaluation of five antibody detection tests for diagnosis of bovine paratuberculosis. Clin. Diagn. Lab. Immunol. 12(6):685-692.

Collins, M. T. 2011. Diagnosis of paratuberculosis. Vet. Clin. North Am. Food Anim. Pract. 27:581-591.

de Lisle, G. W. 2010. Ruminant aspects of paratuberculosis vaccination. Paratuberculosis: Organism, Disease, Control. M. Behr and D. M. Collins eds. CAB International, Boston, MA, USA.

Derks, M., d. V. van, T. van Werven, W. D. J. Kremer and H. Hogeveen. 2012. The perception of veterinary herd health management by Dutch dairy farmers and its current status in the Netherlands: A survey. Prev. Vet. Med. 104:207-215.

Donat, K., N. Hahn, T. Eisenberg, K. Schlez, H. Köhler, W. Wolter, M. Rohde, R. Pützschel, U. Rösler, K. Failing and P. M. Zschöck. 2016. Within-herd prevalence thresholds for the detection of *Mycobacterium avium* subspecies *paratuberculosis*-positive dairy herds using boot swabs and liquid manure samples. Epidemiol. Infect. 144:413-424.

Eisenberg, S. W. F., M. Nielen, W. Santema, D. J. Houwers, D. Heederik and A. P. Koets. 2010. Detection of spatial and temporal spread of *Mycobacterium avium* subspecies *paratuberculosis* in the environment of a cattle farm through bio-aerosols. Vet. Microbiol. 143:284-292.

Eisenberg, S. W. F., A. P. Koets, M. Nielen, D. Heederik, R. Mortier, J. De Buck and K. Orsel. 2011. Intestinal infection following aerosol challenge of calves with *Mycobacterium avium* subspecies *paratuberculosis*. Vet. Res.42:117.

Ellingson, J. L., C. A. Bolin and J. R. Stabel. 1998. Identification of a gene unique to *Mycobacterium avium* subspecies *paratuberculosis* and application to diagnosis of paratuberculosis. Mol. Cell. Probes. 12:133-142.

Ellis-Iversen, J., A. J. C. Cook, E. Watson, M. Nielen, L. Larkin, M. Wooldridge and H. Hogeveen. 2010. Perceptions, circumstances and motivators that influence implementation of zoonotic control programs on cattle farms. Prev. Vet. Med. 93:276-285.

Fecteau, M. E. and R. H. Whitlock. 2010. Paratuberculosis in cattle. Paratuberculosis: Organism, Disease, Control. M. Behr and D. M. Collins eds. CAB International, Boston, MA, USA.

Fecteau, M. E. and R. H. Whitlock. 2011. Treatment and chemoprophylaxis for paratuberculosis. Vet. Clin. North Am. Food Anim. Pract. 27:547-557.

Francis, J. J., M. P. Eccles, M. Johnston, A. Walker, J. Grimshaw, R. Foy, E. F. S. Kaner, L. Smith and D. Bonetti. 2004. Constructing Questionnaires Based on the Theory of Planned Behaviour: A Manual for Health Services Researchers. University of Newcastle, United Kingdom, Europe.

Garforth, C. J., A. P. Bailey and R. B. Tranter. 2013. Farmers' attitudes to disease risk management in England: A comparative analysis of sheep and pig farmers. Prev. Vet. Med. 110:456-466.

Geraghty, T., D. A. Graham, P. Mullowney and S. J. Moore. 2014. A review of bovine Johne's disease control activities in 6 endemically infected countries. Prev. Vet. Med. 116:1-11.

Gray, C. A., A. C. Blaxter, P. A. Johnston, C. E. Latham, S. May, C. A. Phillips, N. Turnbull and B. Yamagishi. 2006. Communication education in veterinary in the United Kingdom and Ireland: The NUVACS project coupled to progressive individual school endeavors. J. Vet. Med. Educ. 33:85-92.

Green, E. P., M. L. V. Tizard, M. T. Moss, J. Thompson, D. J. Winterbourne, J. J. McFadden and J. Hermon-Taylor. 1989. Sequence and characteristics of IS900, an insertion element identified in a human Crohn's disease isolate or *Mycobacterium paratuberculosis*. Nucleic Acids Res. 17(22):9063-9073.

Groenendaal, H., M. Nielen and J. W. Hesselink. 2003. Development of the Dutch Johne's disease control program supported by a simulation model. Prev. Vet. Med. 60:69-90.

Groenendaal, H., M. Nielen, A. W. Jalvingh, S. H. Horst, D. T. Galligan and J. W. Hesselink. 2002. A simulation of Johne's disease control. Prev. Vet. Med. 54:225-245.

Groenendaal, H., F. J. Zagmutt, E. A. Patton and S. J. Wells. 2015. Cost-benefit analysis of vaccination against *Mycobacterium avium* subspecies *paratuberculosis* in dairy cattle, given its cross-reactivity with tuberculosis tests. J. Dairy Sci. 98(9):6070-6084.

Gunn, G. J., C. Heffernan, M. Hall, A. McLeod and M. Hovi. 2008. Measuring and comparing constraints to improved biosecurity amongst GB farmers, veterinarians and the auxiliary industries. Prev. Vet. Med. 84:310-323.

Hargie, O., M. Boohan, M. McCoy and P. Murphy. 2010. Current trends in communication skills training in UK schools of medicine. Med. Teach. 32:385-391.

Haya R., R., G. Barbara, R. William H., K. Mark, M. Colleen A. and W. John E. 1993. Patients' ratings of outpatient visits in different practice settings: Results from the medical outcomes study. JAMA. 270(7):835-840.

He, Z. and J. DeBuck. 2010. Localization of proteins in the cell wall of *Mycobacterium avium* subspecies *paratuberculosis* K10 by proteomic analysis. Proteome Sci. 8:21.

Hendrick, S. H., D. F. Kelton, K. E. Leslie, K. D. Lissemore, M. Archambault, R. Bagg, P. Dick and T. F. Duffield. 2006. Efficacy of monensin sodium for the reduction of fecal shedding of *Mycobacterium avium* subspecies *paratuberculosis* in infected dairy cattle. Prev. Vet. Med. 75:206-220.

Hop, G. E., A. G. J. Velthuis and K. Frankena. 2011. Assessing Dutch farmers' incentives to join a voluntary Johne's disease programme. NJAS - Wagen. J. Life Sc. 58:57-64.

Humphries, G. M. 2002. Communication skills knowledge, understanding and OSCE performance in medical trainees: A multivariate prospective study using structural equation modelling. Med. Educ. 36(9):842-852.

Jackson, J. L., J. Chamberlin and K. Kroenke. 2001. Predictors of patient satisfaction. Soc. Sci. Med. 52:609-620.

Jansen, J. 2010. Mastitis and Farmer Mindset: Towards Effective Communication Strategies to Improve Udder Health Management on Dutch Dairy Farms. PhD Thesis. Wageningen University, Wageningen, Netherlands.

Janz, N. K. and M. H. Becker. 1984. The health belief model: A decade later. Health Educ. Q. 11:1-47.

Jin, J., G. E. Sklar, V. M. S. Oh and S. C. Li. 2008. Factors affecting therapeutic compliance: A review from the patient's perspective. Ther. Clin. Risk Manag. 4:269-286.

Kalis, C. H. 2003. Diagnosis and Control of Paratuberculosis in Dairy Herds. PhD Thesis, Utrecht University, Netherlands.

Kanji, N., J. B. Coe, C. L. Adams and J. R. Shaw. 2012. Effect of veterinarian-client-patient interactions on client adherence to dentistry and surgery recommendations in companion-animal practice. J. Am. Vet. Med. Assoc. 240:427-436.

Kennedy, D. J. 2011. International efforts at paratuberculosis control. Vet. Clin. North Am. Food Anim. Pract. 27:647-654.

Kennedy, D. J. and M. B. Allworth. 2000. Progress in national control and assurance programs for bovine Johne's disease in Australia. Vet. Microbiol. 77:443-451.

Klauer, T. and U. K. Zettl. 2008. Compliance, adherence, and the treatment of multiple sclerosis. J. Neurol. 255:87-92.

Kristensen, E. and E. B. Jakobsen. 2011. Challenging the myth of the irrational dairy farmer; understanding decision-making related to herd health. N. Z. Vet. J. 59:1-7.

Kudahl, A. B., S. S. Nielsen and S. Østergaard. 2011. Strategies for time of culling in control of paratuberculosis in dairy herds. J. Dairy Sci. 94:3824-3834.

Kudahl, A. B., S. Østergaard, J. T. Sørensen and S. Nielsen. 2007. A stochastic model simulating paratuberculosis in a dairy herd. Prev. Vet. Med. 78:97-117.

Kuiper, D., J. Jansen, R. J. Renes, C. Leeuwis and H. Zwaag. 2005. Social factors related to mastitis control practices: The role of dairy farmers' knowledge, attitude, values, behaviour and networks. Mastitis in Dairy Production: Current Knowledge and Future Solutions. 4th IDF International Mastitis Conference, Maastricht, Netherlands. 12-15.

Kurtz, S. 2006. Teaching and learning communication in veterinary medicine. J. Vet. Med. Educ. 33:11-19.

Lam, T. J. G. M., J. Jansen, B.H.P. van den Borne, R. J. Renes and H. Hogeveen. 2011. What veterinarians need to know about communication to optimise their role as advisors on udder health in dairy herds. N. Z. Vet. J. 59:8-15.

Lamb, L., N. Affenzeller, L. Hewison, J. M. Kevin, H. Zulch and D. S. Mills. 2018. Development and application of the Lincoln Adherence Instrument Record for assessing client adherence to advice in dog behavior consultations and success. Front. Vet. Sci. 5:37.

Larsen, A. B., R. S. Merkal and R. C. Cutlip. 1975. Age of cattle as related to resistance to infection with *Mycobacterium paratuberculosis*. Am. J. Vet. Res. 36:255-257.

Larsen, D. E. and I. Rootman. 1976. Physician role performance and patient satisfaction. Soc. Sci. Med. 10:29-32.

Latham, C. E. and A. Morris. 2007. Effects of formal training in communication skills on the ability of veterinary students to communicate with clients. Vet. Rec. 160:181-186.

Laurin, E. L. 2015. Study of Shedding Patterns of *Mycobacterium avium* subspecies *paratuberculosis* in Feces, Milk, and Colostrum of Dairy Cows and the Development of Novel Early Detection Methods for Johne’s disease. PhD Thesis, University of Prince Edward Island, Charlottetown, Prince Edward Island, Canada

Laurin, E. L., M. Chaffer, J. T. McClure, S. L. B. McKenna and G. P. Keefe. 2015. The association of detection method, season, and lactation stage on identification of fecal shedding in *Mycobacterium avium* subspecies *paratuberculosis* infectious dairy cows. J. Dairy Sci. 98:211-220.

Lavers, C. J. 2013. Evaluation of diagnostic tests for detection of *Mycobacterium avium* subspecies *paratuberculosis* (MAP) at the herd-level and cow-level. PhD thesis, University of Prince Edward Island, Charlottetown, Prince Edward Island, Canada.

Lavers, C. J., S. L. B. McKenna, I. R. Dohoo, H. W. Barkema and G. P. Keefe. 2013. Evaluation of environmental fecal culture for *Mycobacterium avium* subspecies *paratuberculosis* detection in dairy herds and association with apparent within-herd prevalence. Can. Vet. J. 54:1053-1060.

Lind, A. K., P. T. Thomsen, S. Rintakoski, M. N. Espetvedt, C. Wolff and H. Houe. 2012. The association between farmers' participation in herd health programmes and their behaviour concerning treatment of mild clinical mastitis. Acta Vet. Scand. 54:62.

Locker, D. and D. Dunt. 1978. Theoretical and methodological issues in sociological studies of consumer satisfaction with medical care. Soc. Sci. Med. 12:283-292.

Lombard, J. E., T. M. Byrem, B. A. Wagner and B. J. McCluskey. 2006. Comparison of milk and serum enzyme-linked immunosorbent assays for diagnosis of *Mycobacterium avium* subspecies *paratuberculosis* infection in dairy cattle. J. Vet. Diagn. Invest. 18(5):448-458.

Loomans, J. B. A., P. G. Waaijer, J. T. M. Maree, P. R. Weeren and A. Barneveld. 2009. Quality of equine veterinary care Part 2: Client satisfaction in equine top sports medicine in the Netherlands. Equine Vet. Educ. 21:421-428.

Lu, Z., Y. H. Schukken, R. L. Smith and Y. T. Grohn. 2010. Stochastic simulations of a multi-group compartmental model for Johne’s disease on US dairy herds with test-based culling intervention. J. Theor. Biol. 264:1190-1201.

Martin, L. R., S. L. Williams, K. B. Haskard and M. R. Dimatteo. 2005. The challenge of patient adherence. Ther. Clin. Risk Manag. 1:189-199.

McAloon, C. G., P. Whyte, S. J. More, L. O'Grady and M. L. Doherty. 2015. Development of a HACCP-based approach to control paratuberculosis in infected Irish dairy herds. Prev. Vet. Med. 120:152-161.

McKenna, S. L. B., G. P. Keefe, H. W. Barkema and D. C. Sockett. 2005. Evaluation of three ELISAs for *Mycobacterium avium* subspecies *paratuberculosis* using tissue and fecal culture as comparison standards. Vet. Microbiol. 110:105-111.

McKenna, S. L. B., G. P. Keefe, A. Tiwari, J. VanLeeuwen and H. W. Barkema. 2006a. Johne’s disease in Canada part II: Disease impacts, risk factors, and control programs for dairy producers. Can. Vet. J. 47:1089-1099.

McKenna, S. L. B., J. A. Vanleeuwen, H. W. Barkema, J. T. Jansen, G. Hauer, S. H. Hendrick, G. Côte, E. B. Salsberg and R. E. Empringham. 2006b. Proposed Canadian voluntary national Johne’s disease prevention and control program. Can. Vet. J. 47:539-541.

Mills, J. N., P. Irwin, J. Baguley, M. Meehan, H. Austin, L. Fitzpatrick, B. Parry and T. Heath. 2006. Development of veterinary communication skills at Murdoch University and in other Australian veterinary schools. J. Vet. Med. Educ. 33:93-99.

Mortier, R. A. R., H. W. Barkema, J. M. Bystrom, O. Illanes, K. Orsel, R. Wolf, G. Atkins and J. De Buck. 2013. Evaluation of age-dependent susceptibility in calves infected with two doses of *Mycobacterium avium* subspecies *paratuberculosis* using pathology and tissue culture. Vet. Res. 44:9

Mortier, R. A. R., H. W. Barkema and J. De Buck. 2015. Susceptibility to and diagnosis of *Mycobacterium avium* subspecies *paratuberculosis* infection in dairy calves: A review. Prev. Vet. Med. 121:189-198.

Mullan, B. A. and E. J. Kothe. 2010. Evaluating a nursing communication skills training course: The relationships between self-rated ability, satisfaction, and actual performance. Nurse Educ. Pract. 10:374-378.

Naser, S. A., G. Ghobrial, C. Romero and J. F. Valentine. 2004. Culture of *Mycobacterium avium* subspecies *paratuberculosis* from the blood of patients with Crohn's disease. Lancet. 364(9439):1039-1044.

Nielsen, S. S. 2011. Dairy farmers' reasons for participation in the Danish control programme on bovine paratuberculosis. Prev. Vet. Med. 98:279-283.

Nielsen, S. S. 2007. Danish control programme for bovine paratuberculosis. Cattle Pract. 15:161-168.

Nielsen, S. S., Y. T. Grohn and C. Enevoldsen. 2002. Variation of the milk antibody response to paratuberculosis in naturally infected dairy cows. J. Dairy Sci. 85(11):2795-2802.

Nielsen, S. S. and N. Toft. 2008. Ante mortem diagnosis of paratuberculosis: A review of accuracies of ELISA, interferon-γ assay and faecal culture techniques. Vet. Microbiol. 129:217-235.

Nielsen, S. and N. Toft. 2009. Review: A review of prevalences of paratuberculosis in farmed animals in Europe. Prev. Vet. Med. 88:1-14.

O'Brien, R., C. G. Mackintosh, D. Bakker, M. Kopecna, I. Pavlik and J. Griffin. 2006. Immunological and molecular characterization of susceptibility in relationship to bacterial strain differences in *Mycobacterium avium* subspecies *paratuberculosis* infection in the red deer (*Cervus elaphus*). Infect. Immun. 74:3530-3537.

Ontario Johne's Education and Management Assistance Program. 2014. Johne's program results: End of program testing results. Accessed June 11, 2021. http://www.johnes.ca/program results.htm .

Ott, S. L., S. J. Wells and B. A. Wagner. 1999. Herd-level economic losses associated with Johne's disease on US dairy operations. Prev. Vet. Med. 40:179-192.

Patton, E. A. 2011. Paratuberculosis vaccination. Vet. Clin. North Am. Food Anim. Pract. 27:573-580.

Petrovski, K. R. and M. Mc Arthur. 2015. The art and science of consultations in bovine medicine: Use of modified Calgary-Cambridge-Guides. Maced. Vet. Rev. 38:137-147.

Pieper, L., U. S. Sorge, T. J. DeVries, A. Godkin, K. Lissemore and D. F. Kelton. 2015. Evaluation of the Johne’s disease risk assessment and management plan on dairy farms in Ontario. J. Dairy Sci. 98(10):6792-6800.

Radford, A., P. Stockley, J. Silverman, I. Taylor, R. Turner and C. Gray. 2006. Development, teaching, and evaluation of a consultation structure model for use in veterinary education. J. Vet. Med. Educ. 33:38-44.

Rasmussen, P., H. W. Barkema, S. Mason, E. Beaulieu and D. C. Hall. 2020. Economic losses due to Johne's disease (paratuberculosis) in dairy cattle. J. Dairy Sci. 104:3123-3143.

Ridge, S. E., C. Heuer, N. Cogger, A. Heck, S. Moor, I. M. Baker and S. Vaughan. 2010. Herd management practices and the transmission of Johne’s disease within infected dairy herds in Victoria, Australia. Prev. Vet. Med. 95:186-197.

Ritter, C., J. Jansen, K. Roth, J. P. Kastelic, C. L. Adams and H. W. Barkema. 2016. Dairy farmers’ perceptions toward the implementation of on-farm Johne’s disease prevention and control strategies. J. Dairy Sci. 99:9114-9125.

Ritter, C., G. P. S. Kwong, R. Wolf, C. Pickel, M. Slomp, J. Flaig, S. Mason, C. L. Adams, D. F. Kelton, J. Jansen, J. De Buck and H. W. Barkema. 2015. Factors associated with participation of Alberta dairy farmers in a voluntary, management-based Johne’s disease control program. J. Dairy Sci. 98(11):7831-7845.

Ritter, C., C. L. Adams, D. F. Kelton and H. W. Barkema. 2019. Factors associated with dairy farmers' satisfaction and preparedness to adopt recommendations after veterinary herd health visits. J. Dairy Sci. 102(5):4280-4293.

Ritter, C., C. L. Adams, D. F. Kelton and H. W. Barkema. 2018. Clinical communication patterns of veterinary practitioners during dairy herd health and production management farm visits. J. Dairy Sci. 101(11):10337-10350.

Ritter, C., J. Jansen, S. Roche, D. F. Kelton, C. L. Adams, K. Orsel, R. J. Erskine, G. Benedictus, T. J. G. M. Lam and H. W. Barkema. 2017. Invited review: Determinants of farmers' adoption of management-based strategies for infectious disease prevention and control. J. Dairy Sci. 100(5):3329-3347.

Robins, J., S. Bogen, A. Francis, A. Westhoek, A. Kanarek, S. Lenhart and S. Eda. 2015. Agent-based model for Johne's disease dynamics in a dairy herd. Vet. Res. 46:68

Roche, S. M., A. Jones-Bitton, M. Meehan, M. Von Massow and D. F. Kelton. 2015. Evaluating the effect of focus farms on Ontario dairy producers' knowledge, attitudes, and behavior toward control of Johne's disease. J. Dairy Sci. 98:5222-5240.

Roche, S. 2014. Investigating the role of agricultural extension in influencing Ontario dairy producer behaviour for Johne's disease control. PhD Thesis. Department of Population Medicine. University of Guelph, Ontario, Canada.

Serraino, A., P. Bonilauri, N. Arrigoni, F. Ostanello, M. Ricchi, G. Marchetti, E. Bonfante, S. Albonetti and F. Giacometti. 2014. Quantitative risk assessment of *Mycobacterium avium* subspecies *paratuberculosis* survival in pasteurized milk in three dairy plants in Italy. Food Control. 45:120-126.

Shaw, D. H. and S. L. Ihle. 2006. Communication skills training at the Atlantic Veterinary College, University of Prince Edward Island. J. Vet. Med. Educ. 33:100-104.

Shaw, J. R. 2019. Evaluation of communication skills training programs at North American veterinary medical training institutions. J. Am. Vet. Med. Assoc. 255(6):722-733. DOI: 10.2460/javma.255.6.722.

Shaw, J. R., C. L. Adams and B. N. Bonnett. 2004. What can veterinarians learn from studies of physician-patient communication about veterinarian-client-patient communication? J. Am. Vet. Med. Assoc. 224:676-684.

Shaw, J. R., C. L. Adams, B. N. Bonnett, S. Larson and D. L. Roter. 2012. Veterinarian satisfaction with companion animal visits. J. Am. Vet. Med. Assoc. 240:832-841.

Shaw, J. R., G. E. Barley, K. Broadfoot, A. E. Hill and D. L. Roter. 2016. Outcomes assessment of on-site communication skills education in a companion animal practice. J. Am. Vet. Med. Assoc. 249:419-432.

Shaw, J. R., G. E. Barley, A. E. Hill, S. Larson and D. L. Roter. 2010. Communication skills education onsite in a veterinary practice. Patient Educ. Couns. 80:337-344.

Shippy, D. C., J. J. Lemke, A. Berry, K. Nelson, M. E. Hines, and A. M. Talaat. 2017. Superior protection from live-attenuated vaccines directed against Johne's disease. Clin. Vaccine Immunol. 24:e00478-16.

Silverman, J., S. M. Kurtz and J. Draper. 2013. Skills for Communicating with Patients. 3rd ed. CRC Press, Taylor & Francis Group. Boca Raton, Florida, USA.

Sitzia, J. and N. Wood. 1997. Patient satisfaction: A review of issues and concepts. Soc. Sci. Med. 45:1829-1843.

Sorge, U., D. Kelton, K. Lissemore, A. Godkin, S. Hendrick and S. Wells. 2010. Attitudes of Canadian dairy farmers toward a voluntary Johne’s disease control program. J. Dairy Sci. 93:1491-1499.

Sorge, U. S., K. Lissemore, A. Godkin, J. Jansen, S. Hendrick, S. Wells and D. F. Kelton. 2011. Changes in management practices and apparent prevalence on Canadian dairy farms participating in a voluntary risk assessment-based Johne’s disease control program. J. Dairy Sci. 94:5227-5237.

Sweeney, R. W. 1996. Transmission of paratuberculosis. Vet. Clin. North Am. Food Anim. Pract... 12:305-312.

Sweeney, R. W., R. H. Whitlock and A. E. Rosenberger. 1992. *Mycobacterium paratuberculosis* isolated from fetuses of infected cows not manifesting signs of the disease. Am. J. Vet. Res. 53:477-480.

Sweeney, R. W. 2011. Pathogenesis of paratuberculosis. Vet. Clin. North Am. Food Anim. Pract. 27:537-546.

Talamonti, Z., C. Cassis, P. G. Brambilla, P. Scarpa, D. Stefanello, S. Cannas, M. Minero and C. Palestrini. 2015. Preliminary study of pet owner adherence in behaviour, cardiology, urology, and oncology fields. Vet. Med. Int. 2015:1-7.

Tiwari, A., J. A. VanLeeuwen, S. L. B. McKenna, G. P. Keefe and H. W. Barkema. 2006. Johne's disease in Canada Part I: Clinical symptoms, pathophysiology, diagnosis, and prevalence in dairy herds. Can. Vet. J. 47:874-882.

Turner, A. P., D. R. Kivlahan, A. P. Sloan and J. K. Haselkorn. 2007. Predicting ongoing adherence to disease modifying therapies in multiple sclerosis: Utility of the health beliefs model. Mult. Scler. 13(9):1146-1152.

USDA-APHIS-VS-CEAH, 2008. Johne's disease on US dairies, 1991-2007. Accessed June 11. 2021. www.aphis.usda.gov/animal_health/nahms/dairy/downloads/dairy07/Dairy07_is_Johnes_1.pdf.

van Schaik, G., S. M. Stehman, Y. H. Schukken, C. R. Rossiter and S. J. Shin. 2003. Pooled fecal culture sampling for *Mycobacterium avium* subspecies *paratuberculosis* at different herd sizes and prevalence. J. Vet. Diagn, Invest. 15:233-241.

Vande Velde, F., E. Claerebout, V. Cauberghe, L. Hudders, H. Van Loo, J. Vercruysse and J. Charlier. 2015. Diagnosis before treatment: Identifying dairy farmers’ determinants for the adoption of sustainable practices in gastrointestinal nematode control. Vet. Parasitol. 121(3-4):308-317.

VanLeeuwen, J. A., G. P. Keefe, R. Tremblay, C. Power and J. J. Wichtel. 2001. Seroprevalence of infection with *Mycobacterium avium* subspecies *paratuberculosis*, bovine leukemia virus, and bovine viral diarrhea virus in Maritime Canada dairy cattle. Can. Vet. J. 42:193-198.

Vermeire, E., H. Hearnshaw, P. Van Royen and J. Denekens. 2001. Patient adherence to treatment: Three decades of research. A comprehensive review. J. Clin. Pharm. Ther. 26(5):331-342.

Wassink, G. J., T. R. N. George, J. Kaler and L. E. Green. 2010. Footrot and interdigital dermatitis in sheep: Farmer satisfaction with current management, their ideal management and sources used to adopt new strategies. Prev. Vet. Med. 96:65-73.

Wayner, C. J. and M. L. Heinke. 2006. Compliance: Crafting quality care. Vet. Clin. North Am. Small Anim. Pract. 36(2):419-436.

Wells, S. J., W. L. Hartmann and P. L. Anderson. 2008. Evaluation of progress made by dairy and beef herds enrolled in the Minnesota Johne's disease control program. J. Am. Vet. Med. Assoc. 233:1920-1926.

Wells, S. J. and B. A. Wagner. 2000. Herd-level risk factors for infection with *Mycobacterium paratuberculosis* in US dairies and association between familiarity of the herd manager with the disease or prior diagnosis of the disease in that herd and use of preventive measures. J. Am. Vet. Med. Assoc. 216:1450-1457.

Whitlock, R. H. 2010. Paratuberculosis control measures in the USA. Paratuberculosis: Organism, Disease, Control. M. Behr and D. M. Collins eds. CAB International, Boston, MA, USA.

Whitlock, R. H. 1992. Diarrhea in cattle. Veterinary Gastroenterology. 2nd ed. N. V. Anderson ed. Lea & Febiger, Philadelphia, PA.

Whitlock, R. H. and C. Buergelt. 1996. Preclinical and clinical manifestations of paratuberculosis (including pathology). Vet. Clin. North Am. Food Anim. Pract. 12(2). 345-356.

Whitlock, R. H., S. J. Wells, R. W. Sweeney and J. Van Tiem. 2000. ELISA and fecal culture for paratuberculosis (Johne`s disease): Sensitivity and specificity of each method. Vet. Microbiol. 77(3-4): 387-398.

Windsor, P. A. and R. J. Whittington. 2010. Evidence for age susceptibility of cattle to Johne's disease. Vet. J. 184:37-44.

Wolf, R., H. W. Barkema, J. De Buck and K. Orsel. 2015a. Factors affecting management changes on farms participating in a Johne’s disease control program. J. Dairy Sci. 98:7784-7796.

Wolf, R., H. W. Barkema, J. De Buck and K. Orsel. 2015b. Sampling location, herd size, and season influence *Mycobacterium avium* subspecies *paratuberculosis* environmental culture results. J. Dairy Sci. 98:275-287.

Wolf, R., H. W. Barkema, J. De Buck, M. Slomp, J. Flaig, D. Haupstein, C. Pickel and K. Orsel. 2014a. High herd-level prevalence of *Mycobacterium avium* subspecies *paratuberculosis* in western Canadian dairy farms, based on environmental sampling. J. Dairy Sci. 97:6250-6259.

Wolf, R., F. Clement, H. W. Barkema and K. Orsel. 2014b. Economic evaluation of participation in a voluntary Johne’s disease prevention and control program from a farmer's perspective - The Alberta Johne’s Disease Initiative. J. Dairy Sci. 97:2822-2834.

World Organization for Animal Health. 2012. OIE recommendations on the competencies of graduating veterinarians ('Day 1 graduates') to assure National Veterinary Services of quality. OIE. Paris, France.

Woodcock, A. and D. Barleggs. 2005. Development and psychometric validation of the Veterinary Service Satisfaction Questionnaire (VSSQ). J. Vet. Med. A Physiol. Pathol. Clin. Med. 52(1):26-38.

Wraight, M. D., J. McNeil, D. S. Beggs, R. K. Greenall, T. B. Humphris, R. J. Irwin, S. P. Jagoe, A. Jemmeson, W. F. Morgan, P. Brightling, G. A. Anderson and P. D. Mansell. 2000. Compliance of Victorian dairy farmers with current calf rearing recommendations for control of Johne’s disease. Vet. Microbiol. 77(3-4):429-442.

CHAPTER 2: THE ATLANTIC JOHNE'S DISEASE INITIATIVE - PROGRAM DESCRIPTION, PREVALENCE AND IMPACTS ON PRODUCTIVITY

2.1 ABSTRACT

The Atlantic Johne's Disease Initiative (AJDI) was launched in 2011 with the overall goal of reducing the substantial prevalence and impact of Johne's disease (JD) in dairy cattle in Atlantic Canada. The objectives of this study were to describe the herd and within-herd apparent prevalences of MAP infection, and determine factors associated with MAP infection. Environmental cultures (EC) were conducted annually for AJDI herds. EC-positive herds that conducted individual cow Johne's diagnostics tested all lactating cows for MAP infection using fecal PCR, fecal culture and/or ELISA (milk or serum). Veterinarians certified through AJDI delivered all herd and cow diagnostic results and conducted risk assessment and management plans. Four hundred and sixty-three of the region's 664 herds (70%) enrolled in the AJDI. The overall herd apparent prevalence of MAP infection showed that 122 herds (26.5%) had EC testing positive at least once. Of the EC-positive herds, 42 conducted individual cow MAP diagnostics. The mean apparent within-herd prevalence of JD for the 42 EC-positive herds which tested cows was 5.53% [95% confidence interval (CI): 1.83 – 9.23%] and the likelihood of identifying test positive cows increased with an increasing percentage of positive EC samples per herd. The herd risk of being EC-positive was significantly higher as the number of lactating cows, the number of bull calves, and the percentage of pneumonia in heifers increased. The herd risk of being EC-positive was also significantly higher if the herd planned to purchase cattle in the next year and if the herd had more than 5% mortality in heifers that were between the ages of 1 and 4 months old. Furthermore, the herd risk of being EC-positive was significantly higher in summer (July through

September) compared to winter and spring and was significantly higher if the herd was in Newfoundland and Labrador but significantly lower if the herd was in Nova Scotia. On the cow level, 305-day milk production was significantly lower for cows with MAP infection compared to test-negative cows. Results from this study should help to control JD in the future.

2.2 INTRODUCTION

Johne's disease (JD) is an incurable, chronic, infectious enteritis of domestic and wild ruminants caused by *Mycobacterium avium* subspecies *paratuberculosis* (MAP). Progressive weight loss and chronic diarrhea are the clinical signs for advanced stages of the disease (Chiodini et al., 1984). JD has long burdened the cattle industry worldwide (Barkema et al., 2010) and causes substantial economic losses through decreased milk production and slaughter value, increased culling risk, mortality, treatment costs and reproductive loss (Chi et al., 2002; McKenna et al., 2006; Barkema et al., 2010; Wolf et al., 2014a; Rasmussen et al., 2020). There are also human health concerns regarding a possible association between JD and Crohn's disease (Barkema et al., 2011). Johne's disease has been identified as one of the top disease priorities of Canadian dairy farmers, University researchers and practicing veterinarians (Bauman et al., 2016). Therefore, the dairy industry was interested in programs to minimize the spread of JD and to proactively work to ensure the trust of the dairy consumer (Sorge et al., 2010).

Estimates of the apparent herd-level seroprevalence of JD in dairy herds among Canadian provinces vary between 9.8 and 43.1% (herds with at least 2 seropositive cows) (Tiwari et al., 2006). A study done in Atlantic Canada [New Brunswick (NB), Newfoundland and Labrador (NL), Nova Scotia (NS) and Prince Edward Island (PE)] reported a cow-level seroprevalence of 2.6%, and 16.7% of herds had at least 2 seropositive cows (VanLeeuwen et al., 2001). In those positive herds, the arithmetic mean prevalence of infection was low at 8.5% (VanLeeuwen et al., 2001). Determining whether a herd is MAP-positive or MAP-negative can be challenging because of test characteristics, but it is an important part of a successful control program for JD. Environmental culture is an acceptable test for herd diagnosis of MAP in low-prevalence herds (Lavers et al., 2013).

To reduce the prevalence and impact of JD in the Atlantic Canadian dairy industry, the Atlantic Johne's Disease Initiative (AJDI) was launched in 2011 as a 3-year voluntary risk assessment-based prevention and control program for JD. The AJDI prevalence reduction program consisted of three components: 1) herd categorization by environmental culture (EC), 2) individual cow MAP diagnostics for EC-positive herds, and 3) farm-specific risk assessment and management plan (RAMP) development implemented by herd veterinarians. In addition to these direct infection control strategies, education and research were important components of the AJDI. The genesis, development and implementation of AJDI were through a joint effort from the 4 provincial milk boards (Dairy Farmers of NB, NL, NS & PE), Maritime Quality Milk (MQM) (University of Prince Edward Island, Charlottetown, PE, Canada), the Atlantic Veterinary College (AVC) (University of Prince Edward Island, Charlottetown, PE, Canada) and food animal production medicine (FAPM) veterinarians practicing in Atlantic Canada. There has not been a systematic evaluation of the AJDI data, or factors associated with herds identified as MAP infected in the AJDI.

The objectives of this study were to: 1) describe the implementation and short-term outcomes of the first two prevalence reduction components of the AJDI, through estimation of herd and within-herd apparent prevalences of JD, 2) determine factors related to herd-level MAP infection, and 3) determine if cow-level MAP infection was associated with cow-level 305-day milk production.

2.3 MATERIAL AND METHODS

2.3.1 Study location and population

At the beginning of the AJDI in 2011, the Atlantic Canadian dairy industry consisted of 664 dairy herds. The goal was to recruit at least 60% of these dairy operations to participate in the AJDI. Direct and indirect recruitment strategies were utilized to motivate participation, including presentations at farmer meetings, mailings, popular and agricultural media (e.g., information in NB, NS & PE Dairy Board newsletters), an AJDI website, endorsement from local FAPM veterinarians and personal communication. The recruited farmers became the study population during the 3 years of this study, 2011-2013.

A program goal was to train at least 1 veterinarian from each veterinary clinic providing service to the dairy producers of Atlantic Canada to function as certified AJDI veterinarians. Certification was achieved by the completion of an advanced education program designed by the AJDI that included in-person training (small groups or one-on-one) and web-based training and evaluation. Topics covered in the training included JD pathogenesis, MAP diagnostic test interpretation, and how to conduct on-farm RAMPs. The certified veterinarians sampled individual cows for testing (details below), delivered the diagnostic test results to the producers, and performed the farm-specific RAMPs annually.

2.3.2 Data and sample collection

Herd MAP infection categorization in participating herds was determined using an EC procedure modeled on the United States Department of Agriculture (USDA) Voluntary Bovine JD Control Program (USDA-APHIS-VS-CEAH, 2008). For each herd, six mixed manure samples were collected from prescribed locations by trained AJDI technical staff, including two samples from manure storage areas and 4 samples from mature cow concentration areas. This set of 6 samples was referred to as an EC-6 set. Herds were retested once yearly (minimum 10 months to a maximum of 14 months) and if they were categorized EC-negative for 2 consecutive years, retesting was conducted every other year as long as they remained EC-negative. Herd categorization was fully funded by AJDI. Details of the EC sampling protocol are in Appendix A.1.

During each EC, trained AJDI technical staff completed a questionnaire with the producer(s) about herd demographics, herd morbidity and mortality, and producer opinion of the AJDI, using a 7-point Likert scale, with 1 being completely disagree and 7 being completely agree. Further details about the structure of the EC questionnaires are in Appendix A.2 and copies of the questionnaires are in Appendix A.3.

Herds that were categorized EC-positive were eligible for voluntary co-funded individual cow MAP diagnostic testing. To be eligible for co-funding, herds had to test all lactating cows and could voluntarily test all dry cows using the following diagnostic modalities alone or in combination: fecal culture, fecal PCR, or enzyme-linked immunosorbent assay (ELISA) on serum or milk.

Individual cow sample collection was conducted by or under the direction of the certified veterinarians. Submission forms were completed at the time of sample collection and included the following cow information: date, barn identification, Canadian Cattle Identification Agency (CCIA) number and/or Valacta identification number, date of birth, lactation number, most recent calving date, and breed. Individual manure sample collection for both fecal culture and fecal PCR was conducted using the same protocol. Approximately 30g of feces was collected per rectum and placed into a clean, labelled specimen container using a clean rectal palpation sleeve lubricated with water. Blood collection for serum samples was done using primarily the Vacutainer Blood Collection Tube with gel serum separator. Blood samples were spun and if the gel serum separator was not used, the serum was separated into a new tube for shipping. Milk samples were primarily obtained through composite samples collected as part of routine herd milk testing by the regional dairy herd improvement (DHI) organization (Valacta, Sainte-Anne-de-Bellevue, QC, Canada). For producers not subscribing to Valacta, milk was collected manually from clinically healthy quarters. All samples were kept refrigerated or on ice during transport to the laboratory.

2.3.3 Laboratory analyses

All EC samples were processed and tested by the MQM laboratory at AVC, which was approved by the USDA proficiency-testing process for this diagnostic technique. The protocol was previously described in Lavers et al. (2013). Briefly, the fresh EC-samples were cultured using an ESP *para*-JEM broth culture system (TREK ESP® Culture System II, Thermo Scientific, Oakwood Village, Ohio) for a maximum incubation of 49 days. When the TREK incubator sensor indicated growth (i.e., headspace pressure change), or at the end of the 49 day incubation period, acid-fast staining was performed on the culture broth. Presumptive positive samples (positive TREK growth curve and/ or acid-fast positive) were selected for confirmation with quantitative polymerase chain reaction (PCR) (VetAlert™ Johne's Real-Time PCR kit, Tetracore®, Rockville, Maryland) through the targeting of the *hspX* gene (McKenna et al., 2005; Lavers et al., 2013). An EC sample was considered positive if the presumptive positive sample was positive based on PCR testing. A herd was categorized as positive if there was ≥1 positive EC sample within an EC-6 set of samples. A herd was categorized as negative if no EC samples tested positive within an EC-6 set of samples. Certified veterinarians informed producers of their herd EC categorization and the result breakdown for the EC-6 set. The sensitivity and specificity of the EC protocol was reported to be 71% (95% CI: 49-86%) and 99% (95% CI: 95-100%), respectively (Lavers et al., 2013).

All individual cow samples were also tested by the MQM laboratory, which was also approved by the USDA proficiency-testing process for these diagnostic techniques. The protocols used for individual cow fecal culture and ELISA were previously described in Lavers et al. (2014), while the protocol used for individual cow fecal PCR was previously described in Laurin et al. (2015). Briefly, for fecal cultures or PCRs, pooled fecal samples were created by the laboratory staff for each herd by pooling 2g of fresh feces from each of 5 cows, clustered by cow age. The remaining feces were stored as individual cow fecal samples at -20^{o}C. The pooled samples of feces intended for fecal culture were tested using the protocol outlined above for the EC samples. The pooled samples of feces intended for fecal PCR were tested using direct PCR methods as outlined in the VetAlert Real-Time PCR kit (Tetracore, Rockville, MD), targeting the *hspX* gene. If a pooled fecal sample was considered positive by culture or PCR, it was recommended to retest the cows contained within the positive pool by performing direct fecal PCR on the frozen individual fecal sample for each cow. Indirect ELISA was used to test individual cow serum and/or milk samples (PARACHEK® 2 ELISA kit, Prionics AG, Schlieren-Zürich, Switzerland), following the recommendations of the kit. Certified veterinarians informed producers of their individual cow MAP diagnostic test results.

2.3.4 Environmental culture status registry

Herds that were categorized EC-negative were eligible to have their status voluntarily registered on the AJDI website (www.atlanticjohnes.ca; site is no longer active). There were 2 levels in the Registry: EC-Negative Level 1 (Entry Level) and EC-Negative Level 2 (Maintenance of Status). Herds entered as EC-Negative Level 1 if their most recent EC was negative on all 6 samples. If a previous EC was positive for a herd, a minimum of 10 months had to pass before a valid retest could be done. EC-Negative Level 1 herds were retested 10 to 14 months after their most recent EC-negative categorization. If the EC retest on an EC-Negative herd was again negative on all 6 EC samples, the herd achieved an EC-Negative Level 2 status.

To access the Registry online, viewers had to accept a disclaimer that waived any and all liability for decisions or actions taken based upon information contained in the Registry. The disclaimer also clearly explained that being listed on the Registry did not guarantee that a herd was free of MAP. Instead, being listed meant that MAP was not detected in the herd's environment using standard industry procedures on the day of testing only.

2.3.5 Data management and statistical analysis

Cow production and management data were obtained from the regional DHI database (Valacta) for consenting herds enrolled in DHI. The records for the most recent lactation of all cows that were on test during the study period were collected. For continuous DHI variables, herd production and management data were computed as the median of the cow records obtained from the DHI database for each herd. For the categorical variable of whether or not a cow was culled throughout the study period, the percent of cows culled was calculated for each herd. Cow production and management data were also merged with AJDI individual cow JD testing results.

The season of the EC sample collection variable was created by categorizing the dates of EC sample collection into summer (June 21st to September 21st), fall (September 22nd to December 20th), winter (December 21st to March 19th), and spring (March 20th to June 20th). The variable for number of lactating cows was centered by subtracting 11, the smallest herd size, to create a biologically plausible meaning for a zero value when interpreting the intercept.

Statistical analyses were performed using STATA/MP 14.1 (StataCorp LP, College Station, Texas, USA). Descriptive statistics [means and 95% confidence intervals (CI)] were calculated for the participant data, herd demographics obtained through EC questionnaires, EC and individual cow laboratory test results, and DHI herd production and management data. Pearson Chi^2 tests were used to test associations between overall herd EC categorization and province, overall herd EC categorization and whether or not a herd participated in DHI, and percentage of positive EC samples within positive EC-6 sets and province. Statistical significance was set at a p-value of <0.05.

In addition to these univariable associations for various outcomes, multivariable models were developed for two outcomes. The first determined if herd demographics or management factors were associated with herd-level MAP infection from EC testing. The second determined if cow-level MAP infection status was associated with cow-level 305-day milk production. The focus on this specific cow-level outcome was to investigate whether decreased milk production was evident for cows with MAP infection in AJDI herds, alike reported in literature (VanLeeuwen et al., 2002; Lombard et al., 2005; McAloon et al., 2015). These analyses are described below.

A herd-level generalized estimating equation (GEE) logistic regression model was developed with an exchangeable correlation structure and robust standard errors to evaluate if herd demographics, season of EC testing, herd morbidity and mortality, and/or management factors (e.g., whether or not there were plans to purchase animals in the next year, cow housing types) were associated with the odds of a herd testing positive for MAP infection. Initially, univariable analyses were conducted, and those variables that were significant using a cut-off of $P<0.10$ were eligible for multivariable modeling. Determination of variable inclusion in the final multivariable model was done by backward stepwise elimination of variables that had a Wald test P-value greater than 0.05. Possible interactions between variables were evaluated by the addition of the cross-product interaction term and determining if the coefficient for the term was statistically significant using a Wald test. Possible confounding was assessed by adding and removing potential confounding variables to the model to determine whether or not the coefficients of the variables in the model changed substantially; a change of ≥30% was considered substantial confounding, leading to retention of the variable in the model. The final model was evaluated using an independent correlation structure to permit the execution of additional post-estimation procedures, including the Pearson Chi^2 and Hosmer-Lemeshow goodness-of-fit tests, the calculation of Pearson and standardized Pearson residuals, and the identification of important observations (outliers and observations with high leverage).

A mixed effect linear regression model with herd as a random effect was used to determine whether or not cow MAP infection status was associated with cow-level 305-day milk production. Infection status was based upon each cow's latest diagnostic test result over the study period. The predictor variables used in the model included: cow MAP infection status, cow lactation number, cow average somatic cell count linear score, and number of cows in the herd's DHI record for the study period. Initially, all the predictor variables were included in the model and backward stepwise elimination of variables that had a Wald test P-value > 0.05 was done for determination of variable inclusion in the final multivariable model. Similar model-building techniques and goodness-of-fit assessments were conducted for this second model.

2.4 RESULTS

2.4.1 Participants

In total, 463 herds (70%) from the 4 Atlantic Provinces voluntarily enrolled in the AJDI. Enrollments per province were 62% for New Brunswick (129 of 209 herds), 86% for Newfoundland & Labrador (25 of 29 herds), 72% for Nova Scotia (169 of 235 herds) and 73% for Prince Edward Island (140 of 191 herds). Three of the herds that enrolled did not participate further in the AJDI, leaving 460 herds for the statistical analyses on participating farms.

FAPM veterinarians from all 4 Atlantic Provinces participated in the AJDI by completing an advanced education program to become certified veterinarians. In total, 55 veterinarians were certified from 27 different veterinary clinics.

2.4.2 Herd demographics

For the 460 participant herds, median herd size was 60 milking cows (mean: 80 cows; range: 11 to 420 cows). Two hundred and fifty lactating cow housing facilities (54%) were free-stall, 188 facilities (41%) were tie-stall and 16 facilities (3%) were bedded pack. Four hundred and seventeen herds (86%) used well water as their sole source of water for the cattle. Full confinement of lactating cows occurred in 171 herds (38%) during the summer. Rumensin was administered to over half of the herds (238 of 460), predominately as a premix. Three hundred and eight herds (67%) participated in routine herd milk testing by the regional DHI organization (Valacta) during the study. DHI data was not available for any herds from NL. Details on information extracted from the DHI database is provided in Table 2.1. Almost all of the herds in the study indicated that they planned to remain in operation during the next five years, with 283 herds (62%) planning to maintain their herd size and 166 herds (36%) planning to expand their herd size. Eleven herds (2%) planned not to be farming within the next five years.

2.4.3 Producer experiences, attitudes and perceptions

Prior to their participation in the AJDI, 5% of producers (22 of 460) did not remember hearing about JD previously. Fifty-five percent of producers (255 of 460) had heard other producers discussing JD or heard about it in the media, while 40% of producers (183 of 460) had actively sought out information on JD and/or discussed it with their herd veterinarian. There were 334 farmers that indicated who or what motivated them to participate in the AJDI; of which, over 75% (253 of 334) attributed it to their herd veterinarian.

Over 92% of producers (425 of 460) thought that there should be a national program for the control of JD, and of them, 68% (287 of 425) thought a national program should be voluntary while 31% (133 of 425) though a national program should be mandatory.

Figure 2.1 shows a graph of the mean and 95% CI of the disease importance rankings that 458 producers experienced on their farms (two farmers chose not to respond). The order of disease ranking from most to least important herd disease was mastitis, lameness, retained placenta, displaced abomasum, and then JD.

Plans to purchase cattle, primarily heifers and cows, were stated by 170 of the 460 herds (37%). For herds that planned on bringing in new animals for the 1st year of the study, few producers required herd-of-origin information, particularly regarding MAP-infection status. Only 4% of producers asked about the seller's herd JD status and/or the seller's cow JD status in Y1 of the study (2011). A significant increase was detected in the number of producers that required herd-of-origin JD information for new animal purchases for Y2 (2012) versus Y1 [herd status Pearson $Chi^2(1) = 37.16$, $p<0.01$; and cow status Pearson $Chi^2(1) = 3.7242$, $p=0.054$]. Approximately 37% of the producers asked about the seller's herd JD status and 13% asked about the seller's cow JD status for new animal purchases for the 2nd year of the study.

Table 2.2 shows the mean ratings of the experiences of 425 farmers with the AJDI, with 95% CI of the AJDI experience statements. The mean rating for the statement, "My experience with the AJDI has been positive," was 6.4 (95% CI: 6.4 - 6.5).

2.4.4 EC culture results and apparent herd prevalence

In total, 957 EC herd categorizations were conducted on 460 herds, resulting in 218 EC-positive herd categorizations (23% of EC herd categorizations). Of the 460 herds, 18 herds (4%) were categorized once, 387 herds (84%) were categorized twice and 55 herds (12%) were categorized three times. Altogether, 54 herds (12%) were categorized EC-positive once, 40 herds (9%) were categorized EC-positive twice and 28 herds (6%) were categorized EC-positive three times. Of the 122 herds that were categorized EC-positive at least once, 63 herds (51.6%) had inconsistent herd categorizations (i.e., were not categorized EC-positive every year they were tested).

Based upon a parallel interpretation of the herds' EC categorizations throughout the study period (herds tested positive at least once), the apparent herd prevalence of MAP infection was 26.5% (122 of 460 herds). In the first year of testing (Y1), 19.3% of herds (89 of 460) were categorized positive by EC. When herds were tested a second time (Y2), 21.0% (93 of 442) were categorized positive by EC. Herds that were categorized positive in either of their first two years were tested a third time (Y3), with 65.4% (36 of 55) being categorized positive by EC.

The overall apparent herd prevalence of JD differed significantly by province, with 28.3% of NB herds, 75.0% of NL herds, 11.2% of NS herds and 34.7% of PE herds being EC-positive t[Pearson chi^2 (3) = 54.57, $p<0.01$]. There was no significant difference detected in the overall apparent herd prevalence of JD with respect to herd DHI participation [Pearson chi^2 (1) = 1.22, $p=0.27$].

The mean percentage of positive EC samples within the EC-positive herds was 45% (95% CI: 39 - 51%). In 14% of the EC-positive herds (17 of 122), all EC samples were positive for all years they were tested. A histogram of the mean percentage of positive EC samples for the EC-positive herds is shown in Figure 2.2.

2.4.5 Individual cow Johne's disease diagnostics

Of the 122 herds that tested EC-positive, individual cow MAP diagnostic testing was performed on 42 (34%) herds, with 31 herds tested once, 8 herds tested twice and 3 herds tested 3 times. Over half of these results were from milk ELISA (53.5%), while 30.9% were from fecal PCR, 10.8% were from serum ELISA, and 4.8% were from fecal culture. The last diagnostic test result for each cow was retained for summarization, assuming it was the best assessment of MAP infection status, totalling 5,496 individual cow MAP diagnostic test results. Of these individual cow diagnostic results, 93.6% were test negative, 6.1% were test positive, and 0.27% had suspect test results. When grouped by herd, the mean apparent within-herd prevalence (aWHP) was 5.5% (95% CI: 1.8 - 9.2%).

The EC test results were compared for herds with negative and positive individual cow test results. The mean percent of positive EC samples was 31.4% (95% CI: 15.8 - 47.0%) for the herds whose individual cow diagnostic test results were negative for all cows tested. The mean percent of positive EC samples was 68.2% (95% CI: 55.9 - 80.5%) for the herds whose individual cow diagnostic test results identified positive cows. These percentages were significantly different.

All herds that were categorized EC-negative were eligible to be included in the online EC status registry. Of the 429 herds that indicated their preference, 408 herd (95%) approved their inclusion in the registry if they were categorized EC-negative.

2.4.6 GEE logistic regression model of environmental culture results

A description of the variables of the multivariable GEE logistic regression analysis clustered at the herd level with a compound symmetry correlation matrix and robust standard errors are shown in Table 2.3. The outcome variable of interest for the model was EC. The significant predictor variables that were kept in the model were: province, season of EC sampling, housing type for lactating cows, housing type for dry cows, mortality >5% in heifers between 1 and 4 months of age, number of lactating cows, plan to purchase animals in the next year, number of bull calves, and percent of pneumonia in heifers born in the previous 6 months (whether or not they were treated). No significant interaction or confounding was detected.

The odds ratio (OR) estimates from the final model are shown in Table 2.5 and graphical presentation of the effects of two continuous variables on the probability scale are shown in Figure 2.3. The OR could be interpreted as risk ratios since a herd with JD was a relatively rare condition (Dohoo et al., 2009). The province that had the smallest risk of a herd being EC-positive was NS. Compared to the effect of NS, the risk significantly increased by approximately 4 times if the herd was in NB, 6 times if the herd was in PE and 28 times if the herd was in NL. The risk of being EC-positive in NL was also significantly higher than in either NB or PE but no significant difference was detected between the risk in NB and PE ($P = 0.28$). The season of EC sampling that had the highest risk of herds being EC-positive was the summer. Compared to the effect of summer, the risk was significantly decreased by approximately 50% if the EC sample was collected in the winter and 66% if the EC sample was collected in the spring. The risk of a herd being EC-positive was 62% less if lactating cows were housed in a tie-stall barn compared to a free-stall barn; however, no significant difference in risk was detected when comparing if dry cows were housed in a tie-stall barn versus a free-stall barn. Housing dry cows on a bedded pack did appear to significantly increase the risk by almost 2.5 times compared to housing dry cows in a free-stall barn. The risk of a herd being EC-positive was significantly increased by 60% if the herd planned to purchase cattle within the next year and significantly increased by 76% if the mortality in the heifers between 1 to 4 months of age was >5%. The risk of a herd being EC-positive was significantly increased as the number of lactating cows in the herd increased. For example, increasing the number of lactating cows in a herd by 25 appeared to increase the risk by about 16% ($1.006^{(25)} = 1.16$) while an increase of 100 cows appeared to increase the risk by about 82% ($1.006^{(100)} = 1.82$). Increasing the number of bull calves in a herd also was associated with a significantly increased risk of a herd being EC-positive, with each increase of 1 bull calf increasing the risk by about 5%. The percent of pneumonia in heifer calves born within the previous 6 months was positively and significantly associated with the risk of a herd being EC-positive. For example, when the percent of pneumonia increased 30%, the risk increased by 92% ($1.022^{(30)} = 1.92$).

Both Pearson and standardized Pearson residuals were computed for the model, with 95% of Pearson residuals and standardized Pearson residuals falling within the interval (-2, 2) (Dohoo et al., 2009). Four herds had standardized Pearson residuals >4 and as such, appear to be outlying observations. Examination of the data for the 4 outlying observations indicated that these herds had very low predicted probabilities of being a case herd (2.4% to 5.6%), but their leverage values and delta-betas were not high, which indicated that the observations did not have undue influence on the model. Goodness-of-fit tests were computed on the model and found to be not significant:

Pearson χ^2 (911) = 864.47 with Prob> χ^2 =0.8629 and Hosmer-Lemeshow χ^2 (8) = 5.23 with Prob> χ^2 =0.7329. All model evaluations indicated that the model fit the observed data well.

The predictive ability of the model was assessed using a receiver operating characteristic (ROC) curve and by graphing computed sensitivity (Se) and specificity (Sp) values of the model at various probability thresholds (Figure 2.4a and 2.4b respectively). The ROC curve extended reasonably well into the upper left-hand corner of the graph and the area under the curve was 0.81, which indicated that the model had moderate predictive ability (Dohoo et al., 2009). At the predicted probability cut-off of 0.5, the Se of the model was 34.56%, the Sp was 94.43%, and 80.80% of the observations were correctly classified.

2.4.7 Association of Johne's disease status with 305-day milk production

In the mixed effect linear regression models to determine whether or not the latest cow MAP diagnostic test result was associated with 305-day milk production, all variables initially included in the model were retained in the final model; specifically, cow MAP infection status, cow lactation number, cow average somatic cell count linear score, and number of cows in the herd's DHI record for the study period. A significant association was detected between 305-day milk production and the latest cow MAP diagnostic test result; test-positive cows produced 682 kg of milk less than test-negative cows.

2.5 DISCUSSION

In this study, 460 herds (70%) from the 4 Atlantic Provinces voluntarily participated in the AJDI, surpassing our participation goal of 60%. The AJDI participation rate was higher than many previously reported rates for JD control programs, including the USA (USDA-APHIS-VS-CEAH, 2008) (31.7%), Ontario (Pieper et al., 2015) (51.8%), and Alberta (Wolf et al., 2014a) (60%) but was lower than in Saskatchewan (Wolf et al., 2014a) (99%).

In our study, the apparent herd prevalence of MAP infection was 26.5% and the apparent within-herd prevalence was 5.5%. Furthermore, there was a significant difference in the estimates of the apparent herd prevalences between the Atlantic Provinces. These prevalences were similar to the reported cow-level prevalence of 2.6% and estimated true herd-level prevalence of 30% using serologic testing of dairy cows (VanLeeuwen et al., 2001). However, the cow-level prevalence of MAP infection from our study was substantially lower than the prevalence of 15.1% that was previously reported in culled dairy cattle in Atlantic Canada, but those test results were based upon histological testing of mesenteric lymph nodes and intestines where are known to be more sensitive than fecal, blood or milk tests (McKenna et al., 2004). In comparing to previous studies done in other parts of Canada, the herd-level prevalence values from this study are similar to the herd-level ELISA-positive prevalence of 27.2% reported for Ontario (Pieper et al., 2015) but are less than the herd-level EC apparent prevalence of 47% and 53% for Alberta and Saskatchewan, respectively (Wolf et al., 2014a). The herd-level prevalence is also less than the reported 68.1% of US dairies that are infected with MAP (USDA-APHIS-VS-CEAH, 2008).

Only 34% of the EC-positive herds elected to conduct individual cow MAP diagnostic tests. While this was lower than we expected during the design of the AJDI, it was encouraging that the focus of control may have been placed upon herd diagnostics and management changes instead of cow diagnostics for test-and-cull strategies. Test-and-cull strategies without addressing infection transmission routes have been found, by simulation, to be ineffective in reducing prevalence and were not cost-effective methods of JD control (Kudahl et al., 2008).

The new knowledge obtained on the prevalence of MAP infection in Atlantic Canada has important implications for the control of JD in the region. Considering that approximately three quarters of our study herds were uninfected or low prevalence, management practices that focus on external biosecurity will be essential to minimize the risk of acquiring more MAP infections through animal acquisitions. Although a third of the herds in the study indicated they plan to purchase animals within the next year, a significant increase was detected in the number of producers that will now require herd-of-origin JD information for new animal purchases. Also, a study had estimated the economic benefit of participating in the Alberta Johne's Disease Initiative, a management-based control program similar to AJDI, and the authors concluded that participation was cost-effective for herds with low within-herd prevalence (Wolf et al., 2014b). Based on that paper, it would be expected that herds in Atlantic Canada can expect a positive net benefit through participation in the AJDI.

Although Johne's disease was first described in the late 1800s and has since been reported in most countries around the world (USDA-APHIS-VS_CEAH, 2008), only 40% of producers had actively sought info on JD prior to the AJDI. The majority of producers had no knowledge of JD or passively heard about JD from other producers or the media. Therefore, the educational structure of the AJDI to increase awareness and knowledge of JD was required. It was encouraging that the producer responses to the questionnaire statements evaluating their AJDI experience were positive and indicated that the initiative was easy, worthwhile, reasonable and educational.

The significant association between MAP diagnosis for a cow within a herd and mean percent of positive EC samples in EC-6 sets of EC-positive herds is similar to the association reported in Lavers et al. (2013). This result supports the Lavers et al. study (2013), which proposed it is likely that the number of positive EC samples within an EC-6 set provided an indication of apparent within-herd prevalence of MAP infection. The AJDI recommendation is to selectively conduct individual cow diagnostic testing in herds with a high percentage of EC samples testing positive in the EC-6 set. Using this strategy would increase the likelihood of finding JD-infected cows using standard diagnostic modalities, and maximizing the cost-benefit of conducting individual cow MAP diagnostics.

Our study detected a significant difference in cow milk production based on cow JD status. A previous Canadian study found that in their 1st and 5th lactations, ELISA-seropositive cows produced 573 and 1273 kg less than seronegative cow, respectively (VanLeeuwen et al., 2002). These values are similar to the decrease in milk that the model in our study predicted for cows that are positive for JD. These findings support the goal of minimizing JD spread to mitigate economic loss through decreased milk production.

A logistic GEE model of EC result was built to evaluate if herd demographics were associated with the odds of a herd being positive for JD. The risk of being EC-positive was significantly increased as the number of lactating cows, the number of bull calves, and the percentage of pneumonia in heifer increased. The risk of being EC-positive was also significantly increased if the herd planned to purchase cattle in the next year and if the herd had more than 5% mortality in heifers between 1 and 4 months of age. Furthermore, the risk of being EC-positive was significantly higher in the summer (July through September) compared to the winter and the spring, and was significantly higher if the herd was in NB, NL or PE compared to NS. The effect of herd size has been previously reported but the reason for this effect is unknown (Wells and Wagner, 2000; Wolf et al., 2014a). An effect of season has been observed in a number of previous studies but there are inconsistencies as to which season has the highest risk. McKenna et al. (2004) found that June had the highest proportion of cows being JD-positive (included in summer variable) but Laurin et al. (2015) found the opposite. Further research to better understand the relationship between season of diagnostic testing and risk of being Johne's positive is required. The effect of province was partially expected as the herds in NL purchase a high proportion of their replacement animals and as such, have a high risk of bringing JD into their herds. The lower risk for herds in NS was not expected and further investigation into provincial differences in dairy management or purchasing strategies is recommended. The higher risk for herds with worse heifer health (pneumonia and mortality) suggests there is common risk that leads to both heifer health problems and JD. Based on the final model (Table 2.4), the following recommendations can be made to dairy producers to help reduce their herd risk for JD introduction and transmission: do not purchase cattle and focus on management to decrease the risk for heifer health problems and JD.

2.6 CONCLUSIONS

The AJDI was launched with the overall goal of reducing the prevalence and impact of JD in Atlantic Canada. There was good participation from both the dairy producers and the local FAPM veterinarians, and the producer experience with the AJDI was positive. The study estimated that the majority of dairy farms in Atlantic Canada are not infected with MAP and the apparent within-herd prevalence of JD was low. In just 3 years, we did not expect the control program to have a visible impact on the herd prevalence of MAP; however, this study did show that healthy heifer rearing and reducing cattle purchasing may lower a herd's risk for MAP infection.

2.7 REFERENCES

Barkema, H. W., S. Hendrick, J. M. Buck, S. Ghosh, G. G. Kaplan and K. P. Rioux. 2011. Crohn's disease in humans and Johne's disease in cattle - linked diseases?. Zoonotic Pathogens in the Food Chain. D. O. Krause and S. Hendrick eds. CAB International, Cambridge, MA, USA.

Barkema, H. W., J. W. Hesselink, S. L. B. McKenna, G. Benedictus and H. Groenendaal. 2010b. Global prevalence and economics of infection with mycobacterium avium subsp. paratuberculosis in ruminants. Paratuberculosis: Organism, Disease, Control. M. Behr and D. M. Collins eds. CAB International, Boston, MA, USA.

Bauman, C. A., H. W. Barkema, J. Dubuc, G. P. Keefe and D. F. Kelton. 2016. Identifying management and disease priorities of Canadian dairy industry stakeholders. J. Dairy Sci. 99:10194-10203.

Chi, J., J. A. VanLeeuwen, A. Weersink and G. P. Keefe. 2002. Direct production losses and treatment costs from bovine viral diarrhoea virus, bovine leukosis virus, *Mycobacterium avium* subspecies *paratuberculosis*, and Neospora caninum. Prev. Vet. Med. 55:137-153.

Chiodini, R. J., H. J. Kruiningen and R. S. Merkal. 1984. Ruminant paratuberculosis (Johne's disease): The current status and future prospects. Cornell Vet. 74:218-262.

Dohoo, I. R., W. Martin and H. Stryhn. 2009. Veterinary Epidemiologic Research. 2nd edition. VER Inc., Charlottetown, Prince Edward Island, Canada.

Hendrick, S. H., D. F. Kelton, K. E. Leslie, K. D. Lissemore, M. Archambault, R. Bagg, P. Dick and T. F. Duffield. 2006. Efficacy of monensin sodium for the reduction of fecal shedding of *Mycobacterium avium* subspecies *paratuberculosis* in infected dairy cattle. Prev. Vet. Med. 75:206-220.

Kudahl, A. B., S. S. Nielsen and S. Østergaard. 2008. Economy, efficacy, and feasibility of a risk-based control program against paratuberculosis. J. Dairy Sci. 91:4599-4609.

Laurin, E. L., M. Chaffer, J. T. McClure, S. L. B. McKenna and G. P. Keefe. 2015. The association of detection method, season, and lactation stage on identification of fecal shedding in *Mycobacterium avium* subspecies *paratuberculosis* infectious dairy cows. J. Dairy Sci. 98:211-220.

Lavers, C. J., H. W. Barkema, I. R. Dohoo, L. B. McKenna and G. P. Keefe. 2014. Evaluation of milk ELISA for detection of *Mycobacterium avium* subspecies *paratuberculosis* in dairy herds and association with within-herd prevalence. J. Dairy Sci. 97:299-309.

Lavers, C. J., S. L. B. McKenna, I. R. Dohoo, H. W. Barkema and G. P. Keefe. 2013. Evaluation of environmental fecal culture for *Mycobacterium avium* subspecies *paratuberculosis* detection in dairy herds and association with apparent within-herd prevalence. Can. Vet. J. 54:1053-1060.

Lombard, J. E., F. B. Garry, B. J. McCluskey and B. A. Wagner. 2005. Risk of removal and effects on milk production associated with paratuberculosis status in dairy cows. J. Am. Vet. Med. Assoc. 227:1975-1981.

McAloon, C. G., P. Whyte, S. J. More, M. J. Green, L. O'Grady, A. Garcia and M. L. Doherty. 2015. The effect of paratuberculosis on milk yield: A systematic review and meta-analysis. J. Dairy Sci. 99:1449-1460.

McKenna, S. L. B., G. P. Keefe, H. W. Barkema, J. McClure, J. A. VanLeeuwen, P. Hanna and D. C. Sockett. 2004. Cow-level prevalence of paratuberculosis in culled dairy cows in Atlantic Canada and Maine. J. Dairy Sci. 87:3770-3777.

McKenna, S. L. B., G. P. Keefe, H. W. Barkema and D. C. Sockett. 2005. Evaluation of three ELISAs for *Mycobacterium avium* subspecies *paratuberculosis* using tissue and fecal culture as comparison standards. Vet. Microbiol. 110:105-111.

McKenna, S. L. B., G. P. Keefe, A. Tiwari, J. VanLeeuwen and H. W. Barkema. 2006. Johne's disease in Canada part II: Disease impacts, risk factors, and control programs for dairy producers. Can. Vet. J. 47:1089-1099.

Pieper, L., T. J. DeVries, U. S. Sorge, A. Godkin, K. J. Hand, N. R. Perkins, J. Imada and D. F. Kelton. 2015. Variability in risk assessment and management plan (RAMP) scores completed as part of the Ontario Johne's Education and Management Assistance Program (2010-2013). J. Dairy Sci. 98:2419-2426.

Rasmussen, P., H. W. Barkema, S. Mason, E. Beaulieu and D. C. Hall. 2020. Economic losses due to Johne's disease (paratuberculosis) in dairy cattle. J. Dairy Sci. 104:3123-3143.

Sorge, U., D. Kelton, K. Lissemore, A. Godkin, S. Hendrick and S. Wells. 2010. Attitudes of Canadian dairy farmers toward a voluntary Johne's disease control program. J. Dairy Sci. 93:1491-1499.

Tiwari, A., J. A. VanLeeuwen, S. L. B. McKenna, G. P. Keefe and H. W. Barkema. 2006. Johne's disease in Canada Part I: Clinical symptoms, pathophysiology, diagnosis, and prevalence in dairy herds. Can. Vet. J. 47:874-882.

USDA-APHIS-VS-CEAH, 2008. Johne's disease on US dairies, 1991-2007. Accessed June 11. 2021. www.aphis.usda.gov/animal_health/nahms/dairy/downloads/dairy07/Dairy07_is_Johnes_1.pdf.

VanLeeuwen, J. A., G. P. Keefe and A. Tiwari. 2002. Seroprevalence and productivity effects of infection with bovine leukemia virus, *Mycobacterium avium* subspecies *paratuberculosis*, and Neospora caninum in Maritime Canadian dairy cattle. Bov. Pract. 36:86-91.

VanLeeuwen, J. A., G. P. Keefe, R. Tremblay, C. Power and J. J. Wichtel. 2001. Seroprevalence of infection with *Mycobacterium avium* subspecies *paratuberculosis*, bovine leukemia virus, and bovine viral diarrhea virus in Maritime Canada dairy cattle. Can. Vet. J. 42:193-198.

Wells, S. J. and B. A. Wagner. 2000. Herd-level risk factors for infection with *Mycobacterium paratuberculosis* in US dairies and association between familiarity of the herd manager with the disease or prior diagnosis of the disease in that herd and use of preventive measures. J. Am. Vet. Med. Assoc. 216:1450-1457.

Wolf, R., H. W. Barkema, J. De Buck, M. Slomp, J. Flaig, D. Haupstein, C. Pickel and K. Orsel. 2014a. High herd-level prevalence of *Mycobacterium avium* subspecies *paratuberculosis* in western Canadian dairy farms, based on environmental sampling. J. Dairy Sci. 97:6250-6259.

Wolf, R., F. Clement, H. W. Barkema and K. Orsel. 2014b. Economic evaluation of participation in a voluntary Johne’s disease prevention and control program from a farmer's perspective - The Alberta Johne’s Disease Initiative. J. Dairy Sci. 97:2822-283

Table 2.1 Production and reproduction variables for Dairy Herd Improvement (DHI) subscribing herds in Atlantic Canada in 2011-13

DHI Item	n	Median[1]	Range	
Number of cows on record throughout the study period[2]	308	125	29	826
305-day milk production (kg)	308	9,256	5,167	12,097
305-day milk fat percentage	308	3.86	3.26	5.24
305-day milk protein percentage	308	3.15	2.89	3.79
Average somatic cell count (x 1,000)	308	86	36	641
Average somatic cell count linear score	308	2.28	1.23	4.37
Lactation number	308	2	1	5
Days to first service	290	84	59	269
Previous first service to calving interval	292	312	273	485
Calving interval between most recent calvings	307	407	361	530
Calving interval between previous 2 calvings	298	397	337	722
Calving interval between calvings 2 and 3 times ago	256	379	258	585
Percent of cows culled throughout the study period[3]	308	42.1%	1.6%	69.2%

[1]Median of herd values, which are medians of the cow records per herd

[2]Median of count of unique animals on test per herd

[3]Median of percent of cows culled per herd

Table 2.2 Atlantic Johne's Disease Initiative experience statements of 425 dairy producers in Atlantic Canada in 2011-13

Experience Statement	Mean[1]	95% CI	
Completing the risk assessment with our certified veterinarian was easy	6.5	6.5	6.6
The time required to complete the risk assessment and management plan with our certified veterinarian was worthwhile	6.4	6.3	6.4
The Johne's disease management plan was reasonable	6.3	6.3	6.4
The Johne's disease management plan also helps manage other diseases (e.g. calf scours, pneumonia, etc.)	5.4	5.3	5.6
I learned a lot about Johne's disease by completing the Johne's disease risk assessment and designing the management plan with our certified veterinarian	5.6	5.5	5.7
My experience with the AJDI has been positive	6.4	6.4	6.5

[1]Using a 7-point Likert scale, with 1 being completely disagree and 7 being completely agree

Table 2.3 Description of variables associated with environmental culture herd positivity for Johne's disease infection (P < 0.10) from GEE univariable logistic regression analyses in 460 herds in Atlantic Canada in 2011-13

Description	Codes/Units	Proportion of Herds EC-positive[1]	P-value
Province	1 = NS	0.07	<0.001
	2 = NB	0.24	
	3 = NL	0.67	
	4 = PE	0.32	
Season of environmental culture sampling	1 = summer	0.21	0.070
	2 = fall	0.29	
	3 = winter	0.25	
	4 = spring	0.16	
Housing type for lactating cows	1 = free-stall	0.28	0.019
	2 = tie-stall	0.14	
	3 = other/combo	0.32	
Housing type for dry cows	1 = free-stall	0.21	0.020
	2 = tie-stall	0.13	
	3 = bedded pack	0.33	
	4 = combo	0.23	
Number of lactating cows	Cows	n/a	<0.001
Number of dry cows	Cows	n/a	0.004
Number of heifers (aged 12 months – calving)	Heifers	n/a	0.010
Number of bull calves	Bull calves	n/a	0.065
Percent of pneumonia in heifers born in the previous 6 months	Percent	n/a	0.030
Percent of time lactating cows spent inside during the summer	Percent	n/a	<0.001
Plan to purchase animals in the next year	0 = no	0.19	0.050
	1 = yes	0.29	
Dairy Herd Improvement subscribing herd	0 = no	0.29	0.006
	1 = yes	0.20	

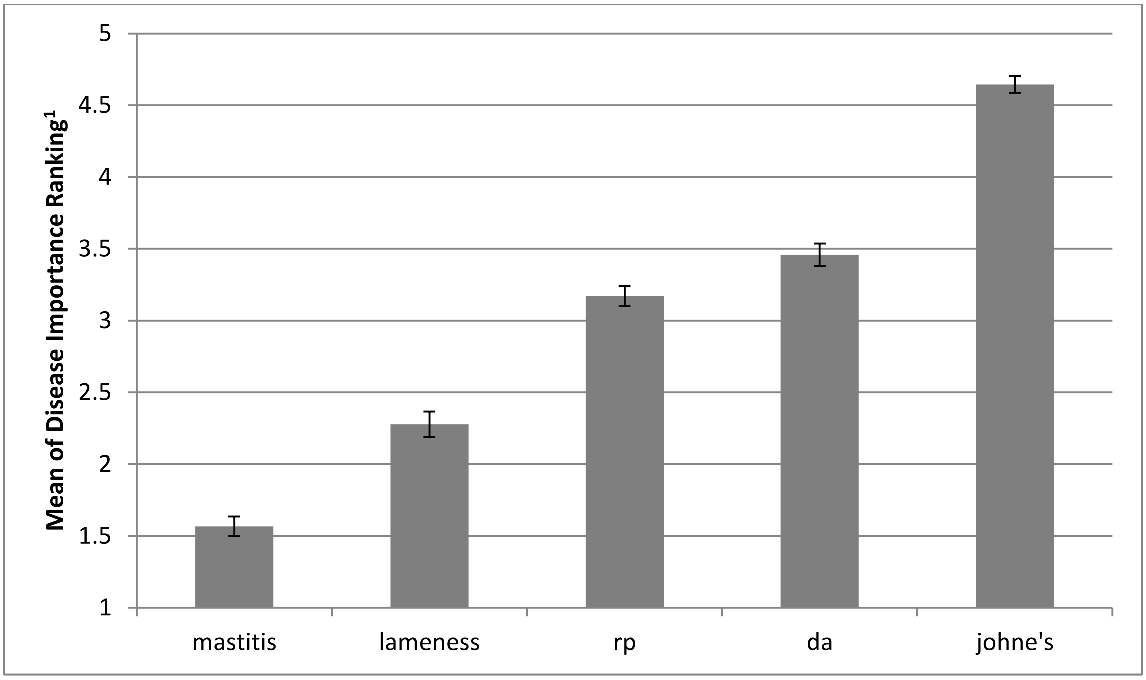
[1]Based on parallel interpretation of environmental culture results

Table 2.4 Final multivariable GEE logistic regression model of environmental culture results in 458 herds in Atlantic Canada in 2011-13

Variable	OR	P-value	95% CI of OR	
Province		<0.001[1]		
Nova Scotia[a]	Baseline			
New Brunswick[b]	4.390	<0.001	2.196	8.777
Newfoundland & Labrador[c]	27.633	<0.001	10.066	75.859
Prince Edward Island[b]	6.151	<0.001	2.915	12.979
Season of environmental culture sampling		0.003[1]		
Summer[a]	Baseline			
Fall[ab]	0.739	0.222	0.455	1.200
Winter[bc]	0.501	0.012	0.292	0.860
Spring[c]	0.343	<0.001	0.191	0.617
Housing type for lactating cows		0.003[1]		
Free-stall[a]	Baseline			
Tie-stall[b]	0.376	0.002	0.204	0.693
Other[ab]	0.419	0.058	0.170	1.030
Housing type for dry cows		0.048[1]		
Free-stall[a]	Baseline			
Tie-stall[ab]	1.183	0.708	0.491	2.845
Bedded pack[b]	2.426	0.012	1.212	4.858
Combo[a]	0.978	0.950	0.489	1.957
Mortality >5% in heifers (1-4 months old)	1.763	0.018	1.103	2.816
Number of lactating cows	1.006	<0.001	1.003	1.010
Number of bull calves	1.053	0.033	1.004	1.103
Percent of pneumonia in heifers born in the previous 6 months	1.022	0.002	1.008	1.036
Plan to purchase animals in the next year	1.597	0.024	1.065	2.394

[a,b,c]Predictor variable categories sharing a letter in the group are not significantly different at the 5% level

Figure 2.1 Mean rankings of importance with 95% confidence intervals from most to least important herd disease for 458 herds in Atlantic Canada in 2011-13



[1]Ranking of 1 considered most important
rp: Retained placenta
da: Displaced abomasum

Figure 2.2 Proportions of herds by mean percentages of positive environmental culture (EC) samples for 122 EC-positive herds in Atlantic Canada in 2011-13

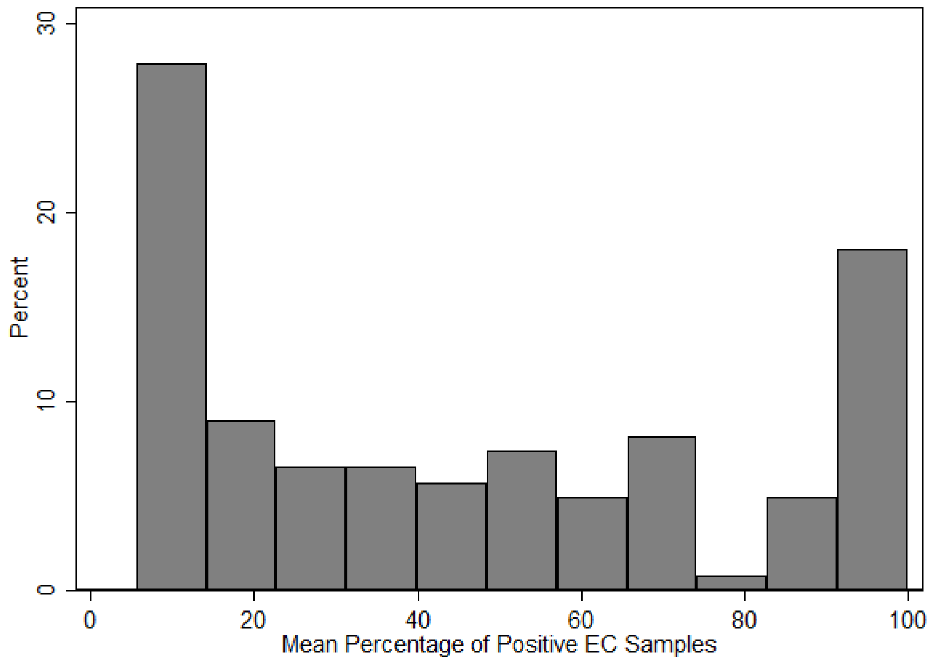
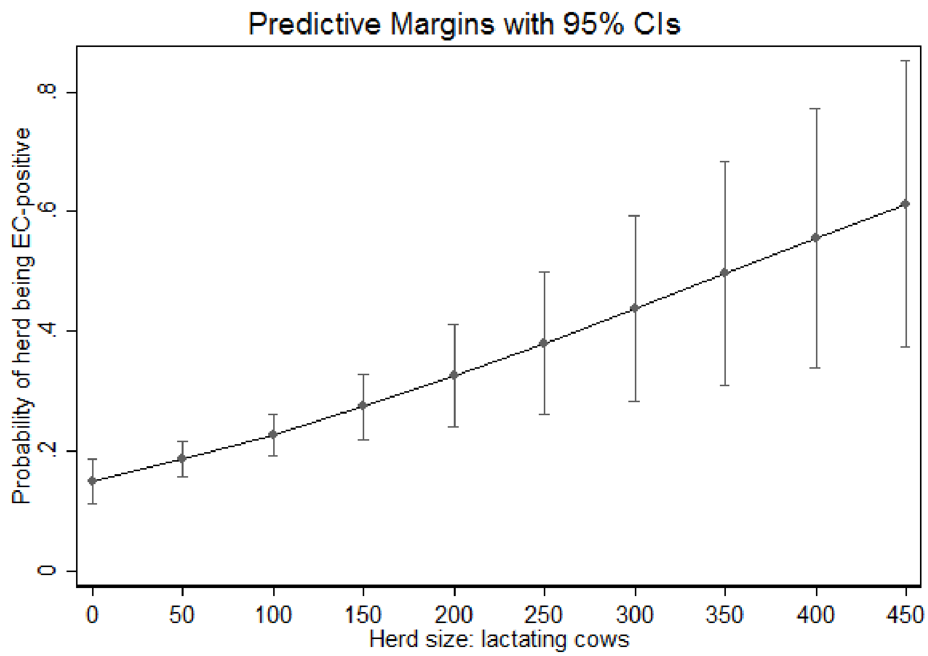


Figure 2.3 Predicted effects of variables with 95% confidence intervals (CIs) on the probability scale from the final multivariable GEE logistic regression model of environmental culture results in 458 herds in Atlantic Canada in 2011-13

a) Variable: number of lactating cows



b) Variable: percent of pneumonia in heifers born in the previous 6 months

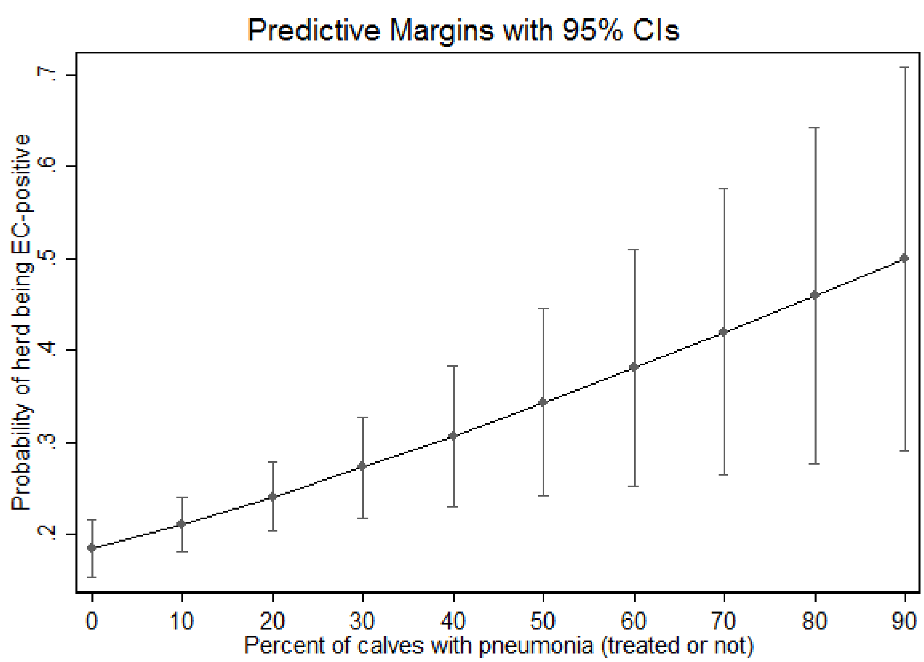


Figure 2.4 Receiver Operating Characteristic (ROC) curve for logistic GEE model of EC result

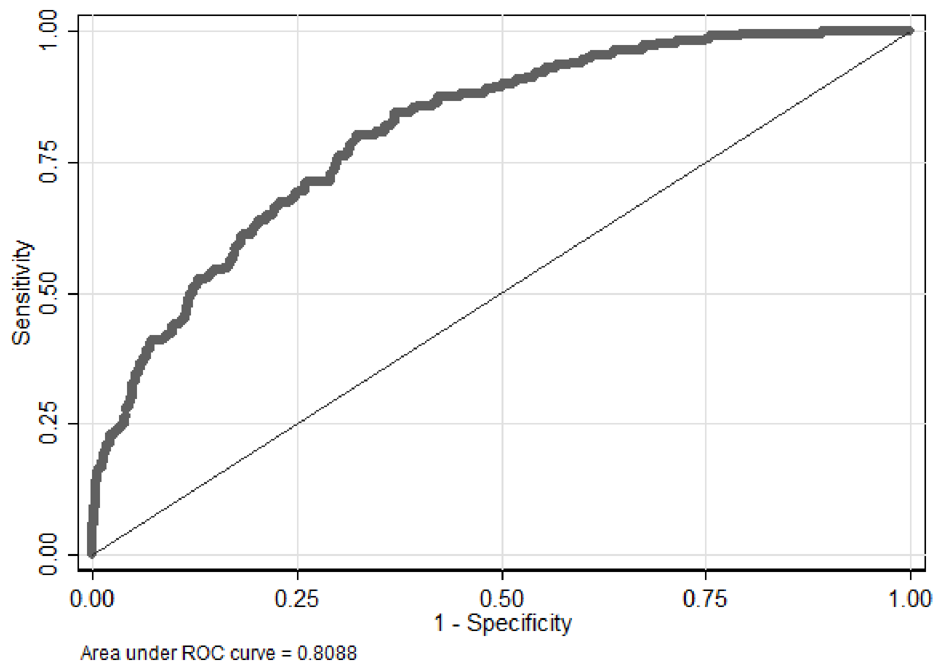
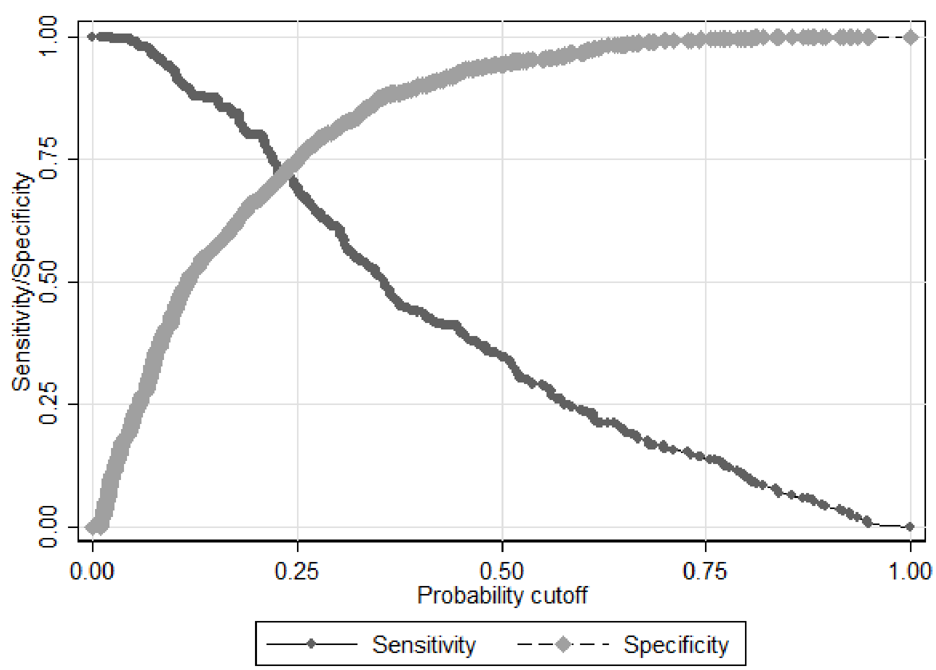


Figure 2.5 Receiver Operating Characteristic (ROC) 2-graph curve for logistic GEE model of EC result



CHAPTER 3: RISK ASSESSMENT AND ADHERENCE TO MANAGEMENT PLAN RECOMMENDATIONS ON DAIRY FARMS PARTICIPATING IN A VOLUNTARY JOHNE'S DISEASE CONTROL PROGRAM

3.1 ABSTRACT

The Atlantic Johne's Disease Initiative (AJDI) was launched as a risk assessment-based control program to reduce the impact and prevalence of Johne's disease in Atlantic Canada through risk assessment and management plan (RAMP) recommendations. The objectives of this study were to: (1) describe the risk assessment and management plan recommendations (RAMP) in the AJDI, (2) assess the adherence to RAMP recommendations using 3 methods: producer self-assessment, veterinary assessment, and comparison of RA scores between year 1 and year 2 of participation in the AJDI, and (3) describe the perception of dairy producers participating in the AJDI about recommended best management practices that had less than ideal adherence. In this study, 894 RAMPs were conducted by AJDI-certified veterinarians on 457 dairy herds from 2012-14, with risk scores assigned to practices and up to 3 management recommendations made each year. For all farms, the overall mean proportion of maximum risk score (PMRS) was 0.448 (95% CI [0.441, 0.455]). The mean PMRS was significantly lower for herds that tested negative throughout the study period compared to herds that tested positive at least once ($P < 0.001$). After herds had at least 1 year of participation in the AJDI, significant reductions were observed in the mean PMRS overall ($P < 0.001$). Even though improvements in management practices were made to control Johne's disease, self-assessed and vet-assessed adherence ratings indicated that there were difficulties with the adherence to management plan recommendations for a substantial proportion of the AJDI herds. The primary reasons for lack of adherence were that practices recommended in the

management plan were viewed as not practical or low priority by the producer. In the future, specific efforts to improve adherence to program recommendations may further improve Johne's disease control.

3.2 INTRODUCTION

Johne's disease (JD), or paratuberculosis, is the clinical manifestation of an incurable, chronic, infectious enteritis of ruminants caused by the bacterium *Mycobacterium avium* subspecies *paratuberculosis* (MAP). MAP is present on farms worldwide (Chiodini et al., 1984; Hendrick et al., 2006) and causes substantial economic losses through decreased milk production and slaughter value, increased culling risk, mortality, treatment costs and reproductive loss (Chi et al., 2002; McKenna et al., 2006a; Barkema et al., 2010; Wolf et al., 2014, Rasmussen et al., 2020). Estimates of apparent herd-level seroprevalence of MAP infection in dairy herds among Canadian provinces vary between 9.8% and 43.1% (Tiwari et al., 2006). In Atlantic Canada, the herd level apparent prevalence of MAP has been recently estimated at 26.5% using an environmental fecal culture (EC) procedure (see Chapter 2).

Fecal-oral transmission is the primary mechanism for MAP transmission, with calves being most susceptible to infection (Windsor and Whittington, 2010). Reducing the prevalence of existing MAP infections has been difficult due to lack of accurate diagnostic tests (McKenna et al., 2005; Nielsen and Toft, 2008). As such, effective JD control programs typically involve both the implementation of best management practices (BMP) to decrease calf exposure to MAP, and test-and-cull to reduce the number of infected animals that may shed MAP (McKenna et al., 2006a; Kudahl et al., 2008).

JD control programs that rely on implementation of BMP use risk assessment (RA) to identify current management practices that have a high potential to spread MAP between and within farms (Sorge et al., 2010; Garry, 2011; Wolf et al., 2015). The RA consists of a questionnaire that evaluates and scores the management practices that cows are exposed to during their lives on a farm (Sorge et al., 2010). Management practices with high scores are considered to be high risk for contributing to the occurrence of new MAP infections. Working in collaboration, veterinarians and dairy producers develop and prioritize a list of BMP in a management plan (MP) in order to modify selected high-risk management practices that were identified by the RA (Sorge et al., 2010; Garry, 2011; Wolf et al., 2015). Materials have been developed to provide standardization for conducting RAs and developing MPs (Garry, 2011; Barker et al., 2012).

Ultimately, the efficacy of a RA-based control program is determined by the adherence of the producer to the MP of proposed modifications to high-risk management practices. Previous studies have reported contrasting findings with respect to adherence to Johne’s disease MPs. In 2 US studies and in the Alberta Johne’s Disease Initiative, farms generally improved their management during participation in a MAP control program (Raizman et al., 2006; Wells et al., 2008; Wolf et al., 2015). Conversely, in Australia, studies have indicated that dairy producers are not implementing MPs as recommended (Wraight et al., 2000; Ridge et al., 2005), In a pilot study for a JD control program in Ontario and Western Canada, the majority of dairy farms significantly improved their overall RA scores at the second RA however, on 20% of the farms, RA scores significantly worsened (Sorge et al., 2011), and producer-reported adherence with recommended management changes was poor overall (Sorge et al., 2010). To our knowledge, no JD control strategy has successfully eradicated JD.

Human behaviour and behavioural change, such as changing a management practice, is complex. In the Canadian pilot study, main reasons given for noncompliance were that dairy producers did not believe: 1) a change of management practices was necessary; or 2) the available barn setting or space allowed for the management change (Sorge et al., 2010). In the Alberta Johne's Disease Initiative, herds that were test-positive were more likely to implement new BMP than test-negative herds, but management improvement decreased over years of participation (Wolf et al., 2015). A variety of methods were used to evaluate adherence in the aforementioned studies, including: farm revisit to directly score adherence with recommended management practices (Wraight et al., 2000; Ridge et al., 2005), telephone questionnaire to obtain producer rating of adherence (Sorge et al., 2010), and comparison of RA scores between different years of participation in a control program (Raizman et al., 2006; Wells et al., 2008; Sorge et al., 2011; Wolf et al., 2015). The disparate study results may be due to the use of different assessment methods for adherence and because of diverse perceptions of BMPs for JD among the participating farmers. However, this remains to be confirmed.

To reduce the impact and prevalence of JD in the Atlantic Canadian dairy industry, the Atlantic Johne's Disease Initiative (AJDI) was launched in 2011. The AJDI had very high participation rates, with 70% of herds voluntarily enrolling in the program (see Chapter 2). A significant component of the AJDI prevalence reduction program was farm-specific veterinary RA and MP development (RAMP). It was difficult to predict how dairy producers would adhere to the AJDI from the above-mentioned studies, particularly since adherence seemed to differ between different dairy populations, prevalences (herd and within-herd) of MAP infection, and JD control strategies. As such, it was important to evaluate the adherence to AJDI MP recommendations using a variety of methods to be able to compare results of the different methods within our study population, and to compare the results to other study populations. It was also important to describe the AJDI RAMP outcomes to provide information for researchers and the dairy industry to improve JD control strategies, particularly for areas with low to moderate disease prevalence. Therefore, the objectives of this study were to: (1) describe the RA and MP recommendations in the AJDI, (2) assess the adherence to MP recommendations in the AJDI using 3 methods: producer self-assessment (AR-self), veterinary assessment (AR-vet), and comparison of RA scores between year 1 and year 2 of participation in the AJDI, and (3) describe the perception of dairy producers participating in the AJDI about recommended BMP that were not adopted or rigorously applied on farm in order to better understand the differences between the assessment methods, and limitations of BMP implementation.

3.3 MATERIALS AND METHODS

3.3.1 Study location and population

The AJDI was launched in 2011 as a 3-year voluntary risk assessment-based prevention and control program for JD in the Atlantic Canadian Provinces [New Brunswick (NB), Newfoundland and Labrador (NL), Nova Scotia (NS) and Prince Edward Island (PE)] (see Chapter 2). The AJDI prevalence reduction program consisted of 3 components: herd JD categorization by environmental culture (EC), individual cow MAP diagnostics for herds that were categorized EC-positive, and farm-specific JD risk assessment and management plan development (RAMP) by certified veterinarians. The first 2 of these components were described in Chapter 2. The farm-specific RAMP component will be the focus of this study.

During the study period, 70% of herds from the 4 Atlantic Provinces (463 of 664 herds) participated in the AJDI. Program goals were to recruit at least 60% of the dairy operations to participate in the AJDI and to train at least 1 veterinarian from each veterinary clinic providing service to the dairy producers of Atlantic Canada to function as certified AJDI veterinarians. Certification was achieved by the completion of an advanced education program designed by the AJDI that included in-person training (small groups or one-on-one) and web-based training and evaluation. Topics covered in the training included JD pathogenesis, MAP diagnostic test interpretation, and the conduct of RAMPs. The certified veterinarians solely delivered diagnostic test results to the producers and conducted the RAMPs.

3.3.2 Data and sample collection

Herds participating in the AJDI were categorized as either EC-negative (EC-neg) or EC-positive (EC-pos) by an EC procedure previously described in Chapter 2. Briefly, for each herd JD categorization, 6 mixed manure samples were collected from prescribed locations by trained technical staff. A herd was categorized as positive if there was ≥1 positive EC sample within a set of 6 samples. Herds were retested and categorized once yearly (minimum 10 months to a maximum of 14 months) and if they were categorized EC-neg for 2 consecutive years, retesting was conducted every other year as long as they remained EC-neg. Each year, when the certified veterinarians delivered the EC results to the producers, they conducted a farm-specific RAMP.

At the time of each EC sample collection, the trained technical staff also completed a questionnaire with the producer(s) about herd demographics and producer opinions of the AJDI and BMP for JD, as previously described in Chapter 2. The questionnaires for the second and third year EC sample collection included producer self-assessment ratings of the farm's adherence to the management plan in the previous RAMP, using a 7-point Likert scale.

Risk assessment workbooks, designed using the Canadian national standards for risk assessment, were used for the RAMP process (McKenna et al., 2006b; Barker et al., 2012). Elements from the risk assessment tools of the Ontario Johne's Education and Management Assistance Program and Alberta Johne's Disease Initiative were incorporated into the workbooks (Pieper et al., 2015; Wolf et al., 2015). The risk assessment workbooks were designed to serve multiple purposes: (1) assist the certified veterinarians to conduct thorough assessment of each farm's JD risk practices, (2) aid in determining priority areas to control within-herd and between-herd spread of MAP (in conjunction with the herd EC data), (3) document that a consensus was built with the producer on a practical management plan, (4) allow for simple filing of the RAMP data with the AJDI, (5) provide a written copy of the RAMP to the producer, and (6) serve as an on-farm educational tool. Different risk assessment workbooks were designed for EC-neg and EC-pos farms. Workbooks for EC-neg herds assigned higher risk assessment scores to risk factors related to external biosecurity, notably animal purchase history. Conversely, EC-pos herds assigned higher risk assessment scores to management practices related to internal biosecurity, specifically the source of colostrum fed to calves and the exposure of pre-weaned calves to cow manure. The workbooks also differed in the recommended management practices regarding the source of colostrum fed to calves; the most practical control measure of feeding colostrum from one cow to one calf was recommended for EC-neg herds, whereas feeding pasteurized or artificial colostrum was recommended for known infected herds.

The RAMP was semi-quantitative, with high scores indicating a high risk of MAP transmission (up to a maximum total of 300 points). The RAMP contained 6 risk assessment sections: (1) general JD and biosecurity questions ("Johne's/biosecurity") (maximum 60 points for EC-neg; maximum 50 points for EC-pos), (2) calving area risk management ("calving area") (maximum 75 points), (3) pre-weaned heifer risk management ("pre-weaned") (maximum 65 points for EC-neg; maximum 75 points for EC-pos), (4) weaned heifer to first calving risk management ("heifer") (maximum 40 points), (5) dry cow risk management ("dry cow") (maximum 30 points), and (6) lactating cow risk management ("lactating cow") (maximum 30 points). Scoring by the certified veterinarians was based on observed management practices, along with clarifying information from the producer. Once a RA was completed, the certified veterinarians transferred the scores from each risk question in the workbook to a score sheet.

Based on the farm RA, and what could be practically achieved in the following 12 months, up to 3 priority items for JD control were identified, and a consensus was built with the producer on action to be taken. If feasible, best management practices related to the identified priority items were chosen as the goal activities for the MP. If the BMP was not practical for the farm to implement within the following 12 months, the lowest score procedure that was feasible was chosen for that target area. The chosen goal activities were indicated and ranked on the MP Sheets (with carbon copy), which were then signed by both the producer and the veterinarian. The workbook and a copy of the MP stayed on farm, whereas the score sheets and the MP sheets were faxed to the AJDI.

When RAMPs were completed for the second or third time on a farm, the certified veterinarians also rated management plan adherence by completing a Management Plan Implementation survey (Appendix B.1). For the survey, the certified veterinarians were asked if the previous year's management plan recommendations were adopted and rigorously applied on the farm. The certified veterinarians rated each MP recommendation separately using a 7-point Likert scale, with 1 being completely disagree and 7 being completely agree that there was good adherence. If a recommendation was rated below 5, the producer was asked to indicate which impediment(s) prevented the adoption of the BMP from the following options: (1) BMP viewed as low priority, (2) BMP viewed as not practical, (3) BMP viewed as too costly, (4) BMP not compatible with other management practices on the farm, or (5) other (describe).

3.3.3 Laboratory Analyses

The fresh manure samples were cultured at the Atlantic Veterinary College (AVC) (University of Prince Edward Island, Charlottetown, PE, Canada) using an ESP *para*-JEM broth culture system (TREK ESP® Culture System II, Thermo Scientific, Oakwood Village, Ohio). A quantitative polymerase chain reaction (PCR) (VetAlert™ Johne's Real-Time PCR kit, Tetracore®, Rockville, Maryland) was used to confirm cultures that were positive for growth through the TREK incubator sensor or were acid-fast positive after 49 days of incubation (McKenna et al., 2005; Lavers et al., 2013). Additional details on laboratory analyses can be found in Chapter 2.

3.3.4 Statistical analyses

Statistical analyses were performed using Stata/MP 14.1 (StataCorp LP, College Station, Texas, USA). Statistical significance was set at a p-value of <0.05.

In order to compare the RA scores of the EC-neg and EC-pos farms, the differences in RA item scoring had to be accommodated; for example, if animals were purchased in the last 5 years from multiple herds, the risk score for EC-neg herds was 30 points out of a maximum of 30 points while the risk score for EC-pos herds was 20 points out of a maximum of 20 points. The RA item scores were used to calculate a proportion of maximum risk score (PMRS) for each management item assessed. For the example given above, the PMRS would be 1.0 (indicating 100%) for this management item for both EC-neg and EC-pos herds.

Calculation of the differences in PMRS between the RAMP years [first year RAMP (RAMP1), second year RAMP (RAMP2), and third year RAMP (RAMP3)] was done to compare the RA scores of herds based upon years of participation in the AJDI. Available-case analysis (ACA), using all cases which have observed values on variables that are part of the analyses, was used for RAMPs with missing RA item scores (van Ginkel et al., 2010). When only a small amount of items are missing (<10% of observations have missing values), simple methods such as ACA may be preferred to more complicated imputation methods for purely practical reasons (Eekhout et al., 2014; Dohoo et al., 2016).

Descriptive statistics [including counts, ranges, medians, means and 95% confidence intervals (CI)] were calculated for the participants, PMRS, MP recommendations and 3 adherence measures, as applicable. For the analysis of PMRS overall and per section, the Mann-Whitney U-test was used to compare PMRS by herd

JD categorization (EC-neg versus EC-pos), and the 1-sample sign test was used to compare PMRS by RAMP year within a herd.

To compare the proportions of MP recommendations that were ranked most important between EC-neg and EC-pos herds, the 2-sample test of proportions was used. Agreement was calculated between the 3 different adherence measures using the weighted Kappa (ordinal adherence ratings). Multilevel mixed-effects logistic regressions, accounting for clustering of RAMPs done by the same veterinarian, were used to determine factors associated with the three adherence measures and between adherence measures.

For models with AR-self or AR-vet as the dependent variable, 7-point Likert scale adherence ratings were transformed to dichotomous dependent variables (value of 0 if <5; value of 1 if >5), as a rating of less than 5 was considered to indicate nonadherence. Associations with AR-self were assessed by regressing dichotomized AR-self on province, herd size, herd categorization based on year 1 EC, number of recommendations in RAMP1, and type of housing facilities for lactating and dry cows. Associations with AR-vet were assessed by regressing dichotomized AR-vet on the same independent variables as AR-self, plus the following additional variables: same veterinarian conducted RAMP1 and RAMP2, and maximum number of RAMPs conducted per veterinarian. Using backward stepwise elimination, final models were created.

For models with total or section mean difference in PMRS as the dependent variable, PMRS differences were transformed into dichotomous dependent variables (value of 0 if difference was ≥ 0; value of 1 if difference was <0), as a negative difference indicated improvement in PMRS (i.e., the PMRS was smaller in RAMP2 than RAMP1).

Associations with total mean PMRS difference were assessed by regressing total PMRS improvement (dichotomous) on province, herd size, herd categorization based on year 1 EC, number of recommendations in RAMP1, type of housing facilities for lactating cows and dry cows, same veterinarian conducted RAMP1 and RAMP2, maximum number of RAMPs conducted per veterinarian, AR-vet, and AR-self. Associations with section mean PMRS difference were assessed by regressing section PMRS improvement (dichotomous) on the same variables as total improvements, with 1 exception; instead of the number of recommendations in RAMP1, a dichotomous variable was used to indicate if RAMP1 included recommendations from the section. Using backward stepwise elimination, final models were created.

3.4 RESULTS

3.4.1 Study population

Throughout the study period, 894 RAMPs were conducted by the AJDI-certified veterinarians on 457 dairy herds (99% of the AJDI participating herds). Of the 457, 54 herds (12%) had a RAMP conducted once, 369 herds (81%) had RAMPs conducted twice, and 34 herds (7%) had RAMPs conducted three times. Of all the RAMPs conducted, 700 RAMPs (78%) were following EC-neg test results (test negative RAMPs) and 194 RAMPs (22%) were following EC-pos test results (test positive RAMPs). Only herds that had tested EC-pos in their 1st and/or 2nd year of testing were eligible for herd retesting and completion of a RAMP in year 3.

Fifty-one certified veterinarians conducted all the RAMPs, with each certified veterinarian conducting a median of 11 RAMPs throughout the study period [mean=18, 95% CI [12, 23], range=1-84]. In 863 of the RAMPs (97%), RA item scores were complete; whereas, in 31 RAMPs (3%), 1 to 3 RA item scores were missing completely at random.

The median herd size for herds conducting RAMPs was 57 lactating cows (mean = 77, range = 11 - 410), and these herds had a mean 305-day milk production (m305) of 9026 kg (95% CI [8896, 9156]). The types of housing facilities for the lactating cows were: free-stall for 249 herds (54%), tie-stall for 185 herds (41%), bedded pack for 19 herds (4%), and a combination of types for 4 herds (1%).

3.4.2 Management practices at first RAMP

Frequencies of management practices for AJDI participating herds as assessed by RAMP1 are listed by RAMP section in Table 3.1.The frequencies of general JD experiences and biosecurity management practices are listed in Table 3.1a. The majority of AJDI herds never observed a clinical case of JD in their herd. The most reported practice for purchasing new animals was to purchase from multiple herds; this practice was reported in EC-pos herds more frequently than EC-neg herds.

Frequencies of calving area management practices are detailed in Table 3.1b. Two-thirds of herds had no or little adult cow manure covering the bedding in the calving pen/area and three-quarters had no or little manure contamination evident on the cows in the calving/close-up area. However, more than half of herds reported calves were rarely removed from the dam within 30 minutes of birth, a high risk management practice for JD transmission.

Table 3.1c lists frequencies of pre-weaned heifer management practices for AJDI herds. Use of BMPs were the most common practices reported for pre-weaned heifer management items related to the physical environment, such as raising calves on-site or in a facility that only rears calves from their farm, calf housing and feeding was remote from adult cows and manure, and feed/water utensils and buckets were clean and washed daily. Most EC-neg herds reported using the BMP of feeding all calves colostrum from only their mother or a single low risk donor cow; whereas, most EC-pos herds reported feeding calves colostrum from a cow other than their dam or a dam of unknown status. The majority of all herds also reported feeding calves bulk tank milk or pooled milk from several cows, another high risk management practice for JD transmission.

Frequencies of management practices for weaned heifer to first calving are shown in Table 3.1d. The management of heifer housing with respect to distance from cow housing and exposure to cow manure varied among AJDI herds. The management practice most frequently reported describing the condition of heifer environments was a BMP: there was segregation of equipment used for feed and manure handling, bunks and waters were clean, and leftover cow feed was not fed to heifers. However, it was also frequently reported that heifers were exposed to forage that was spread with manure the same year and had manure present on hind or forelegs but not above dewclaws, management practices considered moderate risk for JD transmission.

Frequencies of dry cow and lactating cow management practices among AJDI herds are listed in Table 3.1e and Table 3.1f, respectively. Most feed bunks and waterers for dry and lactating cows had no or little manure contamination, and segregation of equipment used for feeding and manure handling was common. There were similar proportions of dry cows that were or were not exposed to cropland that was spread with manure the same year; however, a larger proportion of lactating cows were exposed than not exposed to cropland that was spread with manure the same year. Dry cows and lactating cows were mostly clean, frequently having manure present on hind or forelegs but not above the dewclaws.

3.4.3 Proportion of maximum risk scores (PMRS)

The mean total and section PMRS, overall and divided by RAMP year, for all RAMPs and by herd JD categorization, are detailed in Table 3.2. The mean total PMRS for all herds overall was 0.448 (95% CI: [0.441, 0.455]). The total PMRS for herds that only tested EC-neg overall was significantly lower than the total PMRS for herds that tested EC-pos at least once overall (P < 0.001). The RAMP1 only and RAMP2 only results were similar to the overall results; total PMRS for EC-neg herds was significantly lower than for EC-pos herds in both RAMP1 (P < 0.001) and RAMP2 (P = 0.0012). However, on RAMP3, a significant difference was not detected between the mean total PMRS for EC-neg herds and EC-pos herds.

The section of the RAMPs with the largest PMRS overall was Johne's/biosecurity (mean=0.557, 95% CI [0.540, 0.5401]), followed by calving area (mean=0.513, 95% CI [0.502, 0.523]], heifer (mean=0.437, 95% CI [0.424, 0.449]), lactating cow (mean=0.383, 95% CI [0.373, 0.394]), dry cow (mean: 0.377, 95% CI [0.367, 0.388]), and pre-weaning (mean=0.349, 95% CI [0.340, 0.359]). The PMRS was significantly lower for the always EC-neg herds compared to EC-pos herds for the following sections: Johne's/biosecurity (P < 0.001), dry cow (P = 0.004), and lactating cow (P = 0.0001).

Specific items within the Johne's/biosecurity section that had significantly lower PMRS for always EC-neg herds compared to EC-pos herds were: known or unsure history with clinical cases of JD (P < 0.001) and animal purchase history and sourcing (P < 0.001). In the dry cow section, EC-neg herds had significantly lower PMRS than EC-pos herds for dry cow hygiene/cleanliness (P = 0.014). All 3 items that were assessed in the lactating cow section had significantly lower PMRS for EC-neg herds compared to EC-pos herds; specifically, feed bunk/waterer contamination for the lactating cows ($P = 0.007$), exposure of the lactating cows to manure from feeding equipment/pasture/forage ($P = 0.029$), and lactating cow hygiene/cleanliness ($P = 0.016$).

3.4.4 Management plan recommendations and ratings

Throughout the study period, 894 farm-specific management plans were developed, containing a total of 2,041 management recommendations. The mean number of recommendations per RAMP was 2.28 (95% CI [2.23, 2.34]); however, there was a significant decrease in the number of recommendations per RAMP comparing the first RAMP to those done in subsequent years (RAMP1 compared to RAMP2 $P < 0.001$; RAMP1 compared to RAMP3 $p<0.001$). The mean number of recommendations per RAMP in RAMP1 was 2.56 (95% CI [2.49, 2.62]), in RAMP2 was 2.00 (95% CI [1.91, 2.09]), and in RAMP3 was 1.97 (95% CI [1.63, 2.31]).

The 10 most frequent management plan recommendations and their rankings are listed in Table 3.3. These recommendations are all from Johne's/biosecurity and calving area sections of the RAMP. The dominant management plan recommendation focused on external biosecurity. Eight of the remaining 9 most common management plan recommendations were for the calving area, including 4 recommendations related to the liquid diet fed to calves and the prevention of nursing and 4 recommendations related to calving pen/area management.

When divided by herd JD categorization, the distributions of the most frequent management plan recommendations remained similar by category, with 1 exception; test positive RAMPs recommended that calves were fed pasteurized colostrum or commercial colostrum (11.9% of test positive RAMPs) instead of the general recommendation of preventing calves from nursing the cow. The proportion of number 1 rankings was significantly higher for test-negative RAMPs compared to test-positive RAMPs for 2 recommendations related to external biosecurity: preventing visitor access to cattle or requiring visitors to wear clean footwear and clothing (P = 0.044), and closing the herd or purchasing from only lower risk herd(s) (P = 0.031),

When stratified by RAMP year, the distributions of the most frequent management plan recommendations remained similar by year. For herds that had at least two RAMPs conducted (403 herds), closing the herd or purchasing from only lower risk herd(s) was recommended in both RAMP1 and RAMP2 for 28% of the herds (114 herds). The frequency of repeat recommendations (in both RAMP1 and RAMP2) was substantially lower for each of the other most frequent recommendations, occurring for 3-11% of herds (11-43 herds).

3.4.5 Self-assessed adherence ratings of RAMP1

During the collection of samples for herds' 2nd EC, 423 producers self-assessed the implementation of the recommendations of their JD management plan from RAMP1 on their farm using a 7-point Likert scale (1 indicated completely disagree/poor adherence and 7 indicated completely agree/excellent adherence). A self-assessed adherence rating (AR-self) of less than 5 was considered to indicate nonadherence. A graph depicting the frequency distribution of AR-self is in Figure 3.1. The mean AR-self was 5.3 (95% CI: 5.2, 5.4) and the median was 5.

For the factors associated with the dichotomized AR-self variable (value of 0 if <5) using multilevel mixed-effects logistic regression, significant association was only detected for herd JD categorization (P = 0.024), which had a resulting odds ratio (OR) of 2.21 (95% CI: 1.11, 4.40). Therefore, EC-pos herds had 2.2 times higher odds of having an AR-self rating indicative of adherence to RAMP1 recommendations compared to EC-neg herds.

3.4.6 Vet-assessed adherence rating of RAMP1

During the completion of RAMP2 by certified veterinarians on 403 herds, herds' adherence to 1,017 RAMP1 recommendations were rated using a 7-point Likert scale (1 indicated completely disagree/poor adherence and 7 indicated completely agree/excellent adherence). A graph depicting the frequency distribution of AR-vet overall is in Figure 3.2. The mean AR-vet overall was 4.2 (95% CI [4.1, 4.4]) and the median was 4.3. The percentage of herds that had a mean AR-vet less than 5 (indicating nonadherence) was 57.2% (231 of 403 herds). The mean AR-vet for the recommendations by rating were: 4.5 (95% CI [4.3, 4.8]) for recommendations ranked most important (rank 1), 4.0 (95% CI [3.8, 4.2]) for 2nd rank recommendations, and 3.8 (95% CI [3.6, 4.1]) for 3rd rank recommendations. The percentage of recommendations that had an AR-vet less than 5 was 46.8% (476 of 1,017 recommendations).

There were no factors associated with dichotomized AR-vet (value of 0 if <5) using multilevel mixed-effects logistic regression. The random effect of veterinarian was significant ($P < 0.001$).

For RAMP1 recommendations that had an AR-vet indicative of nonadherence (231 herds), producers were asked to identify the impediment(s) that prevented the adoption of the best management practice(s) on their farm. More than 97% of the herds (225 herds) identified adherence impediments through the selection of possible impediment statements and/or written comments, Of these herds, 48% viewed the BMPs as low priority (108 herds), 60% (134 herds) viewed them as not practical, 25% viewed them as too financially costly (56 herds), and 20% thought they were not compatible with other management practices on the farm (45 herds). Comments describing adherence impediments were written by 42% of the herds (94 herds) and included concerns such as: complacent as herd Johne's test was negative, first attempt to implement was not done rigorously so would attempt again, occasional purchase of milking animals necessary, and labour restrictions.

3.4.7 Reductions in Proportion of Maximum Risk Score (PMRS) between RAMP1 and RAMP2

The mean differences in total and section PMRS between RAMP1 and RAMP2 are detailed in Table 3.4. For the 403 herds that had at least 2 RAMPs conducted, there was a significant reduction in mean total PMRS between RAMP1 and RAMP2 for all herds ($P < 0.001$), and this difference was similar among EC-neg and EC-pos herds. Almost two-thirds of herds did have a reduction in total PMRS between RAMP1 and RAMP2 (263 herds); whereas, 19% of herds had an increase (77 herds).

All sections of the RAMPs, with the exception of the dry cow section ($P = 0.051$), had significant reductions ($P < 0.001$) in mean PMRS for all herds between RAMP1 and RAMP2. When divided by herd JD categorization based on year 1 EC, significant reductions were seen for all sections of the RAMPs for EC-neg herds, but for EC-pos herds, significant reductions were only detected for 3 sections: calving area ($P = 0.005$), pre-weaning ($P < 0.001$), and heifer ($P = 0.033$).

The models of associations with total and section PMRS improvement outcomes (value of 0 if PMRS difference ≥ 0) from the multilevel mixed-effects logistic regressions are found in Table 3.5. With the exception of the lactating cow PMRS improvement model, all models contained the independent variable AR-vet. The odds of PMRS improvement were 15% to 48% higher for each unit increase in AR-vet, depending on the model. The odds of PMRS improvement were also higher in the calving area model when a management plan recommendation in RAMP1 was from the calving area section and with increasing lactating cow herd size in the pre-weaning model. The odds of PMRS improvement were lower in the dry cow model when the same vet did RAMP1 and RAMP2. In the lactating cow model, the odds of PMRS improvement were also lower if the same vet did RAMP1 and RAMP2, but were more than 4 times and 2 times higher for herds in NL & NS compared to NB, respectively. The variance for the veterinary random effect ranged from 0.083 (95% CI: 0.004, 1.554) in the pre-wean model to 0.864 (95% CI: 0.324, 2.299) in the total PMRS model. The intraclass correlations (ICC) for these two models suggest that the veterinary random effects compose approximately 2.5% and 20.8% of the total residual variance of each model, respectively. Significance of the veterinary random effect was not detected for 2 of the section models; the pre-wean model ($P = 0.209$) and the lactating cow model ($P = 0.154$). Due to the significant clustering detected in the other sections and to improve comparability between section models, the random effect was retained for these 2 models.

3.4.8 Comparisons of adherence measures

AR-vet and RAMP2 were both conducted by the same certified veterinarian on the same day on each farm, followed by AR-self by a median of 118 days (mean of 129 days, 95% CI [125, 133]). Based upon a weighted kappa calculation of the 7-point Likert scale responses to AR-self and AR-vet, the level of agreement between AR-self and AR-vet was slight above that due to chance alone (κ=0.0665).

In the unconditional multilevel mixed-effects logistic regressions of total PMRS improvement from RAMP1 and RAMP2 (value of 0 if PMRS difference $\geq$0) on AR-self and AR-vet, no significant association was detected between total PMRS improvement and AR-self (multiple Wald test P = 0.426). Conversely, a significant association was detected between total PMRS improvement and AR-vet (OR = 1.479; P < 0.001). For every unit increase in AR-vet, the odds of total PMRS improvement were 48% higher. The random effects of veterinarian was significant in both models [AR-self: chibar^2 (01) = 24.45, P = 0.001; AR-vet: chibar^2 (01) = 12.61, P = 0.0002].

3.5 DISCUSSION

The JD risk analysis of herds participating in the AJDI determined that, on average, management practices utilized on these herds had moderate potential to spread MAP between and within farms. Overall, it was demonstrated that JD risk was significantly lower for herds that always tested negative throughout the study period compared to herds that tested positive at least once, based on PMRS. After at least 1 year of participation in the AJDI, significant reductions were observed in the JD PMRS of herds overall. Even though improvements in management practices were made to control JD, adherence ratings indicated that there were difficulties with adherence to JD management plans for a substantial proportion of herds.

Similar to previous studies (Wolf et al., 2016), the overall JD risk assessments on AJDI herds differed with respect to herd JD categorization, with EC-pos herds having higher PMRS. It is assumed that management practices with high PMRS are likely to lead to the occurrence of new MAP infections. Results in this study agree with this assumption, suggesting that calculated PMRS appropriately reflected the on-farm risks of JD for the AJDI herds.

In this study, difference in risk assessment scores between EC-pos herds and EC-neg herds was not observed in RAMP3; however, there are a number of reasons for this result. Only herds that tested EC-pos in their 1st and/or 2nd year of testing were eligible for herd retesting and completion of a RAMP in year 3. Furthermore, the EC test used in this study had a high specificity and as such, should have a low rate of false positive test results (specificity = 99%, 95% CI [95-100]) (Lavers et al., 2013). Therefore, it is highly probable that most herds that completed a RAMP in year 3 were infected with MAP, and therefore, herds that tested EC-neg in year 3 were likely misclassified. If EC-neg herds were actually infected, it would be unlikely to find significant differences in RA scores between herd types in RAMP3. Also, the sample size in year 3 was also much smaller than in the previous 2 years, only 34 herds had a RAMP conducted in year 3 and of those, 11 tested EC-neg and 23 tested EC-pos in their 3rd year of testing. The small sample size would result in reduced power to detect significant differences in RA scores for RAMP3 statistical analyses.

Sections of RAMPs with the highest PMRS overall were Johne's/biosecurity and calving area. Minimizing JD risk from management items in both of these sections are of high priority for JD control programs. Particularly in Atlantic Canada, with lower than average herd level apparent prevalence of JD, it is important to maintain strict external biosecurity to minimize the risk of MAP introduction into herds that are not infected. For herds that are infected with MAP, it is important to minimize risk related to calving and preweaned areas because preweaned calves are the group of animals that are most susceptible to MAP infection (Windsor and Whittington, 2010). To improve control of JD in Atlantic Canada, it would be necessary to implement management changes to reduce the risk of JD in both of these sections.

Previous studies have found that JD management plans which contained too many recommendations discouraged and overwhelmed producers. For example, Sorge et al. (2010) reported that with high numbers of recommendations, producers were unable to implement all recommendations at one time and were not able to distinguish between most important and less important recommendations. For the AJDI, MP recommendations were given a rating in order of importance by the certified veterinarian, and the mean number of recommendations per RAMP was significantly lower than the program's suggested maximum of 3.

Over half of all the RAMPs in the AJDI contained the recommendation to close the herd or purchase from only lower risk herd(s), and farmers ranked it as the top priority a majority of the times that it was recommended. In the design of the AJDI, it was anticipated that many herds and certified veterinarians would prioritize recommendations to reduce the risk of MAP introduction into a herd.

The apparent prevalence of JD in Atlantic Canada (herd and within-herd) was lower than for many of its neighbors (Tiwari et al., 2006; USDA-APHIS-VS_CEAH, 2008; Wolf et al., 2014), and there was a perceived risk of JD test positive cows being sold to Atlantic Canada from other areas that had already started a JD control program. For herds that were unable to cease cattle purchasing, the AJDI published a voluntary online list of AJDI test-negative herds to assist in the sourcing of lower risk replacements (www.atlanticjohnes.ca; site is no longer active).

The top-10 most frequent management plan recommendations in the AJDI were similar for test negative and test positive RAMPs overall with 1 exception; test-positive RAMPs frequently recommended that calves were fed pasteurized or commercial colostrum while test-negative RAMPs frequently recommended to prevent calves from nursing the cow. While fecal-oral transmission from contaminated environments is deemed the most important source of exposure to MAP, infective colostrum represents an additional potential source of exposure (Godden and Wells, 2012; Godden et al., 2015). The differences in BMP recommendations by herd categorization may have been influenced by AJDI training of certified veterinarians. It was emphasized during training that the BMP recommended by AJDI for infected herds (EC-pos) was pathogen elimination through pasteurization or feeding commercial colostrum, a recommendation AJDI considered impractical for negative or low within-herd prevalence herds (EC-neg).

Adherence ratings (AR) to RAMP1 recommendations in this study varied depending upon the adherence measure used. AR-self indicated fair adherence, AR-vet indicated slight adherence, and total PMRS difference between RAMP1 and RAMP2 showed significant improvement. AR-vet and total PMRS difference between RAMP1 and RAMP2 were significantly correlated with each other, but AR-self had poor to slight agreement with the other 2 measures. Considering RAMP2 and AR-vet were done by the same veterinarian, it was not unexpected that total PMRS difference between RAMP1 and RAMP2 and AR-vet were correlated. However, these two measures of adherence evaluated different things, total PMRS was based on the assessment of 27 different management practices for each RAMP and AR-vet was based on whether the veterinarian considered the previous year's MP recommendations (maximum of 3 recommendations) to have been adopted and rigorously applied. Unfortunately, even though the 3 assessment measures indicated some adherence overall, a substantial proportion of the AJDI herds did not adhere to RAMP1 recommendations, and too few significant associations were detected with the adherence measures to help explain the adherence difficulties. Since the AJDI is a RA-based control program, adherence to the MP recommendations is a crucial component in determining its success (Sorge et al., 2010). There is a growing body of research into the relationship between a person's attitudes, behaviours and adherence; some studies found that attitude was the most important predictor for adherence (Bruijnis et al., 2013; Borges et al., 2016). Further research into factors that affect RAMP adherence in the AJDI, particularly into the attitudes and behaviours of participating producers, is strongly recommended.

During development of each farm-specific JD management plan, a consensus was to be reached between the certified veterinarian and the producer as to which BMP were to be implemented on the farm to control JD, For RAMP1 recommendations that had an AR-vet indicative of nonadherence, producers were asked to identify adherence impediments. Many of the impediments indicated that the producers did not approve of the MP recommendations in RAMP1. This suggests that when management options were being chosen, producers' perspectives were not adequately understood or their preferences were not sufficiently incorporated into the decision making process. Communication failure between the veterinarians and the producers could have contributed to these problems. There is strong evidence in human and veterinary health research that effective communication plays a significant role in adherence, and that limitations in communication skills exist in the veterinary population (American Animal Hospital Association, 2009; Coe et al., 2010; Kanji et al., 2012). Further research is recommended to evaluate the communication skills of veterinarians involved with JD control programs. Formal training in communication skills may be necessary to address concerns with communication and adherence in JD control programs.

3.6 CONCLUSIONS

The JD risk analysis of AJDI herds determined that, on average, management practices utilized on these herds had moderate potential to spread MAP between and within farms. JD risk differed based on herd categorization, with significantly lower risk identified for EC-neg herds compared to EC-positive herds overall. Significant reductions were observed in JD PMRS for herds after at least 1 year of participation in the AJDI. In spite of these improvements, difficulties with adherence were detected for a substantial proportion of AJDI herds. Information gained in this study about specific barriers to adherence will be valuable to further improve Johne's disease control.

3.7 REFERENCES

American Animal Hospital Association. 2009. Compliance: Taking Quality Care to the Next Level: A Report of the 2009 AAHA Compliance Follow-Up Study. AAHA Press, Lakewood, Colorado, USA.

Barkema, H. W., J. W. Hesselink, S. L. B. McKenna, G. Benedictus and H. Groenendaal. 2010. Global prevalence and economics of infection with *Mycobacterium avium* subspecies *paratuberculosis* in ruminants. Paratuberculosis: Organism, Disease, Control. M. Behr and D. M. Collins eds. CAB International, Boston, MA, USA.

Barker, R. A., H. W. Barkema, G. Fecteau, G. K. Keefe and D. F. Kelton. 2012. Johne's Disease Control in Canada - Coordinated Nationally - Delivered Provincially. Proc. 3rd ParaTB Forum, Sydney, Australia. 45-51.

Borges, J. A. R., L. W. Tauer and A. G. J. M. O. Lansink. 2016. Using the theory of planned behavior to identify key beliefs underlying Brazilian cattle farmers' intention to use improved natural grassland: A MIMIC modelling approach. Land use Policy. 55:193-203.

Bruijnis, M., H. Hogeveen, C. Garforth and E. Stassen. 2013. Dairy farmers' attitudes and intentions towards improving dairy cow foot health. Livest. Sci. 155:103-113.

Chi, J., J. A. VanLeeuwen, A. Weersink and G. P. Keefe. 2002. Direct production losses and treatment costs from bovine viral diarrhoea virus, bovine leukosis virus, *Mycobacterium avium* subspecies *paratuberculosis*, and Neospora caninum. Prev. Vet. Med. 55:137-153.

Chiodini, R. J., H. J. Kruiningen and R. S. Merkal. 1984. Ruminant paratuberculosis (Johne's disease): The current status and future prospects. Cornell Vet. 74:218-262.

Coe, J. B., C. L. Adams, K. Eva, S. Desmarais and B. N. Bonnett. 2010. Development and validation of an instrument for measuring appointment-specific client satisfaction in companion-animal practice. Prev. Vet. Med. 93:201-210.

Dohoo, I. R., C. R. Nielsen and U. Emanuelson. 2016. Multiple imputation in veterinary epidemiological studies: a case study and simulation. Prev. Vet. Med. 129:35-47.

Eekhout, I., H. C. W. de Vet, J. W. R. Twisk, J. P. L. Brand, M. R. de Boer and M. W. Heymans. 2014. Missing data in a multi-item instrument were best handled by multiple imputation at the item score level. J. Clin. Epidemiol. 67:335-342.

Garry, F. 2011. Control of paratuberculosis in dairy herds. Vet. Clin. North Am. Food Anim. Pract. 27:599-607.

Godden, S. and S. Wells. 2012. Evaluation of critical control points in dairy herd management to reduce transmission of *Mycobacterium avium* subspecies *paratuberculosis* - Results from controlled clinical trials. Proc. 3rd ParaTB Forum, Sydney, Australia. 29-35.

Godden, S. M., S. Wells, M. Donahue, J. Stabel, J. M. Oakes, S. Sreevatsan and J. Fetrow. 2015. Effect of feeding heat-treated colostrum on risk for infection with *Mycobacterium avium* subspecies *paratuberculosis*, milk production, and longevity in Holstein dairy cows. J. Dairy Sci. 98:5630-5641.

Hendrick, S. H., D. F. Kelton, K. E. Leslie, K. D. Lissemore, M. Archambault, R. Bagg, P. Dick and T. F. Duffield. 2006. Efficacy of monensin sodium for the reduction of fecal shedding of *Mycobacterium avium* subspecies *paratuberculosis* in infected dairy cattle. Prev. Vet. Med. 75:206-220.

Kanji, N., J. B. Coe, C. L. Adams and J. R. Shaw. 2012. Effect of veterinarian-client-patient interactions on client adherence to dentistry and surgery recommendations in companion-animal practice. J. Am. Vet. Med. Assoc. 240:427-436.

Kudahl, A. B., S. S. Nielsen and S. Østergaard. 2008. Economy, efficacy, and feasibility of a risk-based control program against paratuberculosis. J. Dairy Sci. 91:4599-4609.

Lavers, C. J., S. L. B. McKenna, I. R. Dohoo, H. W. Barkema and G. P. Keefe. 2013. Evaluation of environmental fecal culture for *Mycobacterium avium* subspecies *paratuberculosis* detection in dairy herds and association with apparent within-herd prevalence. Can. Vet. J. 54:1053-1060.

McKenna, S. L. B., G. P. Keefe, H. W. Barkema and D. C. Sockett. 2005. Evaluation of three ELISAs for *Mycobacterium avium* subspecies *paratuberculosis* using tissue and fecal culture as comparison standards. Vet. Microbiol. 110:105-111.

McKenna, S. L. B., G. P. Keefe, A. Tiwari, J. VanLeeuwen and H. W. Barkema. 2006a. Johne's disease in Canada part II: Disease impacts, risk factors, and control programs for dairy producers. Can. Vet. J. 47:1089-1099.

McKenna, S. L. B., J. A. Vanleeuwen, H. W. Barkema, J. T. Jansen, G. Hauer, S. H. Hendrick, G. Côte, E. B. Salsberg and R. E. Empringham. 2006b. Proposed Canadian voluntary national Johne’s disease prevention and control program. Can. Vet. J. 47:539-541.

Nielsen, S. S. and N. Toft. 2008. Ante mortem diagnosis of paratuberculosis: A review of accuracies of ELISA, interferon-γ assay and faecal culture techniques. Vet. Microbiol. 129:217-235.

Pieper, L., T. J. DeVries, U. S. Sorge, A. Godkin, K. J. Hand, N. R. Perkins, J. Imada and D. F. Kelton. 2015. Variability in risk assessment and management plan (RAMP) scores completed as part of the Ontario Johne's Education and Management Assistance Program (2010-2013). J. Dairy Sci. 98:2419-2426.

Raizman, E. A., S. J. Wells, S. M. Godden, J. Fetrow, K. Friendshuh and J. M. Oakes. 2006. Characterization of Minnesota dairy herds participating in a Johne's disease control program and evaluation of the program risk assessment tool. Prev. Vet. Med. 75:22-33.

Rasmussen, P., H. W. Barkema, S. Mason, E. Beaulieu and D. C. Hall. 2020. Economic losses due to Johne's disease (paratuberculosis) in dairy cattle. J. Dairy Sci. 104:3123-3143.

Ridge, S. E., I. M. Baker and M. Hannah. 2005. Effect of compliance with recommended calf-rearing practices on control of bovine Johne's disease. Aust. Vet. J. 83:85-90.

Sorge, U., D. Kelton, K. Lissemore, A. Godkin, S. Hendrick and S. Wells. 2010. Attitudes of Canadian dairy farmers toward a voluntary Johne's disease control program. J. Dairy Sci. 93:1491-1499.

Sorge, U. S., K. Lissemore, A. Godkin, J. Jansen, S. Hendrick, S. Wells and D. F. Kelton. 2011. Changes in management practices and apparent prevalence on Canadian dairy farms participating in a voluntary risk assessment-based Johne's disease control program. J. Dairy Sci. 94:5227-5237.

Tiwari, A., J. A. VanLeeuwen, S. L. B. McKenna, G. P. Keefe and H. W. Barkema. 2006. Johne's disease in Canada Part I: Clinical symptoms, pathophysiology, diagnosis, and prevalence in dairy herds. Can. Vet. J. 47:874-882.

USDA-APHIS-VS-CEAH, 2008. Johne's disease on US dairies, 1991-2007. Accessed June 11. 2021. www.aphis.usda.gov/animal_health/nahms/dairy/downloads/dairy07/Dairy07_is_Johnes_1.pdf.

van Ginkel, J. R., K. Sijtsma, d. A. van and J. K. Vermunt. 2010. Incidence of missing item scores in personality measurement, and simple item-score imputation. Methodology. 6:17-30.

Wells, S. J., W. L. Hartmann and P. L. Anderson. 2008. Evaluation of progress made by dairy and beef herds enrolled in the Minnesota Johne's disease control program. J. Am. Vet. Med. Assoc. 233:1920-1926.

Windsor, P. A. and R. J. Whittington. 2010. Evidence for age susceptibility of cattle to Johne's disease. Vet. J. 184:37-44.

Wolf, R., H. W. Barkema, J. DeBuck and K. Orsel. 2016. Dairy farms testing positive for *Mycobacterium avium* subspecies *paratuberculosis* have poorer hygiene practices and are less cautious when purchasing cattle than test-negative herds. J. Dairy Sci. 99:1-11.

Wolf, R., H. W. Barkema, J. De Buck and K. Orsel. 2015. Factors affecting management changes on farms participating in a Johne's disease control program. J. Dairy Sci. 98:7784-7796.

Wolf, R., H. W. Barkema, J. De Buck, M. Slomp, J. Flaig, D. Haupstein, C. Pickel and K. Orsel. 2014. High herd-level prevalence of *Mycobacterium avium* subspecies *paratuberculosis* in western Canadian dairy farms, based on environmental sampling. J. Dairy Sci. 97:6250-6259.

Wraight, M. D., J. McNeil, D. S. Beggs, R. K. Greenall, T. B. Humphris, R. J. Irwin, S. P. Jagoe, A. Jemmeson, W. F. Morgan, P. Brightling, G. A. Anderson and P. D. Mansell. 2000. Compliance of Victorian dairy farmers with current calf rearing recommendations for control of Johne's disease. Vet. Microbiol. 77(3-4):429-442.

Table 3.1 Descriptive statistics of management practices assessed by certified veterinarians during the first risk assessment for the 456 Atlantic Johne's Disease Initiative participating herds, by risk assessment and management plan section

a) Biosecurity management practices and general JD experiences

Management Practice and Associated Risk Score	Frequency	Percent
What access do farm visitors have to cattle of any age on the farm?		
Visitors do not have access to the cattle or are required to wear clean footwear and clothing (1 point)	92	20.2
Visitors have unrestricted access to the cattle (10 points)	361	79.2
Missing	3	0.7
Have you ever had cows in your herd with clinical Johne's disease?		
No, Clinical JD has not been observed in my herd (1 point)	265	58.1
Don't know (5 points)	151	33.1
Yes, JD has been observed in my herd (10 points)	40	8.8
Did you purchase animals in the last 5 years?		
EC-neg[1]		
No animals have been purchased in the last 5 years (1 point)	107	28.9
Yes, from two or less herds of known negative herd status (7 points)	11	2.8
Yes, from two or less herds of unknown status (20 points)	100	27.0
Yes, from multiple herds (30 points)	152	41.1
EC-pos[1]		
No animals have been purchased in the last 5 years (1 point)	12	14.0
Yes, from two or less herds of known negative herd status (7 points)	0	0.0
Yes, from two or less herds of unknown status (13 points)	18	20.9
Yes, from multiple herds (20 points)	56	65.1
Are any animals from your herd directly commingled with adult animals from other herds OR is there potential for exposure to manure from other farms?		
No, herd members do not attend shows and are not exposed to manure from other herds (1 point)	300	65.8
Yes, herd members attend cattle shows OR are hauled in vehicles that are contaminated with manure from other farms OR manure handling equipment that animals have access to is shared between farms (10 points)	155	34.0
Missing	1	0.2

[1]Management practices presented by Environmental Culture (EC) herd categorization for items that had differences in best management practices or risk assessment item scoring between the EC-negative and EC-positive workbooks

b) Calving area management practices

Management Practice and Associated Risk Score	Frequency	Percent
How many cows are newborn calves exposed to in the calving area?		
There is never more than a single cow in the calving pen/area (1 point)	149	32.7
Occasionally but <25% of the time there is more than one cow in the calving pen/area (4 points)	112	24.6
Between 25 and 50% of the time there is more than one cow in the calving pen/area (7 points)	47	10.3
More than 50% of the time there is more than one cow in the calving pen/area (10 points)	146	32.0
Missing	2	0.4
What is the risk for calf exposure/ingestion of adult cow manure?		
No visible manure, new bedding has been added, bedding is dry (1 point)	75	16.5
Visible manure covering 1-10% of the bedding (4 points)	229	50.2
Visible manure covering 10- 50% of the bedding and bedding is wet (7 points)	108	23.7
Manure covering >50% of calving pen/area and bedding is wet (10 points)	44	9.7
To what degree is manure contamination evident on the cows in the calving/close-up area?		
The cows have no manure visible on hind legs, teats or udder (1 point)	52	11.4
Manure is present on hind legs but not above dewclaws and not on teats or udder (4 points)	285	62.5
Manure is present on hind legs up to the hocks OR is present on the surface of the teats (7 points)	100	21.9
Manure is present above the hocks AND is present on the teats or udder (10 point)	18	4.0
Missing	1	0.2
To what extent is the calving area used for sick or lame cows?		
The calving area is NEVER, EVER, used by non-calving cows (1 point)	107	23.5
The calving area is used occasionally (less than once a month) by non-calving cows (5 points)	195	42.8
The calving area is used at least once monthly by non-calving cows (9 points)	64	14.0
The calving area is used at least once every second week by non-calving cows OR is used at any time by known MAP positive cows (15 points)	85	18.6
Missing	5	1.1
How often are calves born outside the designated calving area?		
In the past year, no calves were born outside the designated calving area/pen (1 point)	67	14.7
In the past year, 1 to 5% of calves were born outside the	204	44.7

Management Practice and Associated Risk Score	Frequency	Percent
designated calving area/pen (4 points)		
In the past year, 6 to 10% of calves were born outside the designated calving area/pen (7 points)	78	17.1
In the past year, more than 10% of calves were born outside the designated calving area/pen (10 points)	102	22.4
Missing	5	1.1
What is the likelihood that calves nurse their dams?		
No calves born on this farm ever nurse the cow (1 point)	53	11.6
Less than 10% of newborn calves nurse the cow (4 points)	164	36.0
Between 10 and 50% of newborn calves nurse the cow (7 points)	107	23.5
More than 50% of newborn calves nurse; either the calves are left with cow more than 4 hours or the owner reports purposively leaving calves to nurse (10 points)	132	29.0
What is the duration of exposure of the newborn calf to the cow?		
More than 90% of calves are removed from the dam within 30 minutes (1 point)	76	16.7
Between 50 and 90% of calves are removed from the dam within 30 minutes (4 points)	50	11.0
Between 10 and 50% of calves are removed from the dam within 30 minutes (7 points)	62	13.6
Less than 10% of calves are removed from the dam within 30 minutes (10 points)	267	58.6
Missing	1	0.2

c) Pre-weaned heifer management practices

Management Practice and Associated Risk Score	Frequency	Percent
Are any calves or replacement heifers of any age raised at a custom heifer rearing operation where they have contact with heifers or adult cows from other herds?		
No, calves are raised on-site or in a facility that only rears calves from my farm (1 point)	422	92.5
Calves/heifers are exposed to pre-calving age cattle only from other herds at these operations (5 points)	18	4.0
Calves/heifers are exposed to adult cattle from other herds at these operations (10 points)	16	3.5
What is the source of colostrum fed to calves?		
EC-neg [1]		
All calves are fed colostrum only from their mother or a single low risk donor cow (1 point)	306	82.7
Calves are fed colostrum from a cow other than their dam (5 points)	54	14.6
Calves are fed pooled colostrum or colostrum from multiple cows (10 points)	10	2.7
EC-pos [1]		
ALL calves are fed 100% pasteurized colostrum or artificial colostrum (1 point)	7	8.1
ALL calves are fed colostrum only from their test negative mother or a single low risk, test negative donor cow (5 points)	17	19.8
Calves are fed colostrum from a cow other than their dam or a dam of unknown status (9 points)	54	62.8
Calves are fed pooled colostrum or colostrum from multiple cows (15 points)	8	9.3
What is the source of the liquid diet fed to calves?		
Calves are fed milk replacer or pasteurized milk only (1 point)	105	23.0
Calves are fed whole milk from individual cows (not pooled) and these cows are selected as low risk (4 points)	26	5.7
Calves are fed whole milk from individual cows (not pooled) without selection (7 points)	68	14.9
Calves are fed bulk tank milk or pooled milk from several cows (10 points)	257	56.4
How often are calves fed non-saleable (high risk) milk?		
Non-saleable milk is never fed to calves (1 point)	127	27.9
Non-saleable milk is rarely fed (less than monthly) to calves (4 points)	103	22.6
Non-saleable milk is once or twice a month to calves (7 points)	79	17.3
Non-saleable milk is frequently fed (typically every week) to calves (10 points)	147	32.2

Management Practice and Associated Risk Score	Frequency	Percent
What is the risk that pre-weaned calves are exposed to cow manure?		
EC-neg[1]		
Calf housing and feeding is remote from cows, cow manure and any cow movement areas (1 point)	201	54.3
Calves are near cows but an effort is made to eliminate manure contact (boots are washed between cow and calf contact etc.) (5 points)	79	21.4
Calves are in proximity to cows or cow traffic areas and occasional exposure to manure is likely (9 points)	67	18.1
Calves are housed near cows and there is direct exposure to manure (15 points)	23	6.2
EC-pos[1]		
Calf housing and feeding is remote from cows, cow manure and any cow movement areas (1 point)	46	53.5
Calves are near cows but an effort is made to eliminate manure contact (boots are washed between cow and calf contact etc.) (7 points)	14	16.3
Calves are in proximity to cows or cow traffic areas and occasional exposure to manure is likely (13 points)	22	25.6
Calves are housed near cows and there is direct exposure to manure (20 points)	4	4.7
Is there exposure to manure by watering or feeding utensils?		
Mixing utensils and feed/water buckets are visibly clean and all are washed daily with soap or disinfectant (1 point)	261	57.2
Trace amounts of manure are visible OR mixing utensils/buckets are washed less frequently than daily but at least weekly (4 points)	171	37.5
Regardless of stated cleaning practises, manure from any age animal is clearly visible (7 points)	19	4.2
Regardless of stated cleaning practises, manure from adult cows is clearly visible (10 points)	4	0.9
Missing	1	0.2

[1]Management practices presented by Environmental Culture (EC) herd categorization for items that had differences in best management practices or risk assessment item scoring between the EC-negative and EC-positive workbooks

d) Weaned heifer to first calving management practices

Management Practice and Associated Risk Score	Frequency	Percent
What is the risk that weaned calves or heifers are exposed to cow manure?		
Never housed near cows, no direct contact or exposure to manure by run-off or splashing (1 point)	181	39.7
Housed near cows, no direct contact, no exposure to cow manure by run-off or splashing (4 points)	103	22.6
Housed near cows, direct contact possible OR exposed to manure by run-off or splashing (7 points)	105	23.0
Housed with cows or next to cows where direct contact always occurs (10 points)	67	14.7
What is the heifer environment like and is manure handling equipment used for feed or is feed shared between adults and heifers?		
Feeding equipment never used for manure handling, heifer bunks and waters clean, and left over feed from cows not fed to heifers (1 point)	216	47.4
Feeding equipment never used for manure handling, heifer bunks and waters clean, BUT heifers fed left over feed from cows (4 points)	135	29.6
Feeding equipment never used for manure handling, but heifer bunks and waters contaminated with heifer source manure (7 points)	32	7.0
Feeding equipment sometimes used for manure handling (10 points)	73	16.0
To what extent are heifers exposed to manure on forage or pasture?		
Manure is never spread on pasture on which heifers graze the same year or on land from which forage is fed to heifers in the same year (1 point)	182	39.9
Manure is spread on land from which forage (non corn) is fed to heifers in the same year (5 points)	205	45.0
Manure is spread on pasture on which heifers graze in the same year (10 points)	68	14.9
Missing	1	0.2
What is the overall heifer hygiene and cleanliness score?		
Heifers have no manure visible on hind legs, forelegs or flanks (1 point)	26	5.7
Manure is present on hind or forelegs but not above dewclaws (4 points)	194	42.5
Manure is present on hind or forelegs up to the hocks/knees OR is present on the flanks (7 points)	179	39.3
Manure is present above the hocks/knees (10 points)	56	12.3
Missing	1	0.2

e) Dry cow management practices

Management Practice and Associated Risk Score	Frequency	Percent
To what degree are feed bunks and waterers contaminated with manure?		
Water troughs and feed bunks are clean with no visible manure contamination (1 point)	201	44.1
Water troughs and feed bunks have a trace amount of manure visible (4 points)	232	50.9
Manure is clearly visible OR mangers and water troughs are cleaned less than once a month (7 points)	21	4.6
There is extensive manure contamination of in mangers and water troughs (10 points)	2	0.4
Is feeding equipment used to remove manure OR is manure spread on forage crop/pasture exposed to dry cows in the same year?		
Feeding equipment is never used to remove manure and manure is not spread on pasture OR cropland exposed to dry cows in the same year (1 point)	172	37.7
Feeding equipment is never used to remove manure and manure is not spread on pasture but is spread on cropland exposed to dry cows in the same year (4 points)	169	37.1
Feeding equipment is never used to remove manure, but manure is spread on pasture (7 points)	55	12.1
Feeding equipment is used to scrape/remove manure (10 points)	60	13.2
What is the overall dry cow hygiene and cleanliness score?		
Dry cows have no manure visible on hind legs, forelegs or flanks (1 point)	51	11.2
Manure is present on hind or forelegs but not above dewclaws (4 points)	280	61.4
Manure is present on hind or forelegs up to the hocks/knees OR is present on the flanks (7 points)	108	23.7
Manure is present above the hocks/knees (10 points)	16	3.5
Missing	1	0.2

f) Lactating cow management practices

Management Practice and Associated Risk Score	Frequency	Percent
To what degree are feed bunks and waterers contaminated with manure?		
Water troughs and feed bunks are clean with no visible manure contamination (1 point)	221	48.5
Water troughs and feed bunks have a trace amount of manure visible (4 points)	215	47.2
Manure is clearly visible OR mangers and water troughs are cleaned less than once a month (7 points)	19	4.2
There is extensive manure contamination of in mangers and water troughs (10 points)	1	0.2
Is feeding equipment used to remove manure OR is manure spread on forage crop/pasture exposed to lactating cows in the same year?		
Feeding equipment is never used to remove manure and manure is not spread on pasture OR cropland exposed to lactating cows in the same year (1 point)	149	32.7
Feeding equipment is never used to remove manure and manure is not spread on pasture but is spread on cropland exposed to lactating cows in the same year (4 points)	199	43.6
Feeding equipment is never used to remove manure but manure is spread on pasture (7 points)	44	9.7
Feeding equipment is used to scrape/remove manure (10 points)	64	14.0
What is the overall lactating cow hygiene and cleanliness score?		
Lactating cows have no manure visible on hind legs, forelegs or flanks (1 point)	42	9.2
Manure is present on hind or forelegs but not above dewclaws (4 points)	262	57.5
Manure is present on hind or forelegs up to the hocks/knees OR is present on the flanks (7 points)	130	28.5
Manure is present above the hocks/knees (10 points)	21	4.6
Missing	1	0.2

Table 3.2 Mean total and section proportion of maximum risk score (PMRS) for 894 risk assessment and management plans (RAMPs) assessed by certified veterinarians for the 456 Atlantic Johne's Disease Initiative participating herds, overall and divided by RAMP year, for all RAMPs and by herd Johne's disease categorization

a) Overall

mean 95% CI n	All	EC-neg (parallel)	EC-pos (parallel)
Total PMRS	0.448 (0.441, 0.455) 863	0.436[a] (0.428, 0.446) 613	0.476[b] (0.463, 0.488) 250
Johne's/Biosecurity PMRS	0.557 (0.540, 0.574) 885	0.514[a] (0.493, 0.535) 631	0.663[b] (0.638, 0.689) 254
Calving Area PMRS	0.513 (0.502, 0.523) 880	0.505[a] (0.493, 0.517) 628	0.531[a] (0.512, 0.550) 252
Pre-weaning PMRS	0.349 (0.340, 0.359) 892	0.347[a] (0.336, 0.358) 640	0.355[a] (0.337, 0.373) 252
Heifer PMRS	0.437 (0.424, 0.449) 890	0.431[a] (0.417, 0.446) 636	0.449[a] (0.425, 0.473) 254
Dry Cow PMRS	0.377 (0.367, 0.388) 893	0.368[a] (0.356, 0.380) 639	0.400[b] (0.381, 0.419) 254
Lactating Cow PMRS	0.383 (0.373, 0.394) 893	0.371[a] (0.358, 0.383) 639	0.415[b] (0.397, 0.433) 254

[a-b]Different letters indicate significant difference (P < 0.05) between herd categorizations

b) Year 1 RAMP

mean 95% CI n	All	EC-neg	EC-pos
Total PMRS	0.463 (0.453, 0.473) 438	0.453[a] (0.441, 0.464) 354	0.506[b] (0.485, 0.526) 84
Johne's/Biosecurity PMRS	0.576 (0.552, 0.560) 452	0.551[a] (0.524, 0.578) 366	0.684[b] (0.640, 0.728) 86
Calving Area PMRS	0.535 (0.521, 0.549) 447	0.525[a] (0.510, 0.540) 363	0.578[b] (0.546, 0.611) 84
Pre-weaning PMRS	0.361 (0.347, 0.374) 455	0.352[a] (0.337, 0.366) 369	0.397[b] (0.367, 0.428) 86
Heifer PMRS	0.451 (0.433, 0.468) 454	0.443[a] (0.425, 0.462) 368	0.484[a] (0.443, 0.525) 86
Dry Cow PMRS	0.382 (0.367, 0.396) 455	0.376[a] (0.360, 0.392) 369	0.407[a] (0.375, 0.439) 86
Lactating Cow PMRS	0.390 (0.375, 0.405) 455	0.384[a] (0.368, 0.400) 369	0.415[a] (0.384, 0.447) 86

[a-b]Different letters indicate significant difference (P < 0.05) between herd categorizations

c) Year 2 RAMP

mean **95% CI** **n**	**All**	**EC-neg**	**EC-pos**
Total PMRS	0.431 (0.420, 0.442) 392	0.423[a] (0.410, 0.436) 307	0.459[b] (0.438, 0.481) 85
Johne's/Biosecurity PMRS	0.529 (0.503, 0.555) 399	0.495[a] (0.465, 0.525) 314	0.654[b] (0.612, 0.696) 85
Calving Area PMRS	0.490 (0.474, 0.505) 399	0.480[a] (0.463, 0.497) 314	0.524[b] (0.492, 0.556) 85
Pre-weaning PMRS	0.339 (0.325, 0.353) 404	0.342[a] (0.327, 0.358) 319	0.328[a] (0.295, 0.360) 85
Heifer PMRS	0.420 (0.403, 0.438) 402	0.420[a] (0.400, 0.440) 317	0.423[a] (0.384, 0.463) 85
Dry Cow PMRS	0.370 (0.355, 0.386) 404	0.363[a] (0.346, 0.380) 319	0.396[a] (0.362, 0.431) 85
Lactating Cow PMRS	0.372 (0.357, 0.388) 404	0.361[a] (0.344, 0.378) 319	0.415[b] (0.384, 0.447) 85

[a-b]Different letters indicate significant difference ($P < 0.05$) between herd categorizations

d) Year 3 RAMP

mean **95% CI** **n**	**All**	**EC-neg**	**EC-pos**
Total PMRS	0.454 (0.421, 0.487) 33	0.457[a] (0.399, 0.535) 10	0.448[a] (0.410, 0.486) 23
Johne's/Biosecurity PMRS	0.636 (0.570, 0.702) 34	0.639[a] (0.519, 0.760) 11	0.635[a] (0.554, 0.715) 23
Calving Area PMRS	0.487 (0.435, 0.538) 34	0.501[a] (0.401, 0.600) 11	0.48[a] (0.419, 0.541) 23
Pre-weaning PMRS	0.324 (0.277, 0.370) 33	0.305[a] (0.222, 0.387) 10	0.332[a] (0.274, 0.389) 23
Heifer PMRS	0.437 (0.373, 0.468) 34	0.443[a] (0.317, 0.570) 11	0.434[a] (0.360, 0.507) 23
Dry Cow PMRS	0.400 (0.350, 0.450) 34	0.409[a] (0.320, 0.499) 11	0.396[a] (0.335, 0.457) 23
Lactating Cow PMRS	0.424 (0.377, 0.470) 34	0.427[a] (0.362, 0.483) 11	0.422[a] (0.359, 0.485) 23

[a-b]Different letters indicate significant difference ($P < 0.05$) between herd categorizations

Table 3.3 Descriptive statistics of the 10 most frequent management plan recommendations and their rankings (percentage of frequency of recommendation) for 864 risk assessment and management plans (RAMPs) assessed by certified veterinarians for the 456 Atlantic Johne's Disease Initiative participating herds

Recommendation	Frequency	Percent	Rank 1 (%)	Rank 2 (%)	Rank 3 (%)
Animals are not purchased or purchased from lower risk herd(s)	451	50.4	74.5	17.5	8.0
More than 90% of calves are removed from the dam within 30 minutes	191	21.4	40.8	35.6	23.6
No visitor access to cattle or clean footwear and clothing required	159	17.8	47.8	28.9	23.3
Calves are fed milk replacer or pasteurized milk only	107	12.0	28.0	44.9	27.1
Non-saleable milk is never fed to calves	107	12.0	28.0	35.5	36.5
No calves ever nurse the cow	106	11.9	29.3	47.2	23.6
There is never more than a single cow in the calving pen/area	89	10.0	37.1	46.1	16.9
The calving area is never used by non-calving cows	58	9.5	32.9	48.2	18.8
No calves are born outside the designated calving pen/area	76	8.5	30.3	57.9	11.8
No visible manure/new bedding added/dry bedding in calving pen/area	68	7.6	41.2	41.2	17.7

Table 3.4 Mean differences in total and section proportion of maximum risk score (PMRS) between first and second risk assessment and management plans assessed by certified veterinarians for 403 Atlantic Johne's Disease Initiative participating herds, overall and by herd Johne's disease categorization

Mean 95% CI n	**All**	**EC-neg (EC1)**	**EC-pos (EC1)**
Total PMRS Difference	-0.034[a] (-0.041, -0.027) 384	-0.033[a] (-0.040, -0.026) 310	-0.037[a] (-0.056, -0.017) 74
Johne's/Biosecurity PMRS Difference	-0.054[a] (-0.070, -0.038) 396	-0.055[a] (-0.073, -0.038) 320	-0.050 (-0.092, -0.008) 76
Calving Area PMRS Difference	-0.045[a] (-0.056, -0.034) 396	-0.044[a] (-0.054, -0.033) 322	-0.051[a] (-0.085, -0.017) 74
Pre-weaning PMRS Difference	-0.021[a] (-0.031, -0.011) 402	-0.013[a] (-0.023, -0.002) 326	-0.057[a] (-0.082, -0.032) 76
Heifer PMRS Difference	-0.032[a] (-0.046, -0.019) 400	-0.034[a] (-0.048, -0.020) 324	-0.025 (-0.064, 0.014) 76
Dry Cow PMRS Difference	-0.009 (-0.020, 0.002) 402	-0.011[a] (-0.023, 0.000) 326	-0.001 (-0.031, 0.029) 76
Lactating Cow PMRS Difference	-0.017[a] (-0.028, -0.007) 403	-0.023[a] (-0.034, -0.012) 327	0.008 (-0.020, 0.036) 254

[a]Significant reduction in PMRS from RAMP1 to RAMP2

Table 3.5 Parameter estimates for the multilevel mixed-effects logistic regression models of total and section proportion of maximum risk score (PMRS) improvement outcomes (value of 0 if PMRS difference ≥0), for 403 Atlantic Johne's Disease Initiative participating herds

Parameter	OR	P-value	95% CI[2]	
Total PMRS Improvement[1]				
Vet-assessed adherence rating	1.479	0.000	1.255	1.747
Constant	0.501	0.081	0.231	1.088
Johne's/Biosecurity PMRS Improvement[1]				
Vet-assessed adherence rating	1.151	0.045	1.003	1.321
Constant	0.350	0.002	0.181	0.676
Calving Area PMRS Improvement[1]				
Management Plan recommendation (Baseline: No)				
Yes	0.577	0.020	0.363	0.916
Vet-assessed adherence rating	1.262	0.001	1.094	1.455
Constant	0.544	0.110	0.258	1.148
Pre-weaning PMRS Improvement[1]				
Vet-assessed adherence rating	1.202	0.008	1.049	1.378
Number of lactating cows	1.006	0.002	1.002	1.010
Constant	0.224	0.000	0.111	0.453
Heifer PMRS Improvement[1]				
Vet-assessed adherence rating	1.150	0.044	1.004	1.318
Constant	0.352	0.002	0.184	0.677
Dry Cow PMRS Improvement[1]				
Same vet for 1st and 2nd Risk Assessment (Baseline: No)				
Yes	0.487	0.031	0.253	0.937
Vet-assessed adherence rating	1.202	0.022	1.027	1.406
Constant	0.257	0.003	0.104	0.633
Lactating Cow PMRS Improvement[1]				
Same vet for 1st and 2nd Risk Assessment (Baseline: No)				
Yes	0.352	0.001	0.189	0.654
Province (Baseline: New Brunswick)		0.022[4]		
Newfoundland & Labrador	4.257	0.015	1.330	13.624
Nova Scotia	2.361	0.016	1.173	4.752
Prince Edward Island	1.310	0.480	0.619	2.774
Constant	0.545	0.093	0.269	1.106

[1]Dependent variable
[2]95% CI around the OR except for the constant which is 95% CI around the coefficient
[3]Multiple Wald test P-value for the parameter
[4]Global P-value

Figure 3.1 Frequency distribution of self-assessed adherence ratings to management plan recommendations in the first risk assessment and management plan for 423 Atlantic Johne's Disease Initiative participating herds

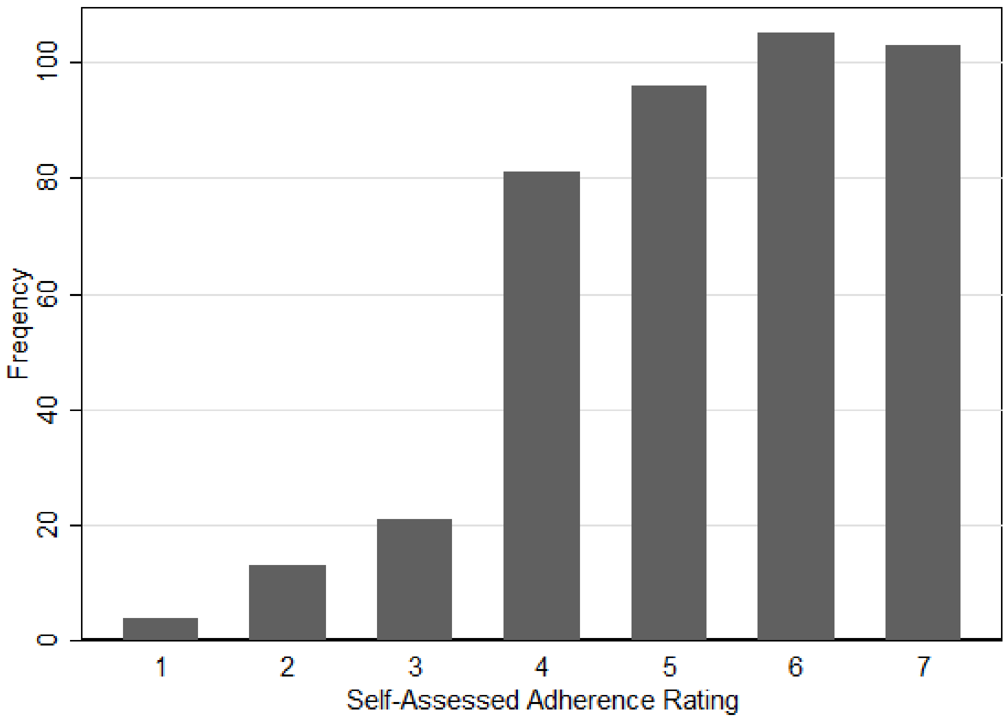
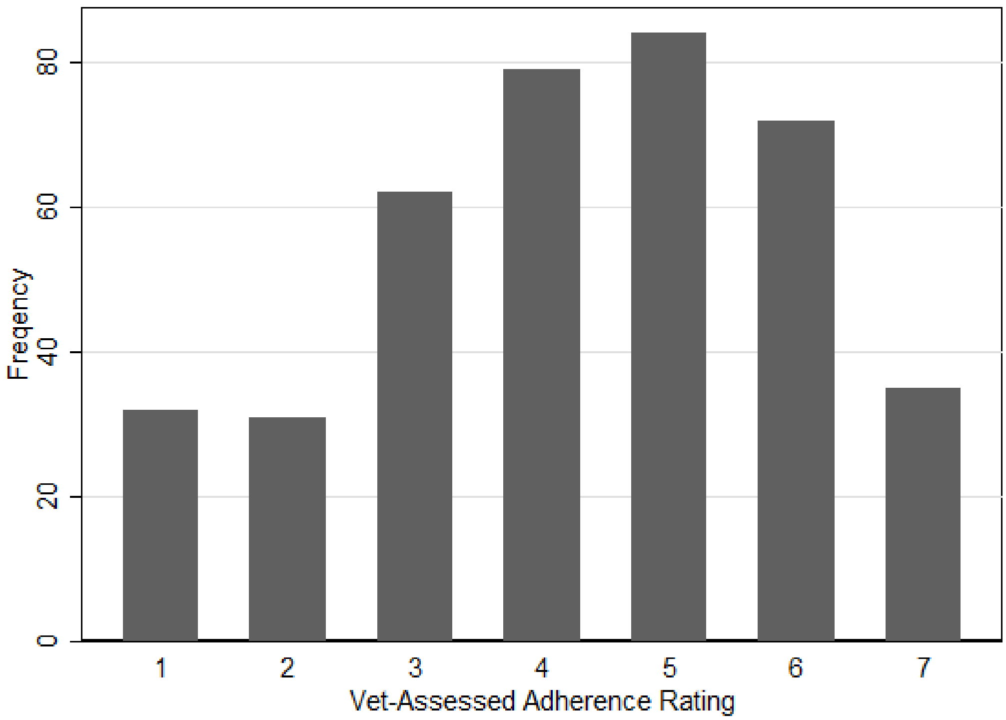


Figure 3.2 Frequency distribution of veterinary-assessed adherence ratings to management plan recommendations in the first risk assessment and management plan for 403 Atlantic Johne's Disease Initiative participating herds



CHAPTER 4: JOHNE'S DISEASE KNOWLEDGE, ATTITUDES, BELIEFS AND BEHAVIOURS OF DAIRY COW HERD MANAGERS PARTICIPATING IN A VOLUNTARY JOHNE'S DISEASE CONTROL PROGRAM

4.1 ABSTRACT

The Atlantic Johne's Disease Initiative (AJDI) was established to reduce prevalence and impact of Johne's disease (JD) in dairy herds of Atlantic Canada. To support success of the AJDI, improved understanding of knowledge, attitudes, beliefs, and behaviours of cow managers (those who made animal health policy decisions for herds) was required. This study used principles of the theory of planned behaviour (TPB) to design a questionnaire to explore intentions of cow managers to utilize strategies to prevent and control JD on farm. Behavioural intention, intention determinants (attitudes, subjective norms and perceived behavioural control), intention simulation scenarios, JD knowledge, and sources of JD information were measured and associations with whether or not cow managers intended to utilize strategies to prevent and control JD (i.e., were intenders) were investigated. A total of 68 cow managers, from AJDI herds who had already done their first Risk Assessment and Management Plan (RAMP) with an AJDI-certified veterinarian, completed in-person questionnaires from June 2012 to September 2013. On average, cow managers had moderate positive intentions to utilize strategies to prevent and control JD. Cow managers held strong positive attitudes towards JD, its prevention and control and moderate positive attitudes towards farm goals and herd culling reasons. Cow managers felt strong social pressure to prevent and control JD from their herd veterinarian and dairy consumers. Nonetheless, cow managers did not have strong confidence that they were capable of using best management practices to prevent and control JD. In this study, strengthening either behavioural beliefs towards JD or

indirectly measured control beliefs and their corresponding evaluations were associated with increased likelihood that the cow manager was an intender. An association of borderline significance was identified between being an intender and the likelihood of improvement in measured JD risk using veterinary-administered risk assessments, a measure indicative of behaviour to implement JD control and prevention strategies. Knowledge scores of cow managers indicated moderate knowledge about JD, with a median score of 80% and a range of scores from 45% to 95% but were not found to have significant associations with the likelihood of being an intender. In response to this TPB research, AJDI developed and delivered a communication skills training workshop to veterinarians involved in the control initiative to strengthen behavioural intention determinants.

4.2 INTRODUCTION

Johne's disease (JD), also known as paratuberculosis, is an incurable infectious disease that is prevalent in dairy herds around the world. It is caused by a bacterium, *Mycobacterium avium* subspecies *paratuberculosis* (MAP), which infects ruminants and results in severe ill thrift due to chronic enteritis. Management practices to reduce on-farm risks of Johne's disease (JD) have effectively reduced the prevalence of MAP infections in dairy herds (Tiwari et al., 2006). As such, JD control programs have been developed that use veterinary-administered risk assessment (RA) to identify high risk management practices and to prompt changes in management behaviour to prevent and reduce JD risk on farm (Kennedy and Allworth, 2000; Groenendaal et al., 2003; Nielsen, 2007; Collins et al., 2010; Barker et al., 2012).

Unfortunately, previous studies have repeatedly shown poor adherence to management practice changes, particularly with increasing duration of participation in a control program (Wraight et al., 2000; Ridge et al., 2010; Sorge et al., 2010; Wolf et al., 2015). Reasons for nonadherence with on-farm recommendations to control JD have been described (Sorge et al., 2010; Roche, 2014; Ritter et al., 2016; Ritter et al., 2017; Roche et al., 2019). Sorge et al. (2010) reported that one of the main reasons for nonadherence was because respondents did not believe a change was necessary. Roche reported that there were both physical resource barriers (i.e., time, money, and infrastructure) and producer mindset barriers (i.e., perceived priority of JD, motivation, and perceived practicality of JD control recommendations) to adoption of on-farm management practices (Roche, 2014; Roche et al., 2019). Ritter et al. (2016) described farmers' perceptions according to their beliefs in the importance of JD and in recommended prevention and control strategies for JD. A review of relevant published literature has described influences (i.e., farmers' own unique circumstances, agricultural contexts, beliefs and goals) and extension tools that affect farmers' management decisions (Ritter et al., 2017). It is not known whether factors identified in the above studies may also be affecting adherence to JD best management practices among dairy producers in the Atlantic provinces of Canada; specifically, New Brunswick (NB), Newfoundland and Labrador (NL), Nova Scotia (NS), and Prince Edward Island (PE).

Socio-psychological research has established a relationship between a person's knowledge, attitudes, beliefs and their behaviour. Studies have described attitudes and perceptions of dairy and beef farmers towards the impacts of JD, participation in JD control programs, and RAMP-based JD control strategies (Sorge et al., 2010; Benjamin et al., 2010; Hop et al., 2011; Nielsen, 2011; Bhattarai et al., 2013; Ritter et al., 2015; Roche et al., 2015; Ritter et al., 2016). However, research has shown that attitudes don't always predict deliberate behaviour, at least not on their own. Socio-psychological theories suggest that behaviour is influenced by a complex set of factors (Janz and Becker, 1984; Roche et al., 2015; Ritter et al., 2015).

Theoretical models have been developed to describe and predict deliberate and planned behaviour. One model that has been extensively used is the Theory of Planned Behaviour (TPB). According to TPB, when people have time to plan how they are going to behave, the best predictor for that behaviour is one's intention, which in turn is determined by three things: attitude, perceived control and subjective norms (Ajzen, 2020). Generally speaking, when more favorable attitudes and subjective norms are combined with greater perceived control, a person's intention to perform the behaviour in question is stronger. Appropriately designed questionnaires can elicit and measure the three behavioural intention determinants. This aids in understanding behaviour and designing intervention strategies to help increase uptake of recommendations (Francis et al., 2004).

The TPB has been used both in human medicine and agricultural research to try to understand, predict and modify behaviour. Studies specific to the dairy industry have used TPB to explain mastitis incidence (Jansen et al., 2009) and to explore intentions of dairy farmers to implement mastitis control measures (Lind et al., 2012; Mekonnen et al., 2017), reduce antibiotic use (Jones et al., 2015), improve dairy cow foot health (Bruijnis et al., 2013), adopt estrus detection techniques (Garforth et al., 2006), and adopt sustainable practices in gastrointestinal nematode control (Vande Velde et al., 2015). The

TPB has also been used to evaluate the effect of a participatory-based experiential learning program that aimed to change behaviour of dairy producers towards JD control in Ontario (Roche et al., 2015).

The dairy industry of Atlantic Canada agreed to implement a program in 2011 to reduce prevalence of MAP infections and impact of JD in dairy herds in the region. The Atlantic Johne's Disease Initiative (AJDI) was established as a risk assessment (RA) based control program, relying on implementation of management behaviour changes to decrease risk of MAP infection and transmission on farm. Just over 70% of dairy herds in the region volunteered to participate in the AJDI (n=462). For each of the AJDI herds, the initiative started with environmental culture herd categorization and on-farm veterinary consultation to perform a farm-specific risk assessment and develop a management plan (RAMP). In the AJDI, herd categorization and RAMP completion was repeated in approximately one year.

Ultimately, the success of a RA-based control program is determined by adherence to recommended JD management practices (Sorge et al., 2010). In order to reduce prevalence of MAP infection in Atlantic Canada, it was necessary to better understand intentions of the cow managers to adhere to recommended JD management practices and to explore determinants affecting JD control.

The objective of the present study was to provide a better understanding of factors that influence cow managers' intentions towards utilizing strategies to prevent and control JD.

4.3 MATERIALS AND METHODS

4.3.1 Source population and sampling method

AJDI participant herds were the source population for this study, and the intended time period for questionnaire completion was between the first and second RAMP. To create the study population, random numbers were assigned to AJDI herds. Based on the order of random numbers, herds were invited by telephone to participate in the research. AJDI herds that completed their second RAMP or ceased operations were not invited to participate. Using this sampling scheme and based upon time and logistics available, the sample size goal was 80 herds, which is generally acceptable for studies using TPB (Francis et al., 2004). Questionnaires were completed in-person with the cow manager of the herd, the person who made the animal health policy decisions for the herd.

4.3.2 Theoretical framework

The TPB proposes a model about how human action is guided. A schematic diagram of the model is shown in Figure 4.1. The theoretical framework of the TPB explains the causal chain linking attitudes, subjective norms and perceived behavioural control to formation of intention, understood to be the immediate antecedent of behaviour. Attitudes are formed through evaluation of the behaviour and are generally positive or negative. Subjective norms are one’s estimate of social pressure about performing the behaviour and are often expressed as others’ approval or disapproval. Perceived behavioural control is how capable one feels about doing the behaviour or the amount of control they have over the environment, and suggests whether it will be easy or hard to accomplish the behaviour. (Francis et al., 2004; Glanz et al., 2015; Ajzen, 2020)

The three behavioural intention determinants (attitudes, subjective norms and perceived behavioural control) are assumed to have two components which work together; beliefs (behavioural, normative, and control) and corresponding evaluations (outcome evaluations, motivation to comply, and perceived power to influence behaviour). Each of the three determinants can be measured directly or indirectly; by asking the person directly about their attitude, subjective norms and perceived control, or indirectly asking the person about the determinants' beliefs and corresponding evaluations (Francis et al., 2004).

4.3.3 Data collection

Using principles of the TPB and direction from the TPB manual prepared by Francis et al. (2004), a questionnaire was designed to study the behaviour of utilizing strategies to prevent and control JD on-farm (Appendix C.1). Behavioural intention was measured using intention performance. One intention performance statement was used with the aim of quantifying the behavioural intention towards utilizing strategies to prevent and control JD on the farm, using a 7-point Likert scale (Appendix C.1, Section 4, Question 62). The intention performance statement used in the questionnaire was "we use strategies to prevent and control JD on our farm."

Attitudes, subjective norms and perceived behavioural control were all measured using indirect measurement of their beliefs and corresponding evaluations. The behavioural, normative and control beliefs and their corresponding evaluations were selected based upon opinions of experts in dairy production and medicine [veterinarians in the Department of Health Management at the Atlantic Veterinary College who had extensive experience with dairy production and medicine (G. Keefe & S. McKenna)].

Behavioural beliefs were measured for three different themes. The first behavioural belief referred to farm goals that could be negatively impacted by JD and its best management practices (Appendix C.1, Section 1). The second behavioural belief focused on reasons cows were culled from the herd (Appendix C.1, Section 2). The final behavioural belief directly concerned JD and its control (Appendix C.1, Section 4). All behavioural beliefs were measured using a 7-point Likert scale and outcome evaluations were measured using a 7-point bipolar ordinal scale (from -3 to +3). Bipolar response scales were used for outcome evaluations because the concepts being measured were bidirectional (i.e., concepts considered important were given positive response values whereas, concepts considered unimportant were given negative response values).

Normative beliefs were assessed by asking about the opinions of the following reference groups towards JD prevention and control: fellow producers, the herd veterinarian, dairy consumers, international dairy industry, and dairy processors (Appendix C.1, Section 6). Motivations to comply were measured through statements to indicate if opinions of those in the reference groups impacted their own behavioural intentions. Normative beliefs were measured using a 7-point Likert scale and motivations to comply were measured using a 7-point bipolar ordinal scale (from -3 to +3).

Perceived behavioural control was measured using two indirect and six direct measures. The two control beliefs and corresponding perceived powers to influence behaviour were related to self-reported JD knowledge (Appendix C.1, Section 4, Questions 66 & 73) and effectiveness of JD control strategies (Appendix C.1, Section 4, Questions 67 & 74). Control belief strengths were measured using a 7-point Likert scale and perceived powers was measured using a 7-point bipolar ordinal scale (from -3 to +3).

The six direct measures of perceived behavioural control reflected the AJDI cow managers' confidence in their capability to implement JD best management practices and possible impediments of time, money and competing herd priorities (Appendix C.1, Section 8). The direct measurements used a 7-point Likert scale.

Other sections in the questionnaire included intention simulation scenarios (Appendix C.1, Section 7), statements to measure JD knowledge (Appendix C.1, Section 3) and gather sources of JD information (Appendix C.1 Section 5), and questions to collect demographic information (Appendix C.1, Section 9). Intention simulation scenarios were used to identify issues about JD that would change prioritization of JD prevention and control on farm. For each scenario, a 7-point Likert scale was used to rate the change in priority, from no change to major change in priority. Knowledge about JD was measured using statements that were rated on a 7-point bipolar ordinal scale (from -3 to +3). Information sources about JD were determined using statements that were rated using a 7-point Likert scale. The final section of the questionnaire gathered demographic information on the herd, farm workers, herd veterinarians and cow manager, using a mixture of open and multiple-choice questions. Questions about farm personnel (including family members), were focused on those who worked with cows (as opposed to field work only), were at least 12 years of age, and worked at least 5 hours per week.

To check the appropriateness and understandability of statements and questions, the questionnaire was reviewed by three professors [Faculty of Agriculture at Dalhousie University (L. Sanderson) and Department of Health Management at Atlantic Veterinary College (G. Keefe & S. McKenna)] and was pre-tested on three AJDI herds.

4.3.4 Statistical analysis

Questionnaires were completed on paper by an in-person interviewer, followed by dual data entry using EpiData 3.1 (EpiData Association, Odense, Denmark). Statistical analysis was completed using STATA 14.2 (StataCorp, LLC, College Station, Texas, USA). For this study, statistical significance was defined as having a P-value <0.05.

Descriptive statistics were calculated for demographic data, knowledge statements, information sources about JD, intention simulation scenarios, the behavioural intention and its determinants. Knowledge statement responses were recoded to have all incorrect endpoints to the left, so that higher numbers always reflected more correct responses. Knowledge statement responses were considered correct if they had scores of +2 or +3.

The single intention performance measure was dichotomized into a variable called intender, representing those who intended to use strategies to prevent and control JD on their farm versus those who did not or were neutral. A cow manager was considered an intender (assigned an intender value of 1) if their response to the intention performance measure was >4 (on a 7-point Likert scale) or a nonintender (assigned a value of 0) if their response was ≤ 4.

To score indirect measures of the behavioural intention determinants, beliefs were multiplied by corresponding evaluations and resulting products for each section were summed to create a composite weighted score. Positive scores meant that overall, cow managers were in favour of using strategies to prevent and control JD on their farm (attitude), experienced social pressure to prevent and control JD on their farm (subjective norm), or felt in control of preventing and controlling JD on their farm (PBC).

The strength of intention determinants (attitude, subjective norm or PBC) was interpreted based upon the possible range of total scores. The range from zero to the maximum score was divided into thirds, and the third closest to zero was considered weak, the middle third was considered moderate, and the third furthest from zero was considered strong.

Items used to directly measure PBC were recoded if they had negatively worded endpoints on the right, so that higher numbers always reflected that cow managers felt more control to prevent and control JD on their farm. Direct measure PBC items were checked for internal consistency and reliability by calculating Cronbach's alpha. Cronbach's alpha was considered to be acceptable for values >0.6, indicating high internal consistency and correlation between items. The overall direct PBC score was calculated as the mean of the direct PBC item scores. An overall direct PBC score >4 meant that cow managers felt in control of preventing and controlling JD on their farm. The strength of the direct score was interpreted as weak control for a score of 5, moderate control for a score of 6 and strong control for a score of 7.

Univariable logistic regressions were used to identify associations between intender status (outcome) and the behavioural intention determinants. Univariable regressions were also used to identify associations between intender status and RAMP data (e.g. JD herd categorization, first RAMP score, and whether or not RAMP score improved between first and second RAMPs) (outcomes).

Multivariable logistic regression modelling was used to identify factors that were associated with intender status (outcome). Independent variables initially included in the model were intention determinant indirect composite scores (attitude-JD, attitude-farm goals, attitude-culling reasons, subjective norm, PBC), intention determinant direct overall score (PBC), cow manger demographics (age, secondary education), herd demographics (lactating cow herd size, lactating cow housing type, 305-day milk production (kg), plans to at least maintain herd size in 5 years, plans to at least maintain herd size in 10 years), JD herd categorization, and first RAMP score. Backward stepwise elimination was used for model-building until only independent variables with P-values <0.05 were included. Removed independent variables were reinserted back into the models to check for confounding (coefficient change of at least 30%) or consideration of *a priori* reasons for inclusion (Dohoo et al., 2009).

4.4 RESULTS

The questionnaires were completed with 68 AJDI cow managers from June 2012 to September 2013. A table summarizing the participant and demographic data is shown in Table 4.1. Of the study participants, 18 of herds were located in NB (26% of questionnaires), 6 were in NL (9%), 24 were in NS (35%), and 20 were in PE (29%). These study herds represented 57% of AJDI herds that were assessed for inclusion into the study (first 120 AJDI herds by random number assignment). Of the AJDI herds assessed for inclusion, two were excluded from the study as they had sold their cattle, two were excluded as they had withdrawn from the AJDI prior to environmental culture herd categorization, and two herds declined to participate in the study. The remaining herds were excluded as they had already done their second RAMP with an AJDI certified veterinarian.

Just over 22% of herds in the study population had been previously categorized as positive by their first environmental culture in the AJDI (n=15). The median lactating herd size was 60 cows (range of 16 to 420 cows). Forty-one of the herds were enrolled in a milk recording program (Valacta), and for these herds, median 305-day milk production was 9,241 kg. These characteristics were very similar to those in the source population of all herds participating in the AJDI. As described in chapter two of this thesis, apparent herd prevalence of MAP infection for first environmental culture herd categorization of AJDI herds was 19%. The median lactating herd size for AJDI herds was 60 cows and median 305-day milk production was 9,256 kg.

At the time of questionnaire administration, cow managers had a median age of 52 years and 56% had completed a university or college program. The median number of farm personnel (including family members) that worked with cows was four, and the median full-time personnel equivalents that worked with cows was two. Herds had a median of three different veterinarians do work on their farm during the previous year. For 75% of herds, all gross farm income came from dairy production. Most herds planned to maintain or increase their dairy operations within the next 5 or 10 years; 94% within 5 years and 88% within 10 years.

4.4.1 Intention performance to prevent and control Johne's disease

The median response to the intention performance statement was 6 out of 7, reflecting a moderate positive intention to perform the target behaviour. When divided into intenders versus nonintenders, 82% of cow managers were categorized as intenders (n=56).

4.4.2 Indirect measurement of attitude to JD, farm goals and culling reasons

The median composite attitude score for statements relating directly to JD and its prevention and control (Table 4.2) was +60 out of a possible range of scores from -84 to +84. Therefore, the attitude score of cow managers reflected a strong positive attitude (median score was in the top third of score range above zero) in favor of JD control and minimizing potential impact of JD. All four items that made up this composite score had median weighted scores that also reflected strong positive attitudes.

A significant association was detected between cow managers' intentions to prevent and control JD (intender status) and the JD composite attitude scores [OR = 1.04 (95% Confidence Interval (CI):1.01, 1.07)]. For each point increase in composite attitude score, there was a 4% increase in odds for being an intender. Of the four weighted items that made up this composite attitude score, intender status was significantly associated with three; wanted to participate in the AJDI, concerned about cost of JD, and concerned about JD.

The median composite attitude score (Table 4.3) for statements related to farm goals that could be negatively impacted by JD and its best management practices was +155 out of a possible range of scores from -273 to +273. Therefore, this attitude score of cow managers reflected a moderate positive attitude in favor of realizing these herd goals. Of the 15 goal items that made up this composite score, 6 had median weighted scores that reflected strong positive attitude.

A significant association was not detected between intender status and the farm goals composite attitude score. Of the 15 weighted items that made up this composite attitude score, intender status was significantly associated with two: having adequate disease prevention strategies; and keeping farm facilities clean.

The median composite attitude score (Table 4.4) for statements relating to reasons cows were culled from the herds was +31 out of a possible range of scores from -84 to +84. Therefore, the beliefs of cow managers about reasons for culling from the herd and the need to decrease these culling reasons were moderately positive. Of the four culling reasons included in this composite score (fertility, mastitis, metabolic disease and lameness), none of the individual weighted scores reflected a strong attitude.

Significant associations were not detected between intender status and the culling reasons composite attitude score, or between intender status and any of the four weighted items that made up this composite attitude score.

4.4.3 Indirect measurement of subjective norms

The median composite normative belief score (Table 4.5) was +60 out of a possible range of scores from -126 to +126. Therefore, the normative belief score of cow managers reflected moderate positive social pressure to prevent and control JD. Of the reference groups that were proposed to have JD prevention and control opinions that may impact the intentions of cow managers, 2 had median weighted scores that reflected strong positive subjective norms; the herd veterinarian and dairy consumers.

The association between intender status and the composite normative belief scores was close to the defined significance cut-off [OR=1.02 (95% CI: 1.00, 1.05), P-value = 0.08]. Significant associations were not detected between intender status and the individual reference group weighted scores.

4.4.4 Indirect measurement of perceived behavioural control

The composite PBC score (Table 4.6) was +29 out of a possible range of scores from -42 to +42. Therefore, the PBC score of cow managers reflected a strong level of positive control and that preventing and controlling JD is easy. The weighted median scores of both of the items that made up this composite score were the same. Strong level of positive control was reflected in the managers' self-reported JD knowledge and the effectiveness of JD prevention and control strategies.

A significant association was detected between intender status and the composite indirect PBC scores [OR = 1.09 (95% CI: 1.01, 1.18)]. For each point increase in composite attitude score, there was a 9% increase in odds for being an intender status. One of the two items making up the indirect composite PBC, self-reported JD knowledge, was also significantly associated with intender status, while the second item, effectiveness of JD prevention and control strategies, had a borderline significant association.

4.4.5 Direct measurement of perceived behavioural control

There was high internal consistency and correlation between the six items presented to the cow managers to directly measure PBC; as such, the items were considered together as an overall PBC score regarding ease of implementation of best management practices to prevent and control JD (Cronbach's $\alpha = 0.66$). The median of the overall PBC scores (Table 4.7) was 6 out of 7, reflecting a moderate level of positive control over implementing best management practices to prevent and control JD. Of the six items proposed to measure ease of implementing JD best management practices, the item with the lowest median PBC score was self-reported ease of implementing best management practices to prevent and control JD (median overall PBC score of 5 out of 7), reflecting a weak level of positive control.

The association between intender status and the overall direct PBC mean scores was borderline significant [OR=1.70 (95% CI: 0.97, 2.98), P-value = 0.06]. One of the PBC direct items also had an association with intender status that was of borderline significance; self-reported ease of implementing JD best management practices.

4.4.6 Knowledge and information sources about Johne's disease

Of the 20 statements to measure cow managers' knowledge about JD, the median percentage of correct responses was 80% and the range of correct response percentages was 45% to 95%. The statements that fewest managers responded to correctly were "when purchasing cattle, the best protocol to prevent JD introduction is to test the animal prior to purchase" (19% of cow managers responded correctly) and "animals with JD tend to lose their appetite" (24% correct). One statement was responded to correctly by all cow managers; "cleanliness of the maternity pen is crucial for decreasing JD transmission." The five best and worst knowledge statements with respect to the percentages of cow managers who responded correctly to the statements are shown in Table 4.8.

A significant association between intender status and the percentage of correct responses was not detected. A significant association was detected between the measured and the self-reported knowledge about JD (both dichotomized using a median split), resulting in an OR of 3.89 (95% CI: 1.04, 14.60).

Of the potential sources of JD information presented to cow managers, 76% of managers indicated they learned about JD from their herd veterinarian (rating of at least 6 out of 7). Other frequent JD information sources included, trade magazines (65% of cow managers rated this source at least 6 out of 7), mailings from the dairy board or AJDI (54% of cow managers), and presentations (47%).

4.4.7 Intention simulation scenarios

There was high internal consistency and correlation among responses to the 10 intention simulation scenarios presented to cow managers (Cronbach's $\alpha = 0.65$). The median response to intention scenarios was 5.6 out of 7, reflecting a moderate intention to increase prioritization of JD prevention and control. The scenario that indicated a strong intention to increase prioritization of JD prevention and control for the largest percentage of cow managers was if test-positive cows had to be culled from the herd to be able to ship milk; 75% of managers rated this scenario 7 out of 7. Three other scenarios also indicated strong intentions to increase prioritization of JD control (rated 7 out of 7): two financial cost scenarios (72% of cow managers if the cost was $20,000 per year and 53% of managers if the cost was $10,000 per year, for a herd of 100 cows with 5% within-herd MAP infection prevalence); and if researchers were able to cause Crohn's disease in mice by exposing them to milk containing MAP (57% of cow managers). The responses to intention simulation scenarios did not correlate with intender status the intention performance measure (Cronbach's $\alpha = 0.20$).

4.4.8 Multivariable model of factors associated with behavioural intention

For the multivariable logistic regression model of intender status, two independent variables were retained in the model; JD composite attitude score and lactating cow herd size. The composite attitude score was significantly associated with intender status, having an odds ratio of 1.05 (95% CI: 1.02, 1.09). Therefore, changing the JD composite attitude score from +42 to +70, reflective of a change from a moderate positive attitude to a strong positive attitude, increased the odds of being an intender by 3.92 times. The size of the lactating cow herd (large herd versus small herd, split on median lactating herd size) had a negative association with intender status that was borderline significant, having an odds ratio of 0.19 (95% CI: 0.04, 1.02) and P-value of 0.053. Therefore, large herds had 81% lower odds of being an intender than did small herds.

4.5 DISCUSSION

In this study, a questionnaire based upon the TPB was used to explore the intentions of cow managers to utilize strategies to prevent and control JD. This information could be used in the development of interventions to improve implementation of JD best management practices.

It was determined that on average, cow managers had moderate positive intentions to utilize strategies to prevent and control JD. A majority of cow managers were categorized as intenders, someone who intended to use strategies to prevent and control JD on their farm.

The overall attitude score for statements related directly to JD generally reflected a strong positive attitude and was significantly associated with intender status. Accordingly, on average, there would not be a lot of room for improvement in the JD behavioural belief strengths and outcome evaluations. Nonetheless, 43% of cow managers had JD attitude scores reflective of weak or moderate positive attitudes. Interventions aimed to increase the JD attitude score of these cow managers would increase their likelihood of being an intender.

The farm goals attitude score of cow managers reflected a moderate positive attitude, but a significant association was not detected with intender status. However, many of the individual farm goals that were included in this attitude construct did have weighted scores that reflected strong positive attitudes. Evidence has been documented that directly links effects of JD to many of these farm goals (Chi et al., 2002; McKenna et al., 2006; Wells et al., 2008). If interventions were designed to increase the cognizance of cow managers to the negative effects JD has on these farm goals, the strength of these attitudes could benefit JD prevention and control. Intervention efforts could include targeting of herd veterinarians to improve communication about the potential benefits of JD control in realizing farm goals. A previous study found that beliefs about negative effects of JD were not strong enough to influence behaviour change on their own, so it was suggested that incorporating this messaging as part of a holistic approach to improving herd health could increase the likelihood that it effectively influences behaviour change (Roche et al., 2015).

The attitude score for statements related to the reasons cows were culled from the herd reflected moderate attitude strength, but significant associations were not detected with intender status. None of the individual reasons for culling had scores that reflected a strong attitude. Due to overall lack of strength in the behavioural beliefs and outcome evaluations for this attitude construct, it is unlikely that behavioural intention would be strongly increased by efforts to raise recognition of the negative impacts of JD on culling.

The normative belief score of cow managers reflected a moderate positive social pressure to prevent and control JD, but a significant association was not detected with intender status. The herd veterinarian and dairy consumers individually exerted strong positive social pressure to prevent and control JD but neither were significantly associated with intender status. Perhaps what was missing between the strength of social pressure from these two reference groups and the likelihood of a cow manager being an intender was a disconnect between the opinions of the reference groups and the applicability of social pressure to their farms specifically. Efforts could be increased to assist herd veterinarians to communicate farm-specific aspects of JD and its control and to negotiate mutually acceptable plans to implement JD best management practices on farm (i.e., communication skills training).

Indirect and direct measures of PBC had associations with intender status that were significant or borderline significant. The indirect PBC score reflected a strong level of positive control over implementing best management practices to prevent and control JD; whereas, the direct PBC score reflected a moderate level of positive control. Given the associations with intender status, direct PBC items with weak to moderate PBC scores could be considered potential barriers to JD control. The lowest direct PBC item score was self-reported ease of implementing best management practices to prevent and control JD.

An argument could be made that one of the items included in the indirect measurement of PBC, effectiveness of JD prevention and control strategies (Appendix C.1, Section 4, Questions 67 & 74), could have been included in the indirect measurement of attitude toward JD. According to Francis et al. (2004), one of the aspects of PBC is how much control a person has over the behaviour, with the example of having low control due to malfunctioning technology. For this study, effectiveness of JD control strategies was considered a control belief as a producer would have low control over utilizing strategies to prevent and control JD on the farm if the control strategies were ineffective. On the other hand, one of the components of attitude is beliefs about consequences of behaviour (behavioural beliefs), where doing the behaviour may result in a desired outcome (Francis et al., 2004). For this study, effectiveness of JD control strategies could have been considered part of the attitude measure if you assume effectiveness ties into the behavioural belief that utilizing strategies to prevent and control JD on the farm will help to reduce MAP prevalence. Based on this argument, whether effectiveness of JD prevention and control strategies is most appropriately categorized as a control belief or a behavioural belief, the strength of the indirect PBC score found in this study should be interpreted with caution.

Cow managers correctly responded to a moderate percentage of the questions about JD, but a significant association between cow managers' knowledge and intender status was not detected. Similar conclusions were made by Roche et al. (2015) who found that knowledge may not have played a significant role in influencing the increased adoption of JD best management practices among Ontario dairy farmers. Therefore, while there is room for more education about JD, this study suggested that knowledge about the disease was not a significant driver to promote changes in JD management behaviour.

In this study, the intention simulation scenarios did not correlate with intender status but this was not unexpected. These two measures focused on slightly different intentions. The intention simulations did identify possible drivers to JD control; substantial financial costs due to JD, perceived zoonotic risk of JD, and threat of mandatory culling of test positive cows to maintain milk shipments all elicited potentially major increases in priority of JD control efforts.

In this study, being an intender increased the likelihood that RAMP scores would improve from the first to the second RAMP, but the relationship was only borderline significant. Lack of power due to only 68 herds in the study was a likely contributor to the inability to detect a significant association. It is also possible that the intention performance measure used was not robust enough to adequately represent the intention to implement JD best management practices. During questionnaire design, it seemed advantageous to use a single item to measure the behavioural intention score and to be able to compare it to the herd's improvement in RAMP scores throughout AJDI participation, as suggested elsewhere (Francis et al., 2004). However, implementation of JD best management practices is a complex behaviour and the intention to perform this behaviour may have been better captured using multiple items and the generalized intention method. In future research, the following three statements would be used to measure this behavioural intention: I **expect** to use best management practices to prevent and control JD; I **want** to use best management practices to prevent and control JD; and I **intend** to use best management practices to prevent and control JD.

It is possible to compare the behavioural intentions from this study to assessments of RAMP adherence that were described in chapter 3 of this thesis. The median response to the intention performance statement used in this study was 6 out of 7. In chapter 3, the median self-assessed adherence was 5 out of 7 and the median veterinary-assessed adherence was 4.2 out of 7. As such, a gap exists between the stated behavioural intentions and actual behaviour. Other studies using TPB have also identified these types of gaps, as intention is not conclusively predictive of behaviour (Top et al., 2010). Perhaps there were unmeasured perceived barriers inhibiting behaviour change, or perceived risk of JD was not enough to take recommended actions. For future research, incorporation of other health behaviour models, such as the Health Belief Model (HBM), into surveys using TPB may be beneficial to broaden elements used to explore factors related to JD management behaviour change (Glanz et al., 2015).

By using the TPB, interventions aimed at improving communication skills of herd veterinarians have been identified as possible methods to strengthen behavioural intention determinants. In response, the AJDI developed and delivered a communication skills training workshop to veterinarians involved in the control initiative. More details about this workshop can be found in chapter six.

For this study, the method of questionnaire delivery was in-person. The rationale for this included length of the questionnaire and the aim of collecting information about cow managers' intentions, beliefs and opinions (Dohoo et al., 2009). In-person delivery also maximized data quality through clear recording of responses, minimizing missing information, and provided opportunity to develop rapport with responders to elicit accurate answers. Unfortunately, the time required to complete in-person questionnaires and difficulty scheduling multiple interviews at geographical dispersed farms, contributed to completion of fewer questionnaires than planned and resulted in a suboptimal sample size.

Herd demographics in the study population (herd size, type of housing and 305-day milk production) were comparable to those in the source population (all AJDI herds), indicative of good internal validity. Herd demographics were also similar to those reported in a study of attitudes of Canadian dairy farmers towards the JD control program in their provinces and to Canadian national averages (Sorge et al., 2010). This is indicative of good external validity as well. Importantly, participation in this study and the AJDI was voluntary and as such, may also be related to the intentions towards preventing and controlling JD. Herds participating in the AJDI and this study may have been more motivated to control JD on their farms than nonparticipants. Differences between participants and nonparticipants have been found in other studies about JD control that suggested participants may be more progressive and informed that the overall population (Raizman et al., 2006; Sorge et al., 2010; Roche et al., 2015). As such, generalizing the results of this study to other populations should be done with prudence.

4.6 CONCLUSIONS

In this study, cow managers had moderate positive intentions to utilize strategies to prevent and control JD. Nonetheless, cow managers did not intend to control JD based upon facts, but rather, behavioural intention was based primarily upon cow managers' beliefs. Strengthening either the behavioural beliefs towards JD, or the indirectly measured control beliefs and their corresponding evaluations, was associated with a higher likelihood of the cow manager being an intender. By using the TPB in this study, interventions aimed at improving communication skills of herd veterinarians were identified as possible methods to strengthen behavioural intention determinants. In response, the AJDI developed and delivered a communication skills training workshop to veterinarians involved in the control initiative. Further research would be beneficial using the TPB alone or in combination with other health behaviour models to broaden the exploration of the intention to change JD management behaviour.

4.7 REFERENCES

Ajzen, I. 2020. The theory of planned behavior: Frequently asked questions. Hum. Behav. Emerg. Technol. 2:314-324.

Barker, R. A., H. W. Barkema, G. Fecteau, G. K. Keefe and D. F. Kelton. 2012. Johne's Disease Control in Canada - Coordinated Nationally - Delivered Provincially. Proc. 3rd ParaTB Forum, Sydney, Australia. 45-51.

Benjamin, L. A., G. T. Fosgate, M. P. Ward, A. J. Roussel, R. A. Feagin and A. L. Schwartz. 2010. Attitudes towards biosecurity practices relevant to Johne's disease control on beef cattle farms. Prev. Vet. Med. 94:222-230.

Bhattarai, B., G. T. Fosgate, J. B. Osterstock, C. P. Fossler, S. C. Park and A. J. Roussel. 2013. Perceptions of veterinarians in bovine practice and producers with beef cow-calf operations enrolled in the US voluntary bovine Johne's disease control program concerning economic losses associated with Johne's disease. Prev. Vet. Med. 112:330-337.

Bruijnis, M., H. Hogeveen, C. Garforth and E. Stassen. 2013. Dairy farmers' attitudes and intentions towards improving dairy cow foot health. Livest. Sci. 155:103-113.

Chi, J., J. A. VanLeeuwen, A. Weersink and G. P. Keefe. 2002. Direct production losses and treatment costs from bovine viral diarrhoea virus, bovine leukosis virus, *Mycobacterium avium* subspecies *paratuberculosis*, and Neospora caninum. Prev. Vet. Med. 55:137-153.

Collins, M. T., V. Eggleston and E. J. B. Manning. 2010. Successful control of Johne's disease in nine dairy herds: Results of a six-year field trial. J. Dairy Sci. 93:1638-1643.

Dohoo, I. R., W. Martin and H. Stryhn. 2009. Veterinary Epidemiologic Research. 2nd edition. VER Inc., Charlottetown, Prince Edward Island, Canada.

Francis, J. J., M. P. Eccles, M. Johnston, A. Walker, J. Grimshaw, R. Foy, E. F. S. Kaner, L. Smith and D. Bonetti. 2004. Constructing Questionnaires Based on the Theory of Planned Behaviour: A Manual for Health Services Researchers. University of Newcastle, United Kingdom, Europe.

Garforth, C., K. McKemey, T. Rehman, R. Tranter, R. Cooke, J. Park, P. Dorward and C. Yates. 2006. Farmers' attitudes towards techniques for improving oestrus detection in dairy herds in south west England. Livest. Sci. 103:158-168.

Glanz, K., B. K. Rimer and K. Viswanath. 2015. Health Behavior: Theory, Research, and Practice. 5th Edition. Jossey-Bass, San Francisco, California, USA.

Groenendaal, H., M. Nielen and J. W. Hesselink. 2003. Development of the Dutch Johne's disease control program supported by a simulation model. Prev. Vet. Med. 60:69-90.

Hop, G. E., A. G. J. Velthuis and K. Frankena. 2011. Assessing Dutch farmers' incentives to join a voluntary Johne's disease programme. NJAS - Wagen. J. Life Sc. 58:57-64.

Jansen, J., B. H. P. Borne, R. J. Renes, G. Schaik, T. J. G. M. Lam and C. Leeuwis. 2009. Explaining mastitis incidence in Dutch dairy farming: The influence of farmers' attitudes and behaviour. Prev. Vet. Med. 92:210-223.

Janz, N. K. and M. H. Becker. 1984. The health belief model: A decade later. Health Educ. Q. 11:1-47.

Jones, P. J., E. A. Marier, R. B. Tranter, G. Wu, E. Watson and C. J. Teale. 2015. Factors affecting dairy farmers' attitudes towards antimicrobial medicine usage in cattle in England and Wales. Prev. Vet. Med. 121:30-40.

Kennedy, D. J. and M. B. Allworth. 2000. Progress in national control and assurance programs for bovine Johne's disease in Australia. Vet. Microbiol. 77:443-451.

Lind, A. K., P. T. Thomsen, S. Rintakoski, M. N. Espetvedt, C. Wolff and H. Houe. 2012. The association between farmers' participation in herd health programmes and their behaviour concerning treatment of mild clinical mastitis. Acta Vet. Scand. 54:62.

McKenna, S. L. B., G. P. Keefe, A. Tiwari, J. VanLeeuwen and H. W. Barkema. 2006. Johne's disease in Canada part II: Disease impacts, risk factors, and control programs for dairy producers. Can. Vet. J. 47:1089-1099.

Mekonnen, S. A., G. Koop, T. J. G. M. Lam and H. Hogeveen. 2017. The intention of north-western Ethiopian dairy farmers to control mastitis. PLoS ONE. 12:1-17.

Nielsen, S. S. 2011. Dairy farmers' reasons for participation in the Danish control programme on bovine paratuberculosis. Prev. Vet. Med. 98:279-283.

Nielsen, S. S. 2007. Danish control programme for bovine paratuberculosis. Cattle Pract. 15:161-168.

Raizman, E. A., S. J. Wells, S. M. Godden, J. Fetrow, K. Friendshuh and J. M. Oakes. 2006. Characterization of Minnesota dairy herds participating in a Johne's disease control program and evaluation of the program risk assessment tool. Prev. Vet. Med. 75:22-33.

Ridge, S. E., C. Heuer, N. Cogger, A. Heck, S. Moor, I. M. Baker and S. Vaughan. 2010. Herd management practices and the transmission of Johne's disease within infected dairy herds in Victoria, Australia. Prev. Vet. Med. 95:186-197.

Ritter, C., J. Jansen, K. Roth, J. P. Kastelic, C. L. Adams and H. W. Barkema. 2016. Dairy farmers' perceptions toward the implementation of on-farm Johne's disease prevention and control strategies. J. Dairy Sci. 99:9114-9125.

Ritter, C., G. P. S. Kwong, R. Wolf, C. Pickel, M. Slomp, J. Flaig, S. Mason, C. L. Adams, D. F. Kelton, J. Jansen, J. De Buck and H. W. Barkema. 2015. Factors associated with participation of Alberta dairy farmers in a voluntary, management-based Johne's disease control program. J. Dairy Sci. 98(11):7831-7845.

Ritter, C., J. Jansen, S. Roche, D. F. Kelton, C. L. Adams, K. Orsel, R. J. Erskine, G. Benedictus, T. J. G. M. Lam and H. W. Barkema. 2017. Invited review: Determinants of farmers' adoption of management-based strategies for infectious disease prevention and control. J. Dairy Sci. 100(5):3329-3347.

Roche, S. M., A. Jones-Bitton, M. Meehan, M. Von Massow and D. F. Kelton. 2015. Evaluating the effect of focus farms on Ontario dairy producers' knowledge, attitudes, and behavior toward control of Johne's disease. J. Dairy Sci. 98:5222-5240.

Roche, S. M., D. F. Kelton, M. Meehan, M. Von Massow and A. Jones-Bitton. 2019. Exploring dairy producer and veterinarian perceptions of barriers and motivators to adopting on-farm management practices for Johne's disease control in Ontario, Canada. J. Dairy Sci. 102:4476-4488.

Roche, S. 2014. Investigating the role of agricultural extension in influencing Ontario dairy producer behaviour for Johne's disease control. PhD Thesis. Department of Population Medicine. University of Guelph, Ontario, Canada.

Sorge, U., D. Kelton, K. Lissemore, A. Godkin, S. Hendrick and S. Wells. 2010. Attitudes of Canadian dairy farmers toward a voluntary Johne's disease control program. J. Dairy Sci. 93:1491-1499.

Tiwari, A., J. A. VanLeeuwen, S. L. B. McKenna, G. P. Keefe and H. W. Barkema. 2006. Johne's disease in Canada Part I: Clinical symptoms, pathophysiology, diagnosis, and prevalence in dairy herds. Can. Vet. J. 47:874-882.

Top, K. A., B. A. Halperin, D. Baxendale, D. MacKinnon-Cameron and S. A. Halperin. 2010. Pertussis immunization in paediatric healthcare workers: Knowledge, attitudes, beliefs, and behaviour. Vaccine. 28:2169-2173.

Vande Velde, F., E. Claerebout, V. Cauberghe, L. Hudders, H. Van Loo, J. Vercruysse and J. Charlier. 2015. Diagnosis before treatment: Identifying dairy farmers' determinants for the adoption of sustainable practices in gastrointestinal nematode control. Vet. Parasitol. 121(3-4):308-317.

Wells, S. J., W. L. Hartmann and P. L. Anderson. 2008. Evaluation of progress made by dairy and beef herds enrolled in the Minnesota Johne's disease control program. J. Am. Vet. Med. Assoc. 233:1920-1926.

Wolf, R., H. W. Barkema, J. De Buck and K. Orsel. 2015. Factors affecting management changes on farms participating in a Johne's disease control program. J. Dairy Sci. 98:7784-7796.

Wraight, M. D., J. McNeil, D. S. Beggs, R. K. Greenall, T. B. Humphris, R. J. Irwin, S. P. Jagoe, A. Jemmeson, W. F. Morgan, P. Brightling, G. A. Anderson and P. D. Mansell. 2000. Compliance of Victorian dairy farmers with current calf rearing recommendations for control of Johne's disease. Vet. Microbiol. 77(3-4):429-442.

Figure 4.1 Schematic diagram of the Theory of Planned Behaviour (Ajzen, 1991)

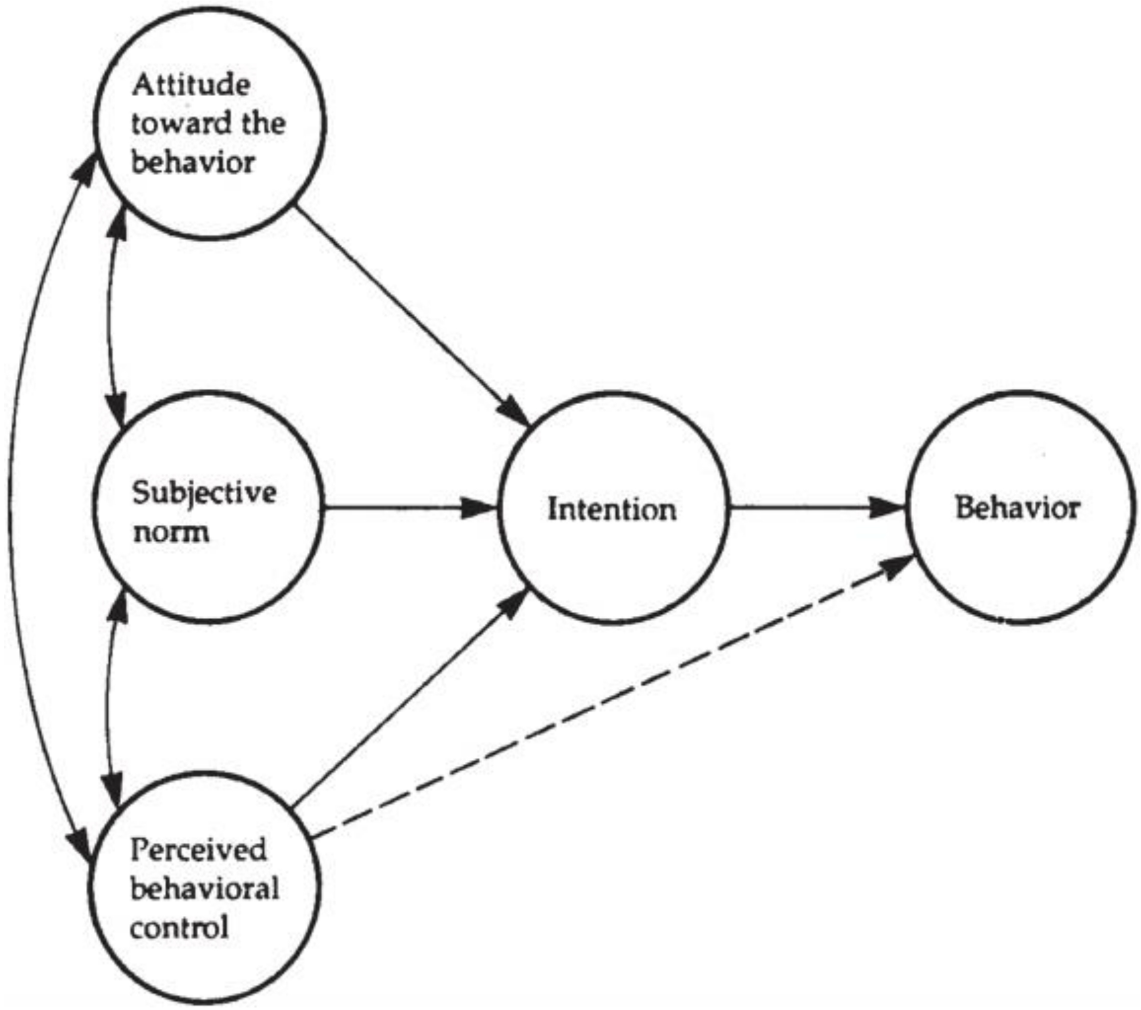


Table 4.1 Cow manager and herd demographic/production information for 68 Atlantic Johne's Disease Initiative respondents from June 2012 to September 2013.

Demographic Variable	Descriptive Statistics
Province, n (%)	
New Brunswick	18 (26)
Newfoundland & Labrador	6 (9)
Nova Scotia	24 (35)
Prince Edward Island	20 (29)
Environmental Culture Herd Categorization, n (%)	
Negative	53 (78)
Positive	15 (22)
Lactating Cow Herd, n	
Median (IQR)	60 (44-97)
Minimum/Maximum	16/420
305-Day Milk Production, kg	
Median (IQR)	9,241 (8,384-9,892)
Minimum/Maximum	5,552/12,018
Milk Fat, %	
Median (IQR)	3.9 (3.8-4.0)
Minimum/Maximum	3.5/4.4
Milk Protein, %	
Median (IQR)	3.1 (3.1-3.2)
Minimum/Maximum	2.9/3.4
Average Somatic Cell Count (1,000 cells/mL)	
Median (IQR)	318 (267-424)
Minimum/Maximum	145/694
Lactating Cow Housing, n (%)	
Tie-stall	26 (38)
Free-stall	37 (54)
Bedded pack	5 (7)
Age in years	
Median (IQR)	52 (52-58)
Minimum/Maximum	28/67
Education, n (%)	
≤ High School	30 (44)
College Diploma	26 (38)
University Degree	12 (18)
Farm personnel (including family members) that worked with cows, n	
Median (IQR)	4 (3-5)
Minimum/Maximum	1/11
Full-time farm personnel equivalents that worked with cows, n	
Median (IQR)	2 (2-2)

Demographic Variable	Descriptive Statistics
Minimum/Maximum	1/6
Veterinarians who worked with the herd in past year, n	
Median (IQR)	3 (2-4)
Minimum/Maximum	1/6
Gross farm income from dairy production, %	
Median (IQR)	100 (99-100)
Minimum/Maximum	10/100
Herd to maintain or increase dairy operation in next 5 years, n (%)	
No	4 (6)
Yes	64 (94)
Herd to maintain or increase dairy operation in next 10 years, n (%)	
No	8 (12)
Yes	57 (88)

Table 4.2 Descriptive statistics of indirect measurements of attitude toward Johne's disease and their univariable associations with intender status for 68 cow manager respondents in Atlantic Canada from June 2012 to September 2013.

Questionnaire Construct	Median Score	Possible Range		Strength Interpretation	Association with Intender		
		Min	Max		OR	P-value	95% CI
Composite attitude score [sum of behavioural belief strengths (scale of 1 to 7) x outcome evaluations (scale of -3 to +3)]	60	-84	84	strong positive	1.04	0.01	1.01 - 1.07
Item 1 - I am concerned about Johne's disease x Being concerned about Johne's disease is:	15	-21	21	strong positive	1.10	0.05	1.00 - 1.21
Item 2 - I am concerned about the costs of Johne's disease x Minimizing financial losses due to Johne's disease is:	17	-21	21	strong positive	1.18	<0.01	1.06 - 1.31
Item 3 - I am concerned about the possible human health risks of Johne's disease x Minimizing the potential impact of Johne's disease on human health is:	15	-21	21	strong positive	1.01	0.72	0.94 - 1.10
Item 4 - I was eager to participate in the AJDI x Having an industry wide Johne's disease prevention and control program in Atlantic Canada is:	18	-21	21	strong positive	1.09	0.03	1.01 - 1.18

Table 4.3 Descriptive statistics of indirect measurements of attitude toward farm goals and their univariable associations with intender status for 68 cow manager respondents in Atlantic Canada from June 2012 to September 2013.

Questionnaire Construct	Median Score	Possible Range		Strength Interpretation	Association with Intender		
		Min	Max		OR	P-value	95% CI
Composite attitude score [sum of behavioural belief strengths (scale of 1 to 7) x outcome evaluations (scale of -3 to +3)]	155	-273	273	moderate positive	1.01	0.22	0.99 - 1.03
Item 1 - Milk production is high on our farm x An important farm goal is to have high milk production per cow	12	-21	21	moderate positive	1.06	0.21	0.97 - 1.17
Item 2 - Cow longevity is good on our farm x An important farm goal is to increase cow longevity	12	-21	21	moderate positive	1.02	0.53	0.96 - 1.09
Item 3 - Herd fertility is good on our farm x An important farm goal is to increase the herd fertility	12	-21	21	moderate positive	1.07	0.16	0.97 - 1.19
Item 4 - We have adequate disease prevention strategies on our farm x An important farm goal is to prevent infectious disease introduction and spread	17	-21	21	strong positive	1.16	0.02	1.03 - 1.31
Item 5 - Fresh cows rarely become ill on our farm x An important farm goal is to minimize fresh cow illness	15	-21	21	strong positive	1.07	0.29	0.95 - 1.20
Item 6 - Farm management is simple on our farm x An important farm goal is to keep farm management simple	18	-21	21	strong positive	0.95	0.43	0.83 - 1.08
Item 7 - Our farm if very profitable x An important farm goal is to maximize profit	15	-21	21	strong positive	0.92	0.27	0.79 - 1.07
Item 8 - Our farm has little debt x An important	9	-21	21	moderate	1.00	0.97	0.93 - 1.07

Questionnaire Construct	Median Score	Possible Range		Strength Interpretation	Association with Intender		
		Min	Max		OR	P-value	95% CI
farm goal is to minimize debt				positive			
Item 9 - Our farm is preparing to transfer from one generation to the next x An important farm goal is to be able to transfer the farm to the next generation	7	-21	21	moderate positive	0.99	0.84	0.92 - 1.07
Item 10 - Our farm has a large land base x An important farm goal is to increase the farm land base	3	-21	21	weak positive	1.00	0.91	0.95 - 1.06
Item 11 - The facilities on our farm are very clean x An important farm goal is to maintain facility cleanliness	15	-21	21	strong positive	1.16	0.02	1.02 - 1.30
Item 12 - Our farm is a closed herd (no cattle purchased including bulls) x An important farm goal is to have a closed herd (no cattle purchased including bulls)	12	-21	21	moderate positive	1.02	0.50	0.97 - 1.07
Item 13 - We always fill our quota credits x An important farm goal is to fill our quota credits	18	-21	21	strong positive	0.99	0.85	0.90 - 1.10

Table 4.4 Descriptive statistics of indirect measurements of attitude toward culling reasons and their univariable associations with intender status for 68 cow manager respondents in Atlantic Canada from June 2012 to September 2013.

Questionnaire Construct	Median Score	Possible Range		Strength Interpretation	Association with Intender		
		Min	Max		OR	P-value	95% CI
Composite attitude score [sum of behavioural belief strengths (scale of 1 to 7) x outcome evaluations (scale of -3 to +3)]	31	-84	84	moderate positive	1.01	0.46	0.98 - 1.04
Item 1 - We often cull cows due to fertility problems x Decreasing the number of cows culled due to fertility problems on our farm is:	9	-21	21	moderate positive	1.03	0.89	0.72 - 1.47
Item 2 - We often cull cows due to mastitis x Decreasing the number of cows culled due to mastitis on our farm is:	10	-21	21	moderate positive	1.03	0.86	0.84 - 1.45
Item 3 - We often cull cows due to metabolic disease (e.g. displaced abomasum/DA, milk fever, ketosis, etc.) x Decreasing the number of cows culled due to metabolic disease (e.g. displaced abomasum/DA, milk fever, ketosis, etc.) on our farm is:	1	-21	21	weak positive	1.47	0.26	0.75 - 2.91
Item 4 - We often cull cows due to lameness problems x Decreasing the number of cows culled cue to lameness problems on our farm is:	8	-21	21	moderate positive	1.20	0.27	0.87 - 1.65

Table 4.5 Descriptive statistics of indirect measurements of subjective norms and their univariable associations with intender status for 68 cow manager respondents in Atlantic Canada from June 2012 to September 2013.

Questionnaire Construct	Median Score	Possible Range		Strength Interpretation	Association with Intender		
		Min	Max		OR	P-value	95% CI
Composite subjective norm score [sum of normative belief strength (scale of -3 to +3) x motivations to comply (scale of 1 to 7)]	60	-126	126	moderate positive	1.02	0.08	1.00 - 1.05
Item 1 - Fellow producers think it is important to prevent and control Johne's disease x Colleague approval matters to me	5	-21	21	weak positive	1.05	0.36	0.95 - 1.15
Item 2 - The majority of dairy producers in Atlantic Canada prevent and control Johne's disease x It is important to me to do what the other Atlantic Canadian dairy producers are doing	3	-21	21	weak positive	1.12	0.05	1.00 - 1.22
Item 3 - Our herd veterinarian thinks it is important to prevent and control Johne's disease x What our veterinarian thinks I should do matters to me	18	-21	21	strong positive	1.06	0.16	0.98 - 1.15
Item 4 - Dairy consumers would approve oh how we prevent and control Johne's disease x Consumer approval of our herd management is important to me	18	-21	21	strong positive	1.01	0.70	0.95 - 1.08
Item 5 - The international dairy industry thinks it is important to prevent and control Johne's disease x It is important to conform to international dairy industry expectations	12	-21	21	moderate positive	1.02	0.57	0.94 - 1.11
Item 6 - Dairy processors think it is important to prevent and control Johne's disease x It is important to conform to the expectations of the dairy processors	12	-21	21	moderate positive	1.03	0.42	0.97 - 1.09

Table 4.6 Descriptive statistics of indirect measurements of perceived behavioural control (PBC) and their univariable associations with intender status for 68 cow manager respondents in Atlantic Canada from June 2012 to September 2013.

Questionnaire Construct	**Median Score**	**Possible Range**		**Strength Interpretation**	**Association with Intender**		
		Min	**Max**		**OR**	**P-value**	**95% CI**
Composite PBC score [sum of control belief strength (scale of 1 to 7) x perceived power to influence behaviour (scale of -3 to +3)]	29	-42	42	strong positive	1.09	0.02	1.01 - 1.18
Item 1 - I know a lot about Johne's disease, its prevention and control x Having knowledge about Johne's disease, its prevention and control is:	15	-21	21	strong positive	1.14	0.03	1.01 - 1.29
Item 2 - I think Johne's disease prevention and control strategies are very effective x Having effective Johne's disease prevention and control strategies are:	15	-21	21	strong positive	1.14	0.06	0.99 - 1.32

Table 4.7 Descriptive statistics of direct measurements of perceived behavioural control (PBC) and their univariable associations with intender status for 68 cow manager respondents in Atlantic Canada from June 2012 to September 2013.

Questionnaire Construct	Median Score	Possible Range		Strength Interpretation	Association with Intender		
		Min	Max		OR	P-value	95% CI
Overall PBC score [mean of direct PBC items (scale of 1 to 7)]	6	1	7	moderate positive	1.70	0.06	0.97 - 2.98
Item 1 - I can prevent and control Johne's disease on our farm if I wanted to	6	1	7	moderate positive	1.08	0.83	0.54 - 2.18
Item 2 - Implementing Johne's disease best management practices is easy	5	1	7	weak positive	1.37	0.05	1.00 - 1.88
Item 3 - I have too little time to implement Johne's disease best management practices	7	1	7	strong positive	1.21	0.27	0.86 - 1.69
Item 4 - Implementing the best management practices to prevent and control Johne's disease is not entirely up to me	7	1	7	strong positive	1.09	0.53	0.83 - 1.44
Item 5 - I am unable to fully implement Johne's disease best management practices because I would need to do things that are too expensive	7	1	7	strong positive	1.23	0.16	0.92 - 1.65
Item 6 - I am unable to fully implement Johne's disease best management practices because of other herd priorities (e.g. need to buy cattle, don't like milk replacer, like letting the cow lick the calf dry, etc.)	6	1	7	moderate positive	1.22	0.21	0.89 - 1.67

Table 4.8 Five best and worst knowledge statements with respect to the percentages of cow managers who responded correctly to the statements among 68 cow manager respondents in Atlantic Canada from June 2012 to September 2013.

Knowledge Statement	Correct Responses (%)
Cleanliness in the maternity pen is crucial for decreasing Johne's disease transmission (true)	100
Johne's disease increases the risk of culling (true)	99
The risk of a newborn calf becoming infected with Johne's disease increases as they are exposed to more cows in the calving area (true)	99
A cow with Johne's disease sheds the bacteria in their manure (true)	97
Adult cattle with Johne's disease can have normal manure and look healthy (true)	93
In the environment, Johne's disease bacteria can survive for one year or longer (true)	57
Johne's disease bacteria are not shed into milk or colostrum (false)	56
Johne's disease has been reported all over the world (true)	56
Animals with Johne's disease tend to lose their appetite (false)	24
When purchasing cattle, the best protocol to prevent Johne's disease introduction is to test the animal prior to purchase (false)	19

CHAPTER 5: DAIRY PRODUCER SATISFACTION WITH THE VETERINARY-ADMINISTERED RISK ASSESSMENT AND MANAGEMENT PLAN IN A VOLUNTARY JOHNE'S DISEASE CONTROL PROGRAM

5.1 ABSTRACT

The Atlantic Johne's Disease Initiative (AJDI) aims to control *Mycobacterium avium* subspecies *paratuberculosis* (MAP) infection by using veterinary-administered risk assessments (RA) to identify high risk management practices and prompt changes in management behaviour. Objectives for this study were to adapt a companion animal appointment-specific satisfaction questionnaire to the veterinary-administered RA and management plan (RAMP) process in the AJDI, to compare RAMP-specific satisfaction results based on herd Johne's disease (JD) status, and to measure knowledge transfer from certified veterinarian to producer during the RAMP. The questionnaire included nine RAMP-specific producer satisfaction items, one global RAMP satisfaction item, and 16 questions to assess producer knowledge and knowledge translation about JD, Bovine Viral Diarrhea (BVD) and Bovine Leukosis Virus (BLV) during the RAMP (BVD and BLV used for comparison purposes). A total of 133 dairy producers in the AJDI (79.6% response rate) completed the questionnaire by telephone. RAMP-specific satisfaction was high among the AJDI producers surveyed, and these results were not found to differ based on herd Johne's disease status. The lowest satisfaction scores and the highest number of "Unable to Assess" responses were for the item relating to cost. Factors that contributed to RAMP-specific producer satisfaction were not identified from the demographic and herd information available in this study. The knowledge scores indicated moderate knowledge about JD and fair knowledge about BVD and BLV. Evidence of knowledge translation from the RAMP was mixed in this study. BVD

knowledge scores were not found to differ based on whether or not the certified veterinarian discussed BVD during the preceding RAMP but BLV knowledge scores were significantly higher among dairy producers that discussed BLV during the preceding RAMP. Strengths and gaps in producer knowledge about these three infectious diseases were identified. By using this producer questionnaire, interventions aimed at improving the content, delivery and satisfaction of RAMPs in JD control programs, such as the AJDI, can be developed.

5.2 INTRODUCTION

Prevention and management of infectious diseases of dairy cattle are important for the production of dairy products that are safe, nutritious, and meet high consumer expectations. Johne's disease (JD), also known as paratuberculosis, is an incurable infectious disease of ruminants that affects dairy herds around the world. It is caused by a bacterium, *Mycobacterium avium* subspecies *paratuberculosis* (MAP), and results in severe ill thrift due to chronic enteritis (Tiwari et al., 2006). JD results in substantial financial cost to the Canadian dairy industry (Wolf et al., 2014). Also, research into associations between MAP and Crohn's disease in humans is ongoing (Chiodini et al., 2012; Sweeney et al., 2012; Atreya et al., 2014). Johne's disease has been identified as one of the top disease priorities of Canadian dairy farmers, University researchers and practicing veterinarians (Bauman et al., 2016).

Control programs for JD have been widely implemented and are largely based on the use of veterinary-administered risk assessment (RA) to identify high risk management practices and to prompt changes in management behaviour to prevent and reduce the JD risk on farm (Nielsen, 2007; Collins et al., 2010; Barker et al., 2012). The success of RA-based control programs for JD depends on the veterinarians' ability to communicate with their clients and the producers' adherence with the recommended best management practices (Sorge et al., 2010; Roche et al., 2015). Previous studies that have evaluated RA-based JD control programs have indicated that dairy producers are not necessarily adopting management practices as recommended, particularly with increasing duration of participation in a control program (Wraight et al., 2000; Ridge et al., 2005; Sorge et al., 2010; Wolf et al., 2015).

To better understand the factors that were associated with behavioural change in JD control programs, several studies have described the characteristics (i.e., demographic factors, knowledge, and attitudes) of producers and the factors as assessed in an RA that motivated producers to make management improvements (Roche et al., 2015; Wolf et al., 2015). To gain additional insight into whether dairy producers are likely to adopt management practices to control JD, it would be useful to know whether they are satisfied with the RA and management plan (RAMP) process.

Satisfaction with care, visits and appointments is considered to be an important outcome of medical encounters in human and veterinary medicine (Woodcock and Barleggs, 2005; Coe et al., 2010; Shaw et al., 2016). Measuring satisfaction in human and veterinary medicine has become important for several reasons: to evaluate the quality of health care provided (Sitzia and Wood, 1997; Jackson et al., 2001; Bragadóttir and Reed, 2002, Loomans et al., 2009), to isolate problem areas in service delivery and generate ideas for solutions (Locker and Dunt, 1978; Jackson et al., 2001; Wassink et al., 2010; Derks et al., 2012; Chand et al., 2014), and to improve adherence with health care regimes, changes and recommendations (Larsen and Rootman, 1976; Bartlett et al., 1984; Bell et al., 2002, Wassink et al., 2010; Kanji et al., 2012; Ritter et al., 2019).

To measure client satisfaction in companion animal practice, two questionnaires have been developed and validated, the Veterinary Service Satisfaction Questionnaire (VSSQ) and the Client Satisfaction Questionnaire (CSQ) (Woodcock and Barleggs, 2005; Coe et al., 2010). The VSSQ is intended to assess clients' overall satisfaction with small animal veterinary services, whereas the CSQ is intended to measure appointment-specific client satisfaction with veterinary care in companion animal practice (Woodcock and Barleggs, 2005; Coe et al., 2010). Coe et al. (2010) demonstrated that the CSQ could be used as an outcome measure of appointment-specific client satisfaction in companion-animal practice however, continued evaluation of the CSQ in different contexts was recommended.

A recent study applied a slightly modified CSQ to dairy farmers [e.g., by exchanging the word "pet(s)" for "animals(s)] to elicit their satisfaction with veterinary advisors after herd health and production management farm visits (Ritter et al., 2019). Overall, Ritter et al. (2019) reported that farmers were satisfied with their veterinarian's communication and their satisfaction was positively associated with their preparedness to adopt veterinary advice. Client satisfaction has also been linked to adherence with treatment and management plans in a number of veterinary studies (Wassink et al., 2010; Kanji et al., 2012; Ritter et al., 2019). Formal research into client satisfaction in food animal production medicine and large animal infectious disease control programs is limited. In the absence of an established instrument to measure satisfaction for food animal purposes, adaptation of the CSQ to measure RAMP-specific client satisfaction may provide valuable insight into whether dairy producers are likely to adopt best management practices to control JD.

The Atlantic Johne's Disease Initiative (AJDI) was established in 2011 as a long-term, voluntary, on-farm, prevention and control program to reduce the prevalence and impact of JD on the dairy herds of Atlantic Canada. A combination of environmental culture herd categorization (EC) and farm-specific veterinary-administered RAMPs were included in the AJDI for the purpose of JD prevalence reduction. Funding was provided by the AJDI for both herd categorizations and veterinary fees to conduct the RAMPs. Producer contributions to the RAMP included their time, providing clarifying information to the herd veterinarian during the assessment of JD risk, and working with the herd veterinarian to reach a consensus on management changes to decrease JD risk on their farm. In the AJDI, herd categorization and RAMP completion was done annually. If a herd was categorized as negative through EC (EC-negative) for two years in a row, herd categorization and RAMP completion was then done every other year, as long as they continued to be EC-negative.

The objectives for this study were to adapt the CSQ to veterinary-administered RAMPs to measure RAMP-specific producer satisfaction in a JD control program, to compare RAMP-specific satisfaction results based on herd JD status, and to measure knowledge transfer from certified veterinarians to producers in a JD control program.

5.3 MATERIALS AND METHODS

5.3.1 Source population and sampling method

The 167 AJDI participant herds who completed a RAMP from July 2013 to March 2014 were invited to participate (the source population) for this study. The farm personnel who completed the RAMPs with the certified veterinarians were requested to complete a satisfaction questionnaire by telephone by one interviewer from January to March 2014. The required sample size was estimated to be 38 herds to estimate the overall satisfaction score to within 0.2 out of 6.0 of the actual value, with 95% confidence, based on calculations with ProMESA 2.3.0.2 (EpiCentre, IVABS, Massey University, and Instituto Nacional de Tecnología Agropecuaria).

5.3.2 Data collection

The 15-item CSQ developed by Coe et al. (2010) was adapted to the veterinary-administered RAMPs, creating a 9-item measure of RAMP-Specific Producer Satisfaction and one global satisfaction item. The individual and global satisfaction items were scored using a 6-point Likert scale with 1 being “Poor” and 6 being “Excellent." There was also a response option of “Unable to Assess.” A direct comparison of the items in the CSQ and the Producer Satisfaction Questionnaire and rationale for item exclusion is shown in Table 1. Two items were excluded from the CSQ due to the differences in focus from individual pets to herds. Four other CSQ items were not applicable due to the structure of the RAMP visits: the reason for the visit was predefined to do the RAMP, some items of the RA were to be assessed by certified veterinarians independent of the producer, certified veterinarians were not administering treatments or doing procedures to conduct the RAMPs, and the costs of the veterinary fees to conduct the RAMPs were paid by AJDI.

To measure knowledge transfer from certified veterinarians to producers during the RAMP, questions about JD were included in the questionnaire. Due to the time period defined for inclusion in the source population, it was likely that most herds that were eligible for inclusion in this study would have been responding to the questionnaire based upon their experience with their second RAMP in the AJDI. Therefore, the responses to the JD knowledge questions would represent both knowledge transfer during the preceding RAMP and knowledge about JD that the producers had prior to the preceding RAMP, possibly from their first RAMP. To increase the likelihood of discussing information novel from previous RAMPs and to broaden the focus of RAMP education from the control of JD to other infectious diseases of dairy cattle, certified veterinarians were requested to also discuss Bovine Viral Diarrhea (BVD) and Bovine Leukosis Virus (BLV) during the RAMPs conducted from July 2013 onward, for two reasons. Clinical experience of the authors suggested that baseline producer knowledge about BVD was low and BLV was moderate. Also, some management practices that decrease the risk of JD introduction to a herd or transmission within a herd are also best management practices (e.g. colostrum or milk pasteurization) to prevent and control BLV in dairy production (LeBlanc et al., 2006; Nekouei et al., 2015a). Two-page information summary sheets about JD, BVD and BLV were prepared and circulated to the certified veterinarians in June 2013.

Fourteen questions to assess producer knowledge about JD, BVD and BLV were included in the questionnaire. All questions used a closed format with either multiple choice or yes/no options. A response option of “Unable to Assess” was also provided for some questions. The specific wording for the knowledge questions and possible responses are included in Appendix D.1. To compare infectious disease baseline knowledge with knowledge transfer during the RAMP, the questionnaire also included two items to determine if the certified veterinarian discussed BVD or BLV during the preceding RAMP. The appropriateness and understandability of the knowledge questions were assessed by questionnaire pre-test with three AJDI herds.

5.3.3 Statistical Analysis

Questionnaire responses on paper were followed by dual data entry using EpiData 3.1 (EpiData Association, Odense, Denmark). Statistical analysis was completed using STATA 14.2 (StataCorp, LLC, College Station, Texas, USA). For this study, statistical significance was defined as having $P < 0.05$. Data about the herds' preceding RAMPs (JD herd categorization by EC, RAMP score, and number of RAMPs completed) and production data (where available) were combined with the questionnaire data for statistical analyses.

Descriptive statistics were calculated for the demographic and herd data, the RAMP-specific satisfaction items, and the knowledge transfer items. Satisfaction item responses of "Unable to Assess" were treated as missing values. Knowledge question responses were coded as dichotomous variables, with the values "correct" and "not correct" (responses that were either incorrect or "I'm uncertain"). Shapiro-Wilk test statistics were used to assess normality for the overall satisfaction scores, the global satisfaction scores, and the knowledge scores.

If the Shapiro-Wilk test indicated the assumptions of normality were violated, non-parametric statistical techniques were used for inferential statistics; Spearman Rank Correlations and Mann-Whitney U tests. T-tests were used if the assumptions of normality were not violated. To identify simple associations between the overall satisfaction score and the demographic and herd information variables, univariable analyses were conducted using linear mixed models with random effects at the veterinarian level. The random effects of veterinarian were included in the models due to the potential for clustering of farms within veterinarians conducting RAMPs.

To further evaluate associations between the overall satisfaction score and the demographic and herd information variables, a multivariable linear mixed model with random effects at the veterinarian level was conducted. The univariable analyses described above were used to screen variables (cut-off at $P < 0.1$) for inclusion into the multivariable model. All variables below the cut-off were initially included in the model, and then backward stepwise elimination of variables that had a Wald test, or multiple Wald test, $P > 0.05$ was to be used to determine the final model. Possible two-way interactions and confounding variables were assessed as well, where relevant, as recommended by Dohoo et al. (2009).

5.4 RESULTS

5.4.1 Demographic and herd information

Of the 167 AJDI herds eligible for the study, 79.6% responded to the telephone questionnaire (n=133 herds). Demographic information for the participating herds is detailed in Table 2. Most of the questionnaires were administered following the herds' second EC herd categorization (90.2%; n=120) and 27.1% were categorized as EC-positive (n=36). Eighty-seven of the herds were enrolled in a milk recording program (Valacta, Sainte-Anne-de-Bellevue, Quebec, Canada). Of the 20 certified veterinarians who conducted the RAMPs in this study, most were men (70.0%).

5.4.2 RAMP-specific producer satisfaction

The mean overall satisfaction score, taken as the mean of the nine individual satisfaction items in the questionnaire, was 5.2 out of 6.0 (95% CI: 5.1, 5.3). The mean global satisfaction score was 5.6 out of 6.0 (95% CI: 5.5, 5.7). The Shapiro-Wilk test statistics for both the overall and global satisfaction scores were significant ($P < 0.01$ for both scores), indicating the assumptions of normality were violated. Therefore, non-parametric statistical techniques were used. A positive correlation was detected between the overall satisfaction score and the global satisfaction score (r=0.68; n=133; $P < 0.01$). Significant differences were not detected in either the overall satisfaction score or the global satisfaction score when stratified by herd EC categorization ($P = 0.31$ and $P = 0.88$ respectively).

Table 3 presents descriptive statistics for the global satisfaction item and the nine individual satisfaction items in the questionnaire. Responses of “Unable to Assess” were received for three of the satisfaction items; specifically, “the vet’s discussion of costs with you” (n=8), “how well the vet addressed all of your concerns” (n=1), and “the amount of time the vet spent with you” (n=1). For five of the nine individual satisfaction items, the mean scores were at least 5.4 out of 6.0, and all of these items had median scores of 6. The mean score for the satisfaction item “the vet’s discussion of costs with you” was substantially lower than the other items at 4.1 out of 6.0 (95% CI: 3.9, 4.4), with a substantially higher standard deviation than the other items. The mean score for “your understanding of the management options for JD on your farm” was slightly lower than the other items at 5.0 out of 6.0 (95% CI: 4.9, 5.2).

5.4.3 Factors associated with RAMP-specific producer satisfaction

Little correlation was detected among satisfaction rating scores within clusters of RAMPs done by the same veterinarian. The largest intraclass correlation coefficient calculated from the univariable analyses was 0.02 (95% CI: 0.00, 0.65). In spite of the low correlation detected statistically, the random effects of veterinarian were retained in the models due to a priori reasoning. The univariable analyses only identified one variable that had an association with a P < 0.10; herds that were enrolled in a milk recording program had overall satisfaction rating scores that were 0.17 out of 6.0 less than herds not enrolled in a milk recording program (P = 0.097; 95% CI: -0.37, 0.03). Due to the lack of associations detected with the other demographic and herd information variables available in this study, a multivariable linear mixed model was not built.

5.4.4 Knowledge transfer in the AJDI

There were no missing responses to the 14 knowledge based questions in the questionnaires. The mean percentage of correct responses for all three infectious diseases (JD, BVD and BLV) was 63.4% (95% CI: 60.6%, 66.1%). The Shapiro-Wilk test statistics for the percentages of correct responses overall and for each of the three infectious diseases were not significant (P > 0.2), indicating the assumptions of normality were not violated. Therefore, parametric statistical techniques were used. The infectious disease that had the highest percentage of correct responses was JD, with a mean percentage of 69.8% (95% CI: 66.6, 72.9%). Compared to JD knowledge responses, both BVD and BLV had significantly lower percentages of correct responses, with mean percentages of 60.7% (95% CI: 56.3%, 65.1%) and 59.1% (95% CI: 54.5%, 63.7%). A significant difference was not detected in JD knowledge based upon the preceding EC herd categorization (P = 0.90).

Participants were asked if the certified veterinarian discussed BLV or BVD during their preceding JD RAMP. Of the 133 dairy producers, 21.1% indicated that the certified veterinarian discussed both BLV and BVD during the preceding RAMP (n=28), 36.1% indicated that the certified veterinarian discussed BLV but not BVD (n=48) and 33.1% discussed BVD but not BLV (n=44). A significant difference was detected in BLV knowledge based upon whether or not the certified veterinarian discussed BLV during the preceding RAMP ($P < 0.01$). Of the dairy producers that discussed BLV during the preceding RAMP, the mean percentage of correct BLV responses was 71.3% (95% CI: 65.3%, 77.2%). In contrast, the mean percentage of correct BLV responses was 52.2% (95% CI: 46.2%, 58.3%) for those who did not discuss BLV during the preceding RAMP. This association was not impacted by the length of time between the herds' preceding RAMP and the questionnaire (i.e. no interaction was found between the effect of discussing BLV during the preceding RAMP and timing of the questionnaire). A significant difference was not detected in BVD knowledge based upon whether or not the certified veterinarian discussed BVD during the preceding RAMP ($P = 0.27$).

Figure 1 depicts the distribution of responses to each of the knowledge-based questions in the questionnaire. For the questions about JD, the items with the highest proportions of producers responding correctly were related to age susceptibility of infection (90.2% of producers responded correctly) and MAP transmission (94.7% were correct). The JD items with the lowest proportions of producers responding correctly were related to individual cow diagnostics (42.1%) and the clinical sign of diarrhea in JD (54.9%). The responses to the questions about BVD indicated good understanding about the virus being able to cause abortion (82.7% of producers responded correctly) and the efficacy of vaccination (81.2% were correct). However, there was a lack of BVD knowledge about diarrhea as a clinical sign (49.6% of producers responded that they were uncertain) and persistent infections (36.1% were uncertain). For the questions about BLV, the responses indicated there was substantial uncertainty about the virus (proportions of producers with uncertain responses ranged from 13.5% to 33.8%), and a majority (78.2%) of the producers underestimated the prevalence of leukosis in the Maritimes.

5.5 DISCUSSION

This study represents one of the methods used to evaluate the AJDI, which was designed to prevent and control JD in Atlantic Canada through the implementation of best management practices. To our knowledge, this is the first explorative quantitative study of satisfaction about the RAMP process in a JD control program. This work contributes to understanding producer satisfaction in the AJDI, which in turn improves understanding of other important outcomes including adherence.

Overall, producers were highly satisfied with the RAMP. High satisfaction was demonstrated using both the overall multi-item satisfaction measure and the global measure. There was a positive correlation detected between the overall satisfaction score and the global satisfaction score. This finding supports construct validity of the adapted satisfaction measure from the CSQ developed by Coe et al (2010).

Unlike previous satisfaction studies in human and veterinary medicine (Martin et al., 2004; Coe et al., 2010; Shaw et al., 2012), factors that influenced RAMP-specific producer satisfaction were not found in this study. In contrast to previous literature, client gender was not shown to have a significant effect on RAMP-specific satisfaction. It is of note that the ratio of male to female clients in this study is opposite to the ratio in the studies to develop and validate the CSQ and the VSSQ (Woodcock and Barleggs, 2005; Coe et al., 2010). Considering that both of those satisfaction measures were designed for companion animal medicine, satisfaction factors may be different due to differences in food animal production medicine and dairy producers. Other factors that had been shown to have significant associations with client satisfaction (e.g., client age, client education, and length of relationship with the veterinarian) were not available in this study. Therefore, we were unable to use them to further investigate construct validity or to describe the influence they had on RAMP-specific satisfaction. It is also possible that the satisfaction questionnaire items were not discerning enough to differentiate producers by RAMP-specific satisfaction and in turn factors that influenced their satisfaction. Additional research to investigate relationships with RAMP-specific producer satisfaction is recommended to support or refute the construct validity of the satisfaction measure used in this study and to better understand factors that influence RAMP-specific producer satisfaction.

In satisfaction questionnaires, multi-item satisfaction measures are often favored because solutions are more easily generated than from single satisfaction item measures (Hudak and Wright, 2000). Indeed, from the multiple satisfaction items in this questionnaire, problem areas in RAMP-specific producer satisfaction were identified. The RAMP item with the lowest satisfaction rating was the certified veterinarians' discussions of costs. This satisfaction item also had the highest number of "Unable to Assess" responses. Similar to the CSQ, the cost-related satisfaction item was framed in a manner that the producers should have been able to answer; therefore, these responses may represent a general lack of cost discussion between the certified veterinarian and the producer (Coe et al., 2010). It is also possible that the cost-related responses were influenced by AJDI covering the costs of veterinary fees to conduct RAMPs, even though this satisfaction item was intended to measure producers' satisfaction with discussion of costs related to JD and management recommendations. Regardless, it is concerning that cost discussions during the RAMP are not highly satisfactory or may not even be occurring. In previous studies on the attitudes of dairy producers towards JD control programs, producers were concerned with the overall economic impact that JD can have on a farm and identified financial cost as a key issue to increase their prioritization of JD prevention and control (Sorge et al., 2010). The RAMP item with the second lowest satisfaction rating was the producers' understanding of the management options for JD on their farm. With the design of the AJDI as a RA-based control program, the successful implementation of management practices is key to reducing the impact and prevalence of JD in Atlantic Canada. In communication research, it is well documented that client-centered care is an effective approach and has been strongly associated with adherence (Kurtz et al., 2005; Silverman et al., 2013). Client-centered care encourages client participation, negotiation, and shared decision making (Shaw et al., 2016). It would be necessary for the producers to understand the management options to control JD on their farm to fully engage in shared decision-making, and in turn be more likely to adhere to the management plan for their farm. Due to the identification of these two problem areas during the veterinary-administered RAMPs, interventions can be developed to improve the communication of the certified veterinarians about costs and management options to control JD.

The producers in this study had moderate knowledge about JD. It is encouraging that most producers understood the age susceptibility of MAP transmission and the risk of MAP transmission even from cows that appear healthy. These items are related to best management practices focusing on internal biosecurity to prevent the spread of MAP within a herd. In contrast, more than half of the producers incorrectly thought that MAP diagnostic tests on individual animals were highly sensitive. This misunderstanding could prevent the proper implementation of best management practices that focus on external biosecurity to prevent introducing or increasing the burden of MAP in a herd. Particularly for herds without JD, keeping MAP out of the herd would be preferred and more practical than trying to eradicate MAP once it had become established. Even with appropriate management, decreasing the prevalence of MAP in a herd is a process that takes years. Additional efforts should be made by the certified veterinarians to communicate information about MAP diagnostics with the dairy producers.

Knowledge about JD was significantly higher than knowledge about BLV and BVD. For the majority of the herds in the study, the questionnaires were administered following the herds' second EC herd categorization. As such, most of the herds had sustained exposure to JD information through the AJDI, including two herd EC categorizations, two farm-specific RAMPs with their certified veterinarian, and a full description of JD best management practices in the AJDI workbook left on farm following each RAMP. We did anticipate that BLV knowledge would also be moderate in the study, as herd and cow prevalence of BLV is very high in this geographic region and has been subject to previous research (Nekouei et al., 2015b). However, BLV knowledge was not significantly different from BVD knowledge in this study, even though BVD has been subject to much less research and discussion in this region.

Evidence of knowledge transfer during the RAMP was mixed in this study. BVD knowledge scores were not found to differ based on whether or not the certified veterinarian discussed BVD during the preceding JD RAMP; whereas, BLV knowledge scores were significantly higher among the dairy producers that discussed BLV during the preceding JD RAMP. It is possible that these findings were impacted by misclassification bias; producers may have remembered incorrectly whether or not they discussed BVD or BLV during their preceding RAMP, and so their exposures were erroneously categorized. This misclassification would bias the measure of knowledge transfer toward the null. If knowledge transfer during the RAMP was indeed poor, it would represent a communication failure. Regardless of the cause for the lack of evidence about knowledge transfer during the RAMP, improved communication skills of the certified veterinarians would be beneficial to enhance the measure of knowledge transfer. Additional research to further explore knowledge transfer during the RAMP is required to determine the degree of urgency required for this intervention.

In this study, there was little evidence of selection bias. The response rate was high and the demographic and production characteristics of the study herds were similar to that of the AJDI herds in total.

5.6 CONCLUSIONS

A RAMP-specific producer satisfaction questionnaire was successfully adapted from a companion animal appointment-specific questionnaire and used in a voluntary JD control program. Overall, producer satisfaction with the veterinary-administered RAMP process was high. The questionnaire items were useful from a programmatic standpoint in that they identified satisfaction items that require attention to be improved during RAMP delivery. The questionnaire found that there were knowledge gaps that should be addressed. Further research in RAMP satisfaction is recommended to expand the evaluation of construct validity of the questionnaire and to identify factors that influence RAMP satisfaction.

5.7 REFERENCES

Atreya, R., M. Bülte, G. Gerlach, R. Goethe, M. W. Hornef, H. Köhler, J. Meens, P. Möbius, E. Roeb and S. Weiss. 2014. Facts, myths and hypotheses on the zoonotic nature of *Mycobacterium avium* subspecies *paratuberculosis*. Int. J. of Med. Microbiol. 304:858-867.

Barker, R. A., H. W. Barkema, G. Fecteau, G. K. Keefe and D. F. Kelton. 2012. Johne's Disease Control in Canada - Coordinated Nationally - Delivered Provincially. Proc. 3rd ParaTB Forum, Sydney, Australia. 45-51.

Bartlett, E. E., M. Grayson, R. Barker, D. M. Levine, A. Golden and S. Libber. 1984. The effects of physician communications skills on patient satisfaction; recall, and adherence. J. Chronic Dis. 37:755-764.

Bauman, C. A., H. W. Barkema, J. Dubuc, G. P. Keefe and D. F. Kelton. 2016. Identifying management and disease priorities of Canadian dairy industry stakeholders. J. Dairy Sci. 99:10194-10203.

Bell, R. A., R. L. Kravitz, D. Thom, E. Krupat and R. Azari. 2002. Unmet expectations for care and the patient-physician relationship. J. Gen. Intern. Med. 17(11):817-824.

Bragadóttir, H. and D. Reed. 2002. Psychometric instrument evaluation: The pediatric family satisfaction questionnaire. Pediatr. Nurs. 28:475-484.

Chand, S., B. S. Meena and H. C. Verma. 2014. A study on farmers' satisfaction with delivery of veterinary services. Indian J. Anim. Res. 48:67-70.

Chiodini, R. J., W. M. Chamberlin, J. Sarosiek and R. W. McCallum. 2012. Crohn's disease and the mycobacterioses: a quarter century later. Causation or simple association?. Crit. Rev. Microbiol. 38:52-93.

Coe, J. B., C. L. Adams, K. Eva, S. Desmarais and B. N. Bonnett. 2010. Development and validation of an instrument for measuring appointment-specific client satisfaction in companion-animal practice. Prev. Vet. Med. 93:201-210.

Collins, M. T., V. Eggleston and E. J. B. Manning. 2010. Successful control of Johne's disease in nine dairy herds: results of a six-year field trial. J. Dairy Sci. 93:1638-1643.

Derks, M., d. V. van, T. van Werven, W. D. J. Kremer and H. Hogeveen. 2012. The perception of veterinary herd health management by Dutch dairy farmers and its current status in the Netherlands: A survey. Prev. Vet. Med. 104:207-215.

Dohoo, I. R., W. Martin and H. Stryhn. 2009. Veterinary Epidemiologic Research. 2nd edition. VER Inc., Charlottetown, Prince Edward Island, Canada.

Hudak, P. L. and J. G. Wright. 2000. The characteristics of patient satisfaction measures. Spine (Phila Pa 1976). 25(14):3167-3177.

Jackson, J. L., J. Chamberlin and K. Kroenke. 2001. Predictors of patient satisfaction. Soc. Sci. Med. 52:609-620.

Kanji, N., J. B. Coe, C. L. Adams and J. R. Shaw. 2012. Effect of veterinarian-client-patient interactions on client adherence to dentistry and surgery recommendations in companion-animal practice. J. Am. Vet. Med. Assoc. 240:427-436.

Kurtz, S. M., J. Silverman and J. Draper. 2005. Teaching and Learning Communication Skills in Medicine. 2nd ed., Radcliffe Publishing Ltd., Abingdon, UK.

Larsen, D. E. and I. Rootman. 1976. Physician role performance and patient satisfaction. Soc. Sci. Med. 10:29-32.

LeBlanc, S. J., K. D. Lissemore, D. F. Kelton, T. F. Duffield and K. E. Leslie. 2006. Major advances in disease prevention in dairy cattle. J. Dairy Sci. 89:1267-1279.

Locker, D. and D. Dunt. 1978. Theoretical and methodological issues in sociological studies of consumer satisfaction with medical care. Soc. Sci. Med. 12:283-292.

Loomans, J. B. A., P. G. Waaijer, J. T. M. Maree, P. R. Weeren and A. Barneveld. 2009. Quality of equine veterinary care Part 2: Client satisfaction in equine top sports medicine in the Netherlands. Equine Vet. Educ. 21:421-428.

Martin, F., K. L. Ruby, T. M. Deking and A. E. Taunton. 2004. Factors associated with client, staff, and student satisfaction regarding small animal euthanasia procedures at a veterinary teaching hospital. J. Am. Vet. Med. Assoc. 224:1774-1779.

Nekouei, O., H. Stryhn, J. VanLeeuwen, D. Kelton, P. Hanna and G. Keefe. 2015b. Predicting within-herd prevalence of infection with bovine leukemia virus using bulk-tank milk antibody levels. Prev. Vet. Med. 122:53-60.

Nekouei, O., J. Vanleeuwen, J. Sanchez, D. Kelton, A. Tiwari and G. Keefe. 2015a. Herd-level risk factors for infection with bovine leukemia virus in Canadian dairy herds. Prev. Vet. Med. 119:105-113.

Nielsen, S. S. 2007. Danish control programme for bovine paratuberculosis. Cattle Pract. 15:161-168.

Ridge, S. E., I. M. Baker and M. Hannah. 2005. Effect of compliance with recommended calf-rearing practices on control of bovine Johne's disease. Aust. Vet. J. 83:85-90.

Ritter, C., C. L. Adams, D. F. Kelton and H. W. Barkema. 2019. Factors associated with dairy farmers' satisfaction and preparedness to adopt recommendations after veterinary herd health visits. J. Dairy Sci. 102(5):4280-4293.

Roche, S. M., A. Jones-Bitton, M. Meehan, M. Von Massow and D. F. Kelton. 2015. Evaluating the effect of focus farms on Ontario dairy producers' knowledge, attitudes, and behavior toward control of Johne's disease. J. Dairy Sci. 98:5222-5240.

Shaw, J. R., C. L. Adams, B. N. Bonnett, S. Larson and D. L. Roter. 2012. Veterinarian satisfaction with companion animal visits. J. Am. Vet. Med. Assoc. 240:832-841.

Shaw, J. R., G. E. Barley, K. Broadfoot, A. E. Hill and D. L. Roter. 2016. Outcomes assessment of on-site communication skills education in a companion animal practice. J. Am. Vet. Med. Assoc. 249:419-432.

Silverman, J., S. M. Kurtz and J. Draper. 2013. Skills for Communicating with Patients. 3rd ed. CRC Press, Taylor & Francis Group. Boca Raton, Florida, USA.

Sitzia, J. and N. Wood. 1997. Patient satisfaction: A review of issues and concepts. Soc. Sci. Med. 45:1829-1843.

Sorge, U., D. Kelton, K. Lissemore, A. Godkin, S. Hendrick and S. Wells. 2010. Attitudes of Canadian dairy farmers toward a voluntary Johne's disease control program. J. Dairy Sci. 93:1491-1499.

Sweeney, R. W., M. T. Collins, A. P. Koets, S. M. McGuirk and A. J. Roussel. 2012. Paratuberculosis (Johne's disease) in Cattle and Other Susceptible species. J. Vet. Intern. Med. 26(6):1239-1250.

Tiwari, A., J. A. VanLeeuwen, S. L. B. McKenna, G. P. Keefe and H. W. Barkema. 2006. Johne's disease in Canada Part I: Clinical symptoms, pathophysiology, diagnosis, and prevalence in dairy herds. Can. Vet. J. 47(9):874-882.

Wassink, G. J., T. R. N. George, J. Kaler and L. E. Green. 2010. Footrot and interdigital dermatitis in sheep: Farmer satisfaction with current management, their ideal management and sources used to adopt new strategies. Prev. Vet. Med. 96:65-73.

Wolf, R., H. W. Barkema, J. De Buck and K. Orsel. 2015. Factors affecting management changes on farms participating in a Johne's disease control program. J. Dairy Sci. 98:7784-7796.

Wolf, R., F. Clement, H. W. Barkema and K. Orsel. 2014. Economic evaluation of participation in a voluntary Johne's disease prevention and control program from a farmer's perspective–The Alberta Johne's Disease Initiative. J. Dairy Sci. 97:2822-2834.

Woodcock, A. and D. Barleggs. 2005. Development and psychometric validation of the Veterinary Service Satisfaction Questionnaire (VSSQ). J. Vet. Med. A. Physiol. Pathol. Clin. Med. 52(1):26-38.

Wraight, M. D., J. McNeil, D. S. Beggs, R. K. Greenall, T. B. Humphris, R. J. Irwin, S. P. Jagoe, A. Jemmeson, W. F. Morgan, P. Brightling, G. A. Anderson and P. D. Mansell. 2000. Compliance of Victorian dairy farmers with current calf rearing recommendations for control of Johne's disease. Vet. Microbiol. 77(3-4):429-442.

Table 5.1 Adaptation of the Client Satisfaction Questionnaire to the Producer Satisfaction Questionnaire for the Risk Assessment and Management Plan (RAMP) in the Atlantic Johne's Disease Initiative

Client Satisfaction Questionnaire Item (Coe et al. 2010)	RAMP-Specific Producer Satisfaction Questionnaire Item or Exclusion Rationale
Your sense of the vet's confidence interacting with you and your pet	Your sense of the vet's comfort and confidence interacting with you regarding Johne's disease
The veterinarian's examination of your pet	How well the vet assessed the Johne's disease risk factors on your farm
The veterinarian's discussion of options with you	Your understanding of the management options for Johne's disease on your farm
How well the veterinarian involved you in decisions	Your level of involvement in the management plan decisions
The veterinarian's discussion of the cost with you	The vet's discussion of costs with you
The interest the veterinarian expressed in your opinion	The interest the vet expressed in your opinion
The amount of information you received from the veterinarian	The amount of information you received from the vet
How well the veterinarian addressed all of your concerns	How well the vet addressed all of your concerns
The amount of time the veterinarian spent with you and your pet	The amount of time the vet spent with you
Global satisfaction item	Your overall experience with the vet during the RAMP
The amount of attention the veterinarian gave your pet	N/A - Certified veterinarian was assessing herd risks as opposed to focusing on individual animals
How well the veterinarian understood the reason for your visit	N/A - Reason for the visit was predefined to do the RAMP
How well the veterinarian involved you in the entire appointment	N/A - Some items in the RA were to be assessed by the certified veterinarian independently
How well the veterinarian explained treatments and procedures	N/A - Certified veterinarian was not administering treatments or doing procedures
How well you understood the costs today	N/A - The veterinary fees to conduct the RAMPs were paid by AJDI
The veterinarian's recognition of the role this pet has in your life	N/A - Certified veterinarian was assessing herd risks as opposed to focusing on individual animals

N/A - Not Applicable (Excluded)

Table 5.2 Herd, producer, and certified veterinarian demographic information for the Producer Satisfaction Questionnaire for the Risk Assessment and Management Plan (RAMP) for 133 dairy producers in the Atlantic Johne's Disease Initiative

Demographic Variable	N	Descriptive Statistics
Province		
New Brunswick	40	30.1%
Nova Scotia	52	39.1%
Prince Edward Island	41	30.8%
Environmental Culture Herd Categorization Year		
Year 1	9	6.8%
Year 2	120	90.2%
Year 3	4	3.0%
Environmental Culture Herd Categorization		
Negative	97	72.9%
Positive	36	27.1%
RAMP - Proportion of Maximum Risk Score		
Median (min, max)	130	0.43 (0.14, 0.66)
Time between RAMP and Questionnaire (days)		
Median (min, max)	133	104 (0, 219)
Lactating Cow Herd Size		
Median (min, max)	133	58 (12, 385)
Lactating Cow Housing Type		
Tie-stall	44	33.1%
Free-stall	85	63.9%
Bedded pack	3	2.3%
305-Day Milk Production (kg)		
Median (min, max)	87[1]	9,285 (5,488, 11,821)
Milk Fat (%)		
Median (min, max)	87[1]	3.9 (3.5, 5.2)
Milk Protein (%)		
Median (min, max)	87[1]	3.1 (2.9, 3.8)
Average Somatic Cell Count (1,000 cells/mL)		
Median (min, max)	87[1]	90 (39, 641)
Gender – Producer		
Female	16	12.0%
Male	117	88.0%
Gender - Certified Veterinarian		
Female	6	30.0%
Male	14	70.0%

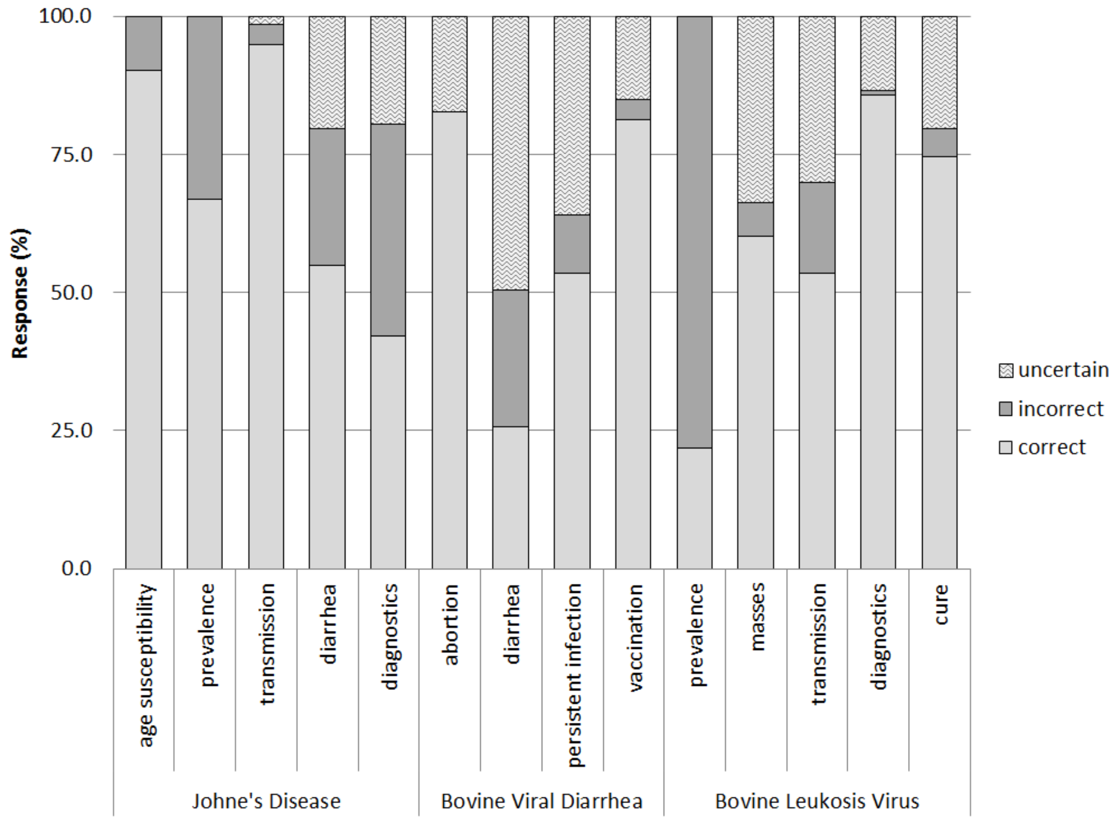
[1] Data only available for 87 herds enrolled in a milk recording program

Table 5.3 Satisfaction item scores in the Producer Satisfaction Questionnaire for the Risk Assessment and Management Plan (RAMP) for 133 dairy producers in the Atlantic Johne's Disease Initiative

Satisfaction Item[1]	Unable to Assess[2]	Min	Mean	SD	Median	Max
Your sense of the vet's comfort and confidence interacting with you regarding Johne's disease	0	3	5.5	0.7	6	6
How well the vet assessed the Johne's disease risk factors on your farm	0	2	5.5	0.7	6	6
Your level of involvement in the management plan decisions	0	3	5.4	0.8	6	6
Your understanding of the management options for Johne's disease on your farm	0	3	5.0	0.8	5	6
The vet's discussion of costs with you	8	1	4.1	1.5	4	6
The interest the vet expressed in your opinion	0	2	5.2	0.9	5	6
The amount of information you received from the vet	0	1	5.2	0.9	5	6
How well the vet addressed all of your concerns	1	3	5.5	0.7	6	6
The amount of time the vet spent with you	1	3	5.5	0.7	6	6
Your overall experience with the vet during the RAMP[3]	0	4	5.6	0.6	6	6

[1]Scored on a 6-point Likert scale, with 1 being poor and 6 being excellent
[2]Number of responses
[3]Global Satisfaction Item

Figure 5.1 Distribution of responses to the knowledge questions in the Producer Satisfaction Questionnaire for the Risk Assessment and Management Plan for 133 dairy producers in the Atlantic Johne's Disease Initiative



CHAPTER 6: COMMUNICATION SKILLS TRAINING AND ASSESSMENT OF FOOD ANIMAL PRODUCTION MEDICINE VETERINARIANS: A COMPONENT OF A VOLUNTARY JOHNE'S DISEASE CONTROL PROGRAM

6.1 ABSTRACT

In food animal production medicine (FAPM), the success of control programs for infectious diseases that have serious animal health and economic consequences frequently rely on veterinarians' effective communication and producer adherence to veterinary recommendations. However, little research on communication skills of practicing FAPM veterinarians has been conducted. During this study, we developed a communication training workshop intervention to support the Atlantic Johne's Disease Initiative (AJDI). Seventeen FAPM veterinarians across 10 clinics practicing within Maritime Canada and three FAPM senior veterinary students participated in a pre-post intervention design. Communication skills were evaluated utilizing three assessment tools; an Objective Structured Clinical Exam (OSCE), standardized client (SC) feedback, and an instrument designed for participants to assess their self-efficacy. The study goals were to: 1) assess communication skills of veterinarians prior to communication skills training using three assessment tools: OSCE, SC feedback, and self-efficacy; 2) develop and implement a communication skills training workshop for FAPM veterinarians; 3) assess the effect of a communication skills training workshop on the communication skills of veterinarians using the same three assessment tools; and 4) assess the reliability of the 4-station communication OSCEs for veterinarians using generalizability theory. Study results showed that prior to training, the communication skills of participants had significant limitations, including skill deficits in communication tasks strongly associated

with increased adherence to veterinary recommendations. Based on all three assessment tools, the communication skills of participants significantly improved with the training provided, including stronger communication process skills that are likely to improve client adherence. The reliability of the OSCEs ranged from 0.26 to 0.78, and varied between pre and post-intervention OSCEs, OSCE scores (checklist percentage scores or global scores) and rater (trained or expert). For expert raters, the largest source of variance was reflective of differences in communication skill development by participants. Rater variance was substantial for OSCE percentage scores from trained raters. This result indicates that significant portions of the differences in OSCE scores from trained raters were due to rater variability and there was likely an issue with rater training. Study results support developing and implementing communication skills training and assessment for FAPM veterinarians.

6.2 INTRODUCTION

Johne's disease (JD), also known as paratuberculosis, is an incurable, chronic, infectious enteritis of domestic and wild ruminants caused by the bacterium *Mycobacterium avium* subspecies *paratuberculosis (*MAP) and is one of the top disease priorities of Canadian dairy farmers, University researchers and practicing veterinarians (Bauman et al., 2016). In an effort to reduce the prevalence and impact of MAP infection in Atlantic Canada, the Atlantic Johne's Disease Initiative (AJDI), a management-based risk control program, was implemented from 2011 to 2014. Seventy percent of dairy herds in Atlantic Canada participated. The program relied on the use of farm-specific risk assessments (RA), conducted by AJDI-trained veterinarians. High-risk management practices were identified and modified to disrupt the MAP infection cycle (Sorge et al., 2010a).

The ultimate success of a management-based control program is determined by adherence of producers to suggested changes in management practices (Sorge et al., 2010b). Previous studies on other JD control programs indicated that recommended management changes are not being followed, particularly with increasing duration of participation in a control program (Wraight et al., 2000; Ridge et al., 2005; Sorge et al., 2010a; Sorge et al., 2010b; Wolf et al., 2015). These studies, as well as studies on a mastitis control program, suggest that inadequate veterinary communication likely contributed to poor adherence, and that improving the communication effectiveness of veterinarians could be important for future control programs (Wraight et al., 2000; Ridge et al., 2005; Lam et al., 2007; Sorge et al., 2010a; Jansen et al., 2010a; Jansen et al., 2010b; Lam et al., 2011).

Evidence from studies conducted over the past 40 years in human medicine clearly indicates that effective communication between physicians and patients has a positive impact on patient health, increases adherence to medical recommendations and improves patient and physician satisfaction (Silverman et al., 2013). Studies have also concluded that major deficiencies exist in communication between physicians and patients, but appropriate training programs can significantly change communication knowledge, skills and attitudes (Shaw et al., 2004). Today, communication is considered a core clinical skill in human medicine, and there has been exponential growth of the evidence regarding both the benefits of communication in medicine and how to teach it effectively (Kurtz et al., 2005).

Skilled communication is also a requisite to the practice of effective and compassionate veterinary medicine (Adams and Kurtz, 2017). It is considered a core clinical competency by the American Veterinary Medical Association Council on Education (American Veterinary Medical Association, 2020) as well as the Association of Veterinary Medical Colleges (Association of American Veterinary Medical Colleges, 2018) and the World Organization for Animal Health (OIE) (World Organization for Animal Health, 2012). Research on, and teaching of, communication as an essential clinical skill in veterinary medicine is a growing discipline, and has drawn upon the extensive literature on clinical communication in human medicine (Kurtz, 2006; Silverman et al., 2013; Adams and Kurtz, 2017). There is an expanding body of evidence in veterinary medical literature to demonstrate that communication competence is related to more efficient and satisfying consultations and improved outcomes of care, specifically satisfaction and adherence (American Animal Hospital Association, 2009; Coe et al., 2010; Kanji et al., 2012; Shaw, et al., 2012; Adams and Kurtz, 2017; Ritter et al., 2019). Unfortunately, evidence also showed that communication deficiencies are evident during veterinary school, and that following graduation, learning communication skills "on the job" is not sufficient to master the necessary skills (Humphries, 2002; Shaw et al., 2004; Mullan and Kothe, 2010). Fortunately, training in communication has resulted in communication skill acquisition for veterinary students and companion animal practitioners (American Animal Hospital Association, 2009; Shaw et al., 2010; Adams and Kurtz, 2017). Veterinary schools around the globe are incorporating communication skills education into their curriculum by training faculty and developing programs that use lectures, small-group interactive sessions involving simulated clients and facilitators, video feedback, assigned readings, role-play and Web-based programs (Gray et al., 2006; Mills et al., 2006; Radford et al., 2006; Shaw and Ihle, 2006; Latham and Morris, 2007; Chun et al., 2009; Hargie et al., 2010; Artemiou et al., 2013; Shaw, 2019). Curriculum on communication skills has also been implemented for veterinary professionals in the small animal practice setting (American Animal Hospital Association, 2009; Shaw et al., 2010; Shaw et al., 2016).

Studies in food animal production medicine (FAPM) suggest that veterinary practitioners' communication skills can benefit from additional training (Jansen, 2010; Cipolla and Zecconi, 2015; Ritter et al., 2018; Ritter et al., 2019). Petrovski and McArthur described specific communication steps to facilitate veterinary-client consultations in bovine medicine, both at the individual animal and population level (2015). These steps were based on the modified Calgary-Cambridge-Guides (CCG), a comprehensive set of communication skills initially developed for human medicine (Silverman et al., 2013) and then modified for veterinary medicine (Adams and Kurtz, 2006; Radford et al., 2006; Adams and Kurtz, 2017). However, there have been no reports of education curricula for communication skills being developed, implemented or assessed specifically for practicing FAPM veterinarians.

Various methods exist for assessing communication skills (Shaw, 2019). Objective Structured Clinical Examination (OSCE) offers a valid and reliable format for assessing communication skills of undergraduate health professional students (Hodges, 2006; Davis et al., 2006). OSCEs provide a simulated environment where students can demonstrate their abilities across various contexts following a standardized examination format (Hecker et al., 2012). During the OSCE, the learner interacts with standardized clients (SCs), who are trained to portray a client's concerns in a standardized manner (Adams and Ladner, 2004; Barton et al., 2006; Artemiou et al., 2014a).

While the majority of work on the reliability of OSCE scores has been done in the human health professional fields, the reliability of communication skills OSCEs in two veterinary undergraduate communication skills training programs have been reported (Hecker et al., 2012; Artemiou et al., 2013). These two studies used generalizability theory to assess OSCE reliability which accounts for several sources of measurement error, such as error due to raters, OSCE station, checklist items, etc. (Goodwin, 2001).

During the OSCE, the communication skills of the learner can also be assessed by SCs. In 2014, a comparison of faculty and SC assessments in a veterinary communication OSCE found that SC assessors offered a valid and reliable method for assessing veterinary communication skills (Artemiou et al., 2014a).

Self-efficacy questionnaires, which represent an individual's self-evaluation on successfully performing a specified task such as communication skills, is another tool that has frequently been used in human medicine (Parle et al., 1997; Ammentorp et al., 2007; Mullan and Kothe, 2010; Roter et al., 2012; Gulbrandsen et al., 2013). Self-efficacy represents an individual's self-evaluation about performing a specified task successfully (Parle et al., 1997). Use of self-efficacy assessment in conjunction with outcome measures, such as an OSCE, has not been reported in veterinary communication skills training.

In this study, a communication skills training workshop and pre-post assessments of communication skills was conducted with FAPM veterinarians as part of the AJDI. It was hypothesized that training in communication would lead to communication skill improvement for the FAPM veterinarians. Accordingly, the goals of the study were to: 1) assess communication skills of veterinarians prior to communication skills training using three assessment tools: OSCE, SC feedback, and self-efficacy; 2) develop and implement a communication skills training workshop for FAPM veterinarians; 3) assess the effect of a communication skills training workshop on the communication skills of veterinarians using the same three assessment tools; and 4) assess the reliability of the 4-station communication OSCEs for veterinarians using generalizability theory. A comparison of the communication assessment tools was also performed. The results were intended to deepen understanding of how to teach and assess communication skills to FAPM veterinarians who are part of an infectious disease control program. Additionally, our study results would inform development of communication skills training and assessment specific to FAPM at the Atlantic Veterinary College (AVC), University of Prince Edward Island (UPEI).

6.3 MATERIAL AND METHODS

The study included the recruitment and training of SCs, communication skills coaches, and OCSE raters. It included the development and delivery of a workshop and tools to teach and assess communication skills to FAPM participants, and a determination of the reliability of the OSCEs. Recruitment, preparation and study implementation are described in the following sections. The layout of the study and its component parts is shown in Figure 6.1.

6.3.1 Participants, Standardized Clients, Coaches, and Raters

Email and telephone invitations to the communication skills workshop were sent to 48 FAPM veterinarians trained by AJDI across 18 different veterinary clinics.

Seventeen of the 48 veterinarians agreed to participate. Resources and workshop design was ideal for 20 participants; as such, three senior veterinary students enrolled at AVC who had received specialized training in FAPM also partook in the training opportunity. Participant consent was obtained to allow video recording of the OSCEs for research purposes (see Appendix E.1).

Eight retired dairy producers from Prince Edward Island were recruited to be SCs and trained by an experienced SC trainer [Consulting Standardized Client Coordinator at University of Calgary Veterinary Medicine (UCVM) (B. Gromoff)]. All eight SCs participated in the OSCEs and five SCs supported small-group communication training sessions.

Six coaches were recruited to facilitate small-group experiential communication training sessions. Four coaches were veterinarians from the Department of Health Management of AVC who had extensive experience with FAPM (3 faculty members and 1 PhD candidate). The other 2 coaches had significant expertise in experiential teaching of communication skills [Professor at UCVM who directs the Clinical Communication Program (C. Adams) and a veterinarian with extensive coaching experience in the Clinical Communication Program at UCVM (J. Wilson)].

Four raters were recruited to independently review all OSCE video recordings. Two raters were veterinary students enrolled at AVC who completed their first and second years of the four year program and had experience with FAPM. Student raters were referred to as “trained raters”. The other two raters were considered experts based on their experience in communication skills assessment, including rating communication OSCEs (referred to as “expert raters”) [Professor at UCVM who directs the Clinical communication Program (C. Adams) and Associate Professor of Clinical Communication at Ross University School of Veterinary Medicine (E. Artemiou)].

6.3.2 Preparations for the communication skills workshop intervention

The framework used to develop the intervention was the CCG. The CCG is comprised of 73 evidence-based communication process skills and organizes the medical consultation into a framework of 6 communication domains and objectives (Adams and Kurtz, 2012; Silverman et al., 2013). Participants were expected to learn and demonstrate skills associated with each of the following CCG domains: 1) initiating the session, 2) gathering information, 3) providing structure, 4) building the relationship, 5) explaining and planning and 6) closing the session.

Materials were developed for the three communication assessment tools used in this study; OSCE, SC feedback and self-efficacy. OSCE cases were designed to assess the participants' competence in communication pre and post-intervention, and hence, to evaluate the effectiveness of the communication skills training workshop. The cases were developed, adapted and standardized by FAPM veterinarians at the AVC in order to represent real-life FAPM scenarios. For case development, a case template from the UCVM Clinical Communication Skills Program was used. Four infectious disease case topics were created for each OSCE; specifically, Johne's disease (JD), Bovine Leukosis Virus (BLV), neonatal calf scours, and Bovine Viral Diarrhea (BVD). The pre- and post-intervention cases were considered to be equivalent in terms of difficulty. Even though the OSCEs were case-based, the intended focus of the consultations was communication skills. OSCE Task Sheets were created to reflect each case context and its task (see example Task Sheet in Appendix E.2). For communication assessment using SC feedback, a SC Feedback Form was adapted from the UCVM Clinical Communication

Skills Program (see Appendix E.3). For self-efficacy assessment tools, questionnaires were adapted from AVC Client Communication Rotation Surveys (see Appendix E.4 & E.5).

Cases were developed to be used during small-group training sessions, for the participants to practice their skills through discussion and simulated interactions with the SC. The cases were developed, tested and standardized at the UCVM and represented real-life FAPM scenarios.

The 8 retired dairy producers participated in 10 hours of SC training prior to the communication skills workshop. Each SC was trained for 2 OSCE cases, 1 pre- and 1 post-intervention. Since there were 2 tracks of OSCE stations, each case was portrayed by 2 SCs. The SCs who portrayed the same cases were trained together to maximize consistency during the OSCEs. The pairs of SCs were maintained for both pre- and post-intervention OSCEs. SCs were trained to provide feedback on participants' OSCE performance using the SC Feedback Form. Five of the dairy producers were also trained for small-group communication training session cases.

During training, SCs were provided with a case overview. This included information about the person they were portraying and about the farm facility, herd and herd history, the current problem, and some relevant background medical information. SCs were taught how to portray their producers' character, including verbal and nonverbal communication. They were instructed to share or retain information, depending on the appropriate prompting of the participant.

The four novice coaches participated in 10 hours (1 and ½ days) of small-group facilitation training prior to the communication skills training workshop. During the sessions, coaches were introduced to communication theory, the CCG and principles of agenda-led outcome-based analysis (ALOBA) (Kurtz et al., 2005). ALOBA is designed to maximize learning and safety while teaching communication skills, and is a well-recognized framework for organizing and leading feedback sessions in communication programs in human and veterinary education (Adams and Kurtz, 2012). The coaches practiced their skills through discussions and role-play interactions among themselves and with SCs.

The two trained raters participated in 3 hours of OSCE rater training with a faculty member from AVC who had significant experience in communication skills training (DS). The training session was designed to enhance inter- and intra-rater reliability. During this session, raters were introduced to specific communication skills, the OSCE checklist and the rating process. Raters were taught to assess the participant's communication skills based on the CCG, using an OSCE Checklist that was developed from the CCG and contained communication skills for each of the 6 communication tasks (see Appendix E.6). The raters practiced their skills through discussions and skill spotting exercises using video recordings of simulated interactions with small animal clients.

6.3.3 Implementation of the communication skills training workshop intervention

The communication skills training workshop was held in the winter of 2014 over 1 ½ days (13 hours in total). In human medicine, training programs were found to be effective if they lasted for at least one day (Berkhof et al., 2011).

All participants completed a self-efficacy questionnaire (Figure 1) before the communication skills training intervention (see Appendix E.4). Participants scored self-efficacy items using a 5-point Likert scale, with 5 being "excellent" and 1 being "poor." The items were totalled and converted into a percentage of self-efficacy items. The pre-intervention survey also included open-ended inquiring about the participant's expectations for the communication skills training workshop.

Additionally, all participants completed a pre-intervention OSCE which consisted of 4 stations (Figure 1). For time efficiency, two OSCE tracks were run simultaneously with the same 4 cases portrayed in each track; thereby utilizing all 8 SCs. Participants would interact with one SC portraying a specific case at each station. Prior to entering a station, participants had 2 minutes to review the OSCE Task Sheet (see Appendix E.2). Participants were informed that they were being assessed on their communication skills and not their medical knowledge. Participants had 10 minutes to complete their interaction with the SC. A 2-minute verbal warning was given before the end of each consultation. Interactions between the participants and SC's were video-recorded at each station. Five support personnel assisted with OSCE set-up, timing of the stations and movement of participants through the stations.

Following each OSCE consultation, the SC completed a SC Feedback Form on the participant's communication performance (see Appendix E.3). For each item on the SC Feedback Form, the SC indicated if the item skill was demonstrated by choosing "no," "yes but" or "yes." The "yes but" score indicated partial demonstration of skill. Feedback item ratings were converted to a score of 0 for "no," 1 for "yes but" and 2 for "yes." Feedback item scores were totalled and converted to a percentage of feedback items.

For each participant, SCs also indicated if they would use that person as their veterinarian (a global feedback rating), by choosing "no," "yes but" and "yes." This global feedback rating was also converted to a score of 0 for “no,” 1 for “yes but” and 2 for “yes.”

The intervention (Figure 1) included two interactive lectures (1 hour on the first day and 1 ½ hours on the second day). These lectures were facilitated by a member of the Faculty of UCVM who had significant experience in teaching communication skills (C. Adams).

Small-group training sessions followed the lectures, where the 20 participants were divided into 5 groups of 4 participants each (Figure 1). Each group also included a coach and a SC. During training sessions, each participant spent a minimum of 45 minutes practicing their communication skills with a SC and received individualized feedback and active coaching from coaches. Following the interaction, small group members, coaches and SCs provided feedback and the opportunity for the interviewing participant to return to their interaction with the SC to integrate feedback. An expert coach (C. Adams) cycled through the groups with the novice coaches to assist in group facilitation and further the training of the coaches.

Post-intervention communication skills assessments were conducted following small-group training sessions (Figure 1). These assessments were similar to the pre-intervention assessments, with all participants completing a self-efficacy questionnaire and an OSCE. Open questions about participant’s satisfaction with the workshop were included in the post-intervention survey (see Appendix E.5). Different OSCE cases were utilized for post-intervention OSCE assessments. Five support personnel again assisted with post-intervention OSCE set-up, timing and movement of participants through stations. Following post-intervention assessment, there was a 30-minute interactive de-brief session with participants, study design team and coaches.

Following the workshop, OSCE video recordings were rated by the 4 independent raters. The raters were provided with the OSCE Task Sheets but were unaware of the OSCE type (whether it was pre- or post-intervention) and used an OSCE Checklist (see Appendix E.6) to score how each communication skill was demonstrated by choosing "no," "yes but" or "yes." The "yes but" score indicated that the skill was partially demonstrated. The checklist item ratings were converted to a score of 0 for "no," 1 for "yes but" and 2 for "yes." Checklist item scores were totalled and converted to a percentage of the checklist items. The OSCE Checklist also included a question on whether the participant ran out of time prior to demonstrating the explanation and planning skills. This item was rated as "no," "yes but" and "yes." Furthermore, raters gave a global rating score for participant's overall communication performance per case using a 5-point Likert Scale, with 5 being "excellent" and 1 being "poor."

6.3.4 Statistical analyses

Missing data frequency and distribution were assessed to determine the randomness of the missing data. Due to the small number of participants, where the missing data were considered random, they were addressed using several different methods. Person mean imputation (Eekhout et al., 2014) was used for missing items in self-efficacy questionnaires, OSCE checklists and SC feedback forms (missing items were imputed using the mean of the participant's non-missing items). For comparison purposes, multiple imputation (Eekhout et al., 2014) for missing items in OSCE checklists was also performed to compare the mean percentage scores and 95% CI with those achieved using person mean imputation. Available-case analysis (ACA) (van

Ginkel et al., 2010), using all cases which have observed values on variables that are part of the analyses, was used for global scores in both the OSCE checklists and the SC feedback forms because these scores did not have other similar items to assist with imputation.

Statistical analyses were performed using STATA/IC 12.1 (StataCorp LP, College Station, Texas, USA). Statistical significance was set at a P-value of <0.05. Descriptive statistics [means and 95% confidence intervals (CI)] were calculated for participant data, self-efficacy questionnaires and OSCEs. Paired *t*-tests were used to confirm whether scores were significantly higher post-intervention compared to pre-intervention (self-efficacy percentage, OSCE checklist percentage, OSCE global checklist score, SC feedback percentage, and SC global feedback score). Paired *t*-tests were also used to determine if a significant difference existed between ratings of trained raters compared to expert raters. Correlation coefficients were calculated to compare ratings of individual raters, trained raters to expert raters, OSCE checklist percentages to OSCE global checklist scores, SC feedback percentage to SC global feedback score, OSCE checklist to self-efficacy percentage, and SC feedback percentage to self-efficacy percentage.

Generalizability Theory analysis (Brennan, 2001) was performed using the freeware G_String IV (G_String version 6.3.8, McMaster University, Ontario, Canada, 2013). Reliability, inter-rater agreement and variance components for all main and interaction effects were assessed using generalizability theory in 8 separate analyses. The G-studies used data from the OSCEs grouped as follows: trained raters pre-intervention, trained raters post-intervention, expert raters pre-intervention and expert raters post-intervention. OSCE checklist percentages were used for the initial 4 G-studies, while

OSCE global scores were used for the final 4 G-studies. All of the G-studies were three-facet fully-crossed designs where each of the 4 raters independently rated the 20 participants in all 4 stations in both OSCE tracks. The participants were nested within 2 tracks (10 participants in each track). The variance components calculated included: the amount of variance due to rater, track, participant within track, station, rater by track, rater by participant within track, rater by station, track by station, participant within track by station, rater by track by station, and rater by participant within track by station (referred to as error variance). Decision studies (D-studies) were performed from these analyses. D-studies use the variance components derived from G-studies to estimate whether there would be an increase or decrease in reliability if the parameters were changed (i.e. number of raters or number of stations) (Hecker et al., 2012).

6.4 RESULTS

6.4.1 Participants

Veterinarian and clinic participation rate was 35% (17 of 48 invitees) and 56% (10 of 18 clinics), respectively. The response rate for the three senior veterinary students was 100%. Seventy percent (n=14) of participants were female and 30% (n=6) were male. For the veterinarian participants, the median years post-graduation from their Doctor of Veterinary Medicine (DVM) was 12 (range: 1 to 29).

6.4.2 Missing data

Self-efficacy questionnaires had 0.5% of items missing. Overall, 5% of questionnaires (n=2) had incomplete data, and the mean percent of missing items per incomplete questionnaire was 9%. Based on dissimilar questions being unanswered, the missing data was considered missing completely at random (MCAR). Person mean imputation was used to replace missing self-efficacy questionnaire items.

During OSCEs, camera malfunction at one station resulted in no video recording in 11 of 160 consultations (7%). The OSCE checklists from the recorded consultations had 1% of items missing from nonresponse that was MCAR. Overall, 15% of the OSCE checklists had incomplete data and the mean percent of missing items per incomplete OSCE checklist was 7% (95% CI: 6, 8%). Person mean imputation was used to replace the missing checklist items for the analyses. Checklist percentage scores and 95% CI that were calculated after using person mean imputation were compared to scores calculated after using multiple imputation. The scores did not differ statistically, with means of 64.6% (95% CI: 63.3%, 65.9%) and 64.7% (95% CI: 63.4%, 66.1%) respectively.

Two global scores were missing for the OSCE observation (0.3%). With only 2 missing observations, the missing data were considered MCAR. ACA was used to analyse the non-missing OSCE global scores.

Both OSCE percentage scores and global scores were used for G-studies. Largely due to video camera malfunction, 6% of pre-intervention OSCE percentage and global scores and 9% of post-intervention OCSE percentage and global scores were missing. One-way ANOVA was not able to detect a difference in percentage scores or global scores between the 4 OSCE stations [$F (594) = 1.30$, $p=0.272$ for percentage scores; $F (592) = 1.12$, $p=0.340$ for the global scores]. Person mean imputation was used for missing OSCE percentage and global scores for the G-studies.

During OSCEs, 17 SC feedback forms were misplaced and 3 were not filled out from the 160 consultations (13% of the SC feedback forms in total). Misplaced forms were primarily from one SC (16 of 17 forms). The 20 consultations with no SC feedback data were discarded from the dataset. The remaining SC feedback forms had 5.0% of items missing due to nonresponse. Overall, 28% of the forms had incomplete data and the mean percent of missing items per incomplete form was 18% (95% CI: 13%, 23%). Based on dissimilar items being unanswered, the missing data were considered MCAR. Person mean imputation was used to replace the missing SC feedback form items.

The SC feedback forms had 23 global scores missing for the 140 consultations retained in the dataset (16%). Based on which scores remained unanswered, the missing data were considered MCAR. Similar to the OSCE global scores, ACA was used to analyse the SC global scores. G-studies were not performed for the SC feedback forms because of the quantity of missing global scores.

6.4.3 Pre- and Post-Intervention Self-Efficacy Questionnaires

On the pre-intervention self-efficacy questionnaire, 80% of participants reported that the primary reason for attending the communication skills training workshop was, to improve my communication skills (n=16). Before the workshop, participants described their previous communication training as below average, with a mean of 1.79 out of 5 (95% CI: 1.32, 2.25). They also reported their knowledge of communication skills was fair, with a mean of 2.35 out of 5 (1.93, 2.77).

Following the intervention, participants reported improvement of their knowledge surrounding communication skills, with a mean of 3.75 out of 5 (3.55, 3.95) on the post-intervention self-efficacy questionnaire. Suggested ways to improve the workshop included: lengthening the workshop (n=5) and spending more time on the cxperiential practice (n=6).

A significant difference was detected between the pre- and post-intervention self-efficacy percentages [65.0% (95% CI: 61.3%, 68.7%) and 72.5% (95% CI: 70.1%, 74.9%), respectively; paired *t*-test: t (38) = -3.59, p<0.01].

6.4.4 Pre- and Post-Intervention Objective Structured Clinical Exams

Table 6.1 shows the pre- and post-intervention OSCE descriptive statistics for percentage scores and global scores from raters and SCs. Based on non-overlapping 95% confidence interval, all percentage and global scores were significantly higher post-intervention compared to pre-intervention.

Paired *t*-tests confirmed significant increases in percentage scores and global scores from pre- to post-intervention OSCEs from both trained raters and expert raters [paired *t*-test for percentage score of trained raters: t (296) = -9.24, p<0.01; paired *t*-test for percentage score of expert raters: t (295) = -12.92, p<0.01; paired *t*-test for global score of trained raters: t (296) = -6.37, p<0.01; paired *t*-test for global score of expert raters: t (293) = -13.59, p<0.01]. Based upon paired *t*-tests of SC feedback, there was also confirmation of significant increases in percentage and global scores from pre- to post-intervention OSCEs [percentage score paired *t*-test: t (138) = -3.88, p<0.01; global score paired *t*-test: t (115) = -3.55, p<0.01].

Table 6.2 shows pre- and post-intervention OSCE descriptive statistics for task percentage scores for each of the six communication domains from raters. Based on non-overlapping 95% confidence intervals, all task percentage scores were significantly higher post-intervention than pre-intervention. Paired *t*-tests confirmed significant increases in task percentage scores from pre- to post-intervention OSCEs for all 6 communication domains (P <0.01). The communication task with the highest and lowest percentage scores for expert raters were "gathering information" and "closing the session," respectively.

6.4.5 Comparison of communication skills assessment tools

There was a significant difference between the scores of trained raters and expert raters for both the pre- and post-intervention OSCEs. The paired *t*-test results for the scores (percentage and global) from the raters for both OSCEs are: (1) pre-intervention percentage score paired t (301) = 11.79, $p<0.01$; (2) post-intervention percentage score paired t (290) = 6.32, $p<0.01$; (3) pre-intervention global score paired t (300) = 17.27, $p<0.01$; and (4) post-intervention global score paired t (289) = 5.91, $p<0.01$.

Percentage scores were strongly correlated (Evans, 1996) with global scores for the SCs (Pearson's r = 0.760) and for trained raters (Pearson's r = 0.763). For the expert raters, percentage scores were very strongly correlated (Evans, 1996) with global scores (Pearson's r = 0.938). Percentage scores for both the trained raters and the expert raters were in poor agreement (Quinn et al., 2009) with the participant's self-efficacy scores (concordance correlation coefficient ρ_c = 0.282 and ρ_c = 0.116, respectively) and the SC feedback percentage scores (concordance correlation coefficient ρ_c = 0.139 and ρ_c = 0.113, respectively). There was also poor agreement (Quinn et al., 2009) between the participant's self-efficacy scores and the SC feedback percentage scores (concordance correlation coefficient ρ_c = 0.036).

6.4.6 G-studies and D-studies for trained raters

Table 6.3 details the results of the G-studies on the checklist percentages from the trained raters for the pre- and post-intervention OSCEs [variance, percentage of variance and generalizability coefficients ($E\rho^2$)]. In the pre-intervention OSCE, the largest percentage of variance was from rater (45.8%). This result indicates that significant portions of the differences in the trained rater checklist percentages were due to rater variability. The largest percentage of variance for the post-intervention OSCE was from track (28.6%). This result indicates that participant performance varied by track, even though the SCs portraying the same case were trained together to maximize consistency. Variance due to the interaction of rater by participant within track indicates there were differences in how trained raters rated the participants (14.2% and 26.8% for pre- and post-intervention OSCE, respectively). Participant within track variance decreased from pre- to post-intervention OSCE, indicating there were smaller differences in skill level between participants in post-intervention OSCE (17.3% and 9.1% for pre- and post-intervention OSCE, respectively). The variance components for station were very small, indicating that the stations were similar in difficulty (0 and 2.45% for pre- and post-intervention OSCE, respectively). The error variance indicates that some interaction effects could not be broken into their respective components (7.6% and 12.0% for post-intervention OSCE, respectively).

The $E\rho^2$ for the pre-intervention OSCE was calculated to be 0.60, which is within the acceptable reliability range (0.60 – 0.80) for educational research purposes (Norman et al., 2002). The post-intervention OSCE $E\rho^2$ was 0.26 (lower than the acceptable reliability range). Inter-rater reliability (from 4 fixed stations) was calculated to be 0.42 for the pre-intervention OSCE and 0.15 for the post-intervention OSCE.

Results of D-studies using variance components from the post-intervention OSCE are shown in table 6.4. D-studies indicate that a total of 9 raters and 4 stations would be required to achieve an acceptable reliability (0.61).

G-studies on global scores from trained raters for pre- and post-intervention OSCEs were also performed. For both OSCEs, the largest percentage of variance was from participant within track (70.7% and 40.9%, respectively). This result indicates that the largest source of variation in the global scores were from differences in participant performance.

The $E\rho^2$ for the trained rater global score G-studies were 0.76 and 0.62 for the pre- and post-intervention OSCE, respectively (within the acceptable reliability range). The inter-rater reliability (from 4 fixed stations) was calculated to be 0.62 and 0.44 for the pre- and post-intervention OSCE, respectively.

6.4.7 G-studies and D-studies for expert raters

The variance, percent variance and $E\rho^2$ for the checklist percentages from the expert raters for the pre- and post-intervention OSCEs are depicted in Table 6.5. For both OSCEs, the largest percentage of variance was from participant within track (47.2% and 30.9%, respectively). This result indicates that the largest source of variation in the checklist scores were from differences in veterinary performance. Unlike trained raters, variance components for rater in both the pre- and post-intervention OSCE were zero, indicating that there was no variance due to raters for expert raters.

The $E\rho^2$ for the pre- and post-intervention OSCEs were calculated to be 0.68 and 0.66, respectively (within acceptable reliability range). Inter-rater reliability (from 4 fixed stations) was calculated to be 0.51 and 0.50 for the pre- and post-intervention OSCE, respectively.

G-studies on global scores from expert raters for pre- and post-intervention OSCEs had a similar trend in variance percentages as the trained raters. For both OSCEs, the greatest amount of variance was from participant within track (57.4% and 27.3%).

The $E\rho^2$ for the global scores was calculated to be 0.78 (within the acceptable reliability range) for the pre-intervention OSCE and 0.57 (below the acceptable reliability range) for the post-intervention OSCE. Inter-rater reliability (from 4 fixed stations) was calculated to be 0.64 and 0.40 for the pre- and post-intervention OSCE, respectively.

Results of the D-studies using variance components from post-intervention OSCEs are in Table 6.6. D-studies indicate that a total of 3 raters and 4 stations would be required to achieve an acceptable reliability (0.67).

6.5 DISCUSSION

This is the first study that followed an experimental, pre- and post-intervention design to evaluate how a communication skills training workshop improved communication skills of practicing FAPM veterinarians. Main findings of the study were: 1) prior to training, communication skills of the participants had significant limitations, including deficits in communication skills that have been strongly associated with producer adherence to veterinary recommendations; 2) an experiential communication skills training workshop significantly improved communication skills of participants; 3) reliability and inter-rater reliability of 4-station communication OSCEs varied depending upon OSCE type (pre- or post-intervention), OSCE score (checklist percentage score or global scores) and rater type (trained or expert); and 4) rater variance accounted for a substantial proportion of the variance from trained raters for OSCE percentage scores. Reliability and inter-rater reliability were lowest for post-intervention percentage scores from trained raters (0.26 and 0.15, respectively) and highest for pre-intervention global scores from expert raters (0.78 and 0.64, respectively).

Prior to communication skills training, participants reported their knowledge of communication skills was only fair. This self-assessment was substantiated by low percentage and global scores from expert raters in the pre-intervention OSCE. Percentage scores indicated that the performance level of participants was less than half of what was expected to properly demonstrate the communication skills. The percentage scores were supported by global scores that were also only fair pre-intervention.

Communication deficiencies to this degree would translate into ineffective communication with participants' food animal production clients, including AJDI participants. Previous research has shown that specific communication tasks inherent to the CCG are strongly associated with adherence to recommendations, particularly in building the relationship and explanation and planning (Silverman et al., 2013). Participants' OSCE performances showed significant deficits in both of these domains. Insufficient communication skills specific to these two communication domains would likely have a negative impact on the adherence of the participants' food animal production clients to recommendations, including AJDI participants. Reduced adherence of AJDI producers would result into unsatisfactory implementation of risk assessment and management plan recommendations, and undermine the goal of controlling JD in Atlantic Canada.

Communication skills of participants significantly improved following training. This study clearly demonstrates that communication interventions such as face-to-face interactive lectures and small-group teaching were effective at helping FAPM veterinarians improve their communication skills. Improved performances were also observed for individual communication tasks, including building the relationship and explanation and planning. Intentional and effective use of communication skills specific to these two communication domains should translate to improved adherence of veterinarians' food animal production clients, including AJDI participants. Improved adherence of AJDI participants to risk assessment and management plan recommendations would ultimately support the goal of controlling JD in Atlantic Canada. This conclusion is supported by previous research which suggested that improved veterinary communication would lead to enhanced adoption of infectious disease control programs by dairy producers (Jansen et al., 2010a; Jansen et al., 2010b; Sorge et al., 2010a; Kleen et al., 2011; Lam et al., 2011).

All communication skill assessment tools used in this study indicated that communication skills of FAPM participants improved with communication skills training (OSCE, SC feedback and self-efficacy). However, none of the assessment tools were significantly correlated with each other. Previous studies in professional human health fields have also found poor agreement between communication skill assessment tools, and at present, there is little consensus on how to best assess the success of communication skills training (Mullan and Kothe, 2010). A paper by Davis et al. (2006) concluded that the resources needed to conduct an OSCE as a determinant of veterinary clinical skills are demanding but the high cost is justified by the value of the information it provides surrounding veterinarians' clinical competence.

Within-rater reliability of OSCEs in this study varied considerably depending upon type of rater (trained versus expert), OSCE score (checklist percentage score versus global score) and OSCE type (pre-intervention versus post-intervention). The G-study with highest reliability was for pre-intervention global scores from expert raters ($E\rho^2$ =

0.78). Two G-studies resulted in reliabilities lower than is acceptable for educational research purposes, specifically the G-studies for the post-intervention percentage scores from the trained raters ($E\rho^2 = 0.26$) and the post-intervention global scores from the expert raters ($E\rho^2 = 0.57$). Considering only 4 OSCE stations were used for this study, these lower $E\rho^2$ are not surprising. Two studies that used OSCE assessment of veterinary student communication were also 4-station OSCEs and had similar pre- and post-intervention $E\rho^2$ [0.50 and 0.46 (Hecker et al., 2012); and 0.65 and 0.70 (Artemiou et al., 2013), respectively]. For trained rater percentage scores from post-intervention OSCEs, the number of raters would have to be increased to 9 (with 4 stations) to achieve an $E\rho^2$ of 0.61. This number of raters is likely impractical for most research settings of similar scale. For expert rater global scores from post-intervention OSCEs, the number of raters would only need to be increased to 3 (with 4 stations) to achieve an $E\rho^2$ of 0.67. Increasing the number of stations did not increase the $E\rho^2$ to an acceptable range.

The inter-rater reliability of the OSCEs in this study followed a similar trend as the $E\rho^2$. In the G-studies using percentage scores, trained raters had much lower inter-rater reliabilities than expert raters. This result indicates that rater experience likely had a significant impact on the ability of the raters to reliably assess the participants using the checklist items. Other factors that may alter the degree of rater stringency/leniency include: their expertise, expectation and standards, and ethnicity (Harasym et al., 2008). The lowest inter-rater reliability in all G-studies was from trained raters using post-intervention percentage scores (0.15). Using global scores, inter-rater reliabilities were quite similar between sets of raters. The highest inter-rater reliability was from expert raters using pre-intervention global scores (0.64). Unlike the checklist items, the global score was rated using a 5-point Likert scale and represented the rater's overall impression of the veterinarian's communication performance. The highest inter-rater reliabilities were using pre-intervention global scores from both trained and expert raters (0.62 and 0.64, respectively). Other studies have also observed an effect of rater training on the ability to assess percentage scores compared to global scores and have suggested that the difference could be due to inherent differences between checklist and Likert scale scores. For example, there can be ceiling effects for some checklist items, and the clinical skills evaluated in the checklist depend upon a greater number of underlying factors than the global Likert rating (Brannick et al., 2011). The inter-rater reliability reported for a study that used OSCE assessment of veterinary student communication was higher than observed in our study, at 0.69 (trained and experienced raters) and 0.73 (expert raters) (Hecker et al., 2012).

The largest variance component in 6 of 8 G-studies performed was the variance for participant within track, ranging from 27.3% in the post-intervention global scores for the expert raters to 70.7% in the pre-intervention global scores for the trained raters. The variance for participant within track simply indicates that there were differences between participants in communication performance. These high subject variances would have had a positive correlation with the $E\rho^2$ of the OSCE scores.

Rater variance was the largest variance component for the G-study on pre-intervention percentage scores from trained raters (45.8%). This result indicates that significant portions of the differences in checklist percentages are due to variability in trained raters, and that there was likely an issue with rater training. In OSCE studies, there is a perennial issue of rater training (Hecker et al., 2012). Given the difficult nature of assessing communication skills, some papers have concluded that it is important when training on this topic to emphasize communication skills spotting, as well as ensuring familiarity with the stations and checklists to facilitate a fair assessment of the communication skills (Hecker et al., 2012). Other studies have concluded that thorough selection, monitoring and training did not eliminate the examiner stringency/leniency effect (McManus et al., 2006). Rater variance decreased to zero for expert ratings of the percentage scores, indicating there was no variance due to expert raters.

In post-intervention G-studies, variance due to track was one of the largest variance components. This result indicates that participant performance varied by track, even though the SCs who portrayed the same case in each track were trained together to maximize consistency. The opposite was seen in pre-intervention OSCEs where variance due to track was small. Issues that could explain the differences between the pre- and post-intervention track variance include: SC fatigue, differences in SC understanding of the post-intervention OSCE cases, and decreased objectivity in case portrayal due to developing a relationship with the participants during the pre-intervention OSCE and small-group training. Additional SC training or using different SCs for the OSCEs and the small-group training sessions may help to decrease the variance due to track.

In all G-studies, station variance was small but the participant within track by station variance had a significant variance component for 7 of 8 analyses. This result indicates that stations were similar in difficulty but there was a difference in how the participants performed on each station, even though they were assessed on the same checklist items. This result is not surprising, as context specificity is well recognized to influence the use of communication skills during the veterinary consultation (Hecker et al., 2012; Artemiou et al., 2013).

In this study, the relatively low veterinary participation rate could have introduced a study limitation of non-response bias. It is possible that AJDI trained veterinarians who participated in the communication skills training workshop had more interest in improving their communication skills than their non-participating colleagues. This could result in differences in their baseline communication skills and responses to communication training compared to non-participating colleagues.

Missing data bias may have been introduced by video-recording failure. However, this bias would only apply if there was a difference in communication performance scores related to the station with the malfunctioning camera. The G-studies of the scores from the expert raters did have a significant variance due to participant within track by station, indicating that there was a difference in how the participants performed on each station. Missing data bias may have also been introduced by missing SC feedback forms, particularly if there was a difference in veterinary performance related to station. However, one-way ANOVA was not able to detect differences in feedback percent scores or feedback global scores between the 4 stations in either OSCE. Missing items within the self-efficacy questionnaires, OSCE checklists and SC feedback forms may also have introduced item missing data bias. It is unlikely that any of these missing data biases would be large as the pattern of missing data in each of these communication assessment tools was MCAR, and the percent of items missing was small.

Bias could also have been introduced into this study by the use of person mean imputation. In OSCE percentage scores, there was no difference detected between score estimates and the 95% CI when comparing person mean imputation and multiple imputation. Multiple imputation has been recommended to handle item score data; however, it is more complicated than simple imputation procedures, such as person-mean imputation. When only a small amount of item scores are missing (<25%) in only a small amount of cases (<10%), simple imputation methods may be preferred purely for practical reasons (Eekhout et al., 2014). The lack of differences when comparing the two imputation methods provides us with confidence that the simpler imputation method was appropriate.

In this study, the CCG was used as a framework for communication skills interventions and assessments with FAPM veterinarians. We found that the CCG's focus on, and organization of, the veterinary consultation applied well to the introduction and early communication learning for FAPM veterinarians in this workshop. This is partially supported by a study that modelled communication in production animal medicine (Kleen et al., 2011). That study agreed that the CCG model of the consultation process applies to companion animal medicine, as well as to most aspects of "traditional," curative, farm animal practice. However, the authors suggested that in veterinary advisory practice, such as FAPM practice, the communication between veterinarian and owner goes beyond the medical curative consultation, and as such, additional communication instruments should be used (Kleen et al., 2011). In future, additional research into the most appropriate communication instrument for advanced training in communication for FAPM veterinarians, particularly FAPM veterinarians in advisory roles, should be considered.

The communication skills training workshop in this study was conducted in-person over 1 ½ days, and used interactive lectures and small-group training as communication interventions. Previous research has found that communication training programs improved communication skills if they lasted for at least one day (Berkhof et al., 2011) and that small-group training was the most effective approach for enhancing communication skills (Artemiou et al., 2013). However, the in-person time commitment required was a concern for some FAPM veterinarians. Some solo practitioners were unable to attend because they couldn't leave their practice for the length of the workshop, and multi-veterinarian clinics could only send some, rather than all, veterinarians in the practice in order maintain clinic operations.

Participating veterinarians suggested that lengthening the workshop or allowing more time for communication training would have been beneficial. Considering the time constraints already experienced by FAPM veterinarians, an alternative could be to incorporate web-based communication interventions into a communication skills workshop. Research has found that web-based communication training was an effective communication training method (Roter et al., 2012; Artemiou et al., 2013; Artemiou et al., 2014b). Web-based communication training could be particularly useful to introduce communication theory and describe the necessary communication skills prior to the workshop. This would allow more time for participants to practice their communication skills during the in-person workshop (small-group training and video skill spotting exercises), and would likely lead to less workshop fatigue.

6.6 CONCLUSIONS

Based on this study, development and implementation of communication skills training and assessment increases the communication competency of FAPM veterinarians. This training would be particularly relevant for those veterinarians involved in infectious disease control programs. Rater training and experience was important to facilitate fair assessment of communication skills.

6.7 REFERENCES

Adams, C. L. 2013. Simulated client feedback form, clinical communication skills program 507.

Adams, C. L. and S. M. Kurtz. 2006. Building on existing models from human medical education to develop a communication curriculum in veterinary medicine. J Vet Med Educ. 33:28-37.

Adams, C. L. and S. M. Kurtz. 2012. Coaching and feedback: enhancing communication teaching and learning in veterinary practice settings. J. Vet. Med. Educ. 39:217-228.

Adams, C. L. and S. M. Kurtz. 2017. Skills for Communicating in Veterinary Medicine. Dewpoint Publishing, Parsippany, NJ, USA.

Adams, C. L., S. M. Kurtz and L. Ladner. 2013. UCVM clinical communication skills program - case template.

Adams, C. L. and L. Ladner. 2004. Implementing a simulated client program: bridging the gap between theory and practice. J. Vet. Med. Educ. 31(2):138-145.

American Animal Hospital Association. 2009. Compliance: Taking Quality Care to the Next Level: A Report of the 2009 AAHA Compliance Follow-Up Study. AAHA Press, Lakewood, Colorado, USA.

American Veterinary Medical Association. 2020. Council on Education (COE) Accreditation Policies and Procedures: Requirements. Accessed March 13, 2021. https://www-avma-org.proxy.library.upei.ca/education/accreditation/colleges/coe-accreditation-policies-and-procedures-requirements.

Ammentorp, J., S. Sabroe, P. Kofoed and J. Mainz. 2007. The effect of training in communication skills on medical doctors' and nurses' self-efficacy. A randomized controlled trial. Patient Educ. Couns. 66:270-277.

Artemiou, E., C. L. Adams, K. G. Hecker, A. Vallevand, C. Violato and J. B. Coe. 2014a. Standardised clients as assessors in a veterinary communication OSCE: a reliability and validity study. Vet. Rec. 175:509-509.

Artemiou, E., C. L. Adams, L. Toews, C. Violato and J. B. Coe. 2014b. Informing web-based communication curricula in veterinary education: a systematic review of web-based methods used for teaching and assessing clinical communication in medical education. J. Vet. Med. Educ. 41:44-54.

Artemiou, E., C. L. Adams, A. Vallevand, C. Violato and K. G. Hecker. 2013. Measuring the effectiveness of small-group and web-based training methods in teaching clinical communication: a case comparison study. J. Vet. Med. Educ. 40:242-251.

Association of American Veterinary Medical Colleges. 2018. Competency-Based Veterinary Education: Part 1 - CBVE framework. Association of American Veterinary Medical Colleges, Washington, DC, USA.

Barton, K., C. D. Cunningham, G. T. Jones and P. Maharg. 2006. Valuing what clients think: standardized clients and the assessment of communicative competence. Clinical Law Review. 13(1):1-65.

Bauman, C. A., H. W. Barkema, J. Dubuc, G. P. Keefe and D. F. Kelton. 2016. Identifying management and disease priorities of Canadian dairy industry stakeholders. J. Dairy Sci. 99:10194-10203.

Berkhof, M., H. J. van Rijssen, A. J. M. Schellart, J. R. Anema and d. B. van. 2011. Effective training strategies for teaching communication skills to physicians: an overview of systematic reviews. Patient Educ. Couns. 84:152-162.

Boulet, J. R., D. W. McKinley, J. J. Norcini and G. P. Whelan. 2002. Assessing the comparability of standardized patient and physician evaluations of clinical skills. Advances in Health Sciences Education. 7:85-97.

Brannick, M. T., H. Erol-Korkmaz and M. Prewett. 2011. A systematic review of the reliability of objective structured clinical examination scores. Med. Educ. 45:1181-1189.

Brennan, R. L. 2001. Generalizability Theory. Springer-Verlag Berlin Heidelberg, New York, USA.

Chun, R., S. Schaefer, C. C. Lotta, J. A. Banning and S. E. Skochelak. 2009. Didactic and experiential training to teach communication skills: The University of Wisconsin-Madison School of Veterinary Medicine collaborative experience. J. Vet. Med. Educ. 36:196-201.

Cipolla, M. and A. Zecconi. 2015. Short communication: study on veterinarian communication skills preferred and perceived by dairy farmers. Res. Vet. Sci. 99:60-62.

Coe, J. B., C. L. Adams, K. Eva, S. Desmarais and B. N. Bonnett. 2010. Development and validation of an instrument for measuring appointment-specific client satisfaction in companion-animal practice. Prev. Vet. Med. 93:201-210.

Davis, M. H., G. G. Ponnamperuma, S. McAleer and V. H. M. Dale. 2006. The Objective Structured Clinical Examination (OSCE) as a determinant of veterinary clinical skills. J. Vet. Med. Educ. 33:578-587.

Eekhout, I., H. C. W. de Vet, J. W. R. Twisk, J. P. L. Brand, M. R. de Boer and M. W. Heymans. 2014. Missing data in a multi-item instrument were best handled by multiple imputation at the item score level. J. Clin. Epidemiol. 67:335-342.

Evans, J. D. 1996. Straightforward Statistics for the Behavioral Sciences. Thomson Brooks/Cole Publishing Co, Belmont, CA, US.

Goodwin, L. D. 2001. Interrater agreement and reliability. Measurement in Physical Education & Exercise Science. 5:13-34.

Gray, C. A., A. C. Blaxter, P. A. Johnston, C. E. Latham, S. May, C. A. Phillips, N. Turnbull and B. Yamagishi. 2006. Communication education in veterinary in the united kingdom and Ireland: The NUVACS project coupled to progressive individual school endeavors. J Vet Med Educ. 33:85-92.

Gulbrandsen, P., B. F. Jensen, A. Finset and D. Blanch-Hartigan. 2013. Long-term effect of communication training on the relationship between physicians' self-efficacy and performance. Patient Educ. Couns. 91:180-185.

Harasym, P. H., W. Woloschuk and L. Cunning. 2008. Undesired variance due to examiner stringency/leniency effect in communication skill scores assessed in OSCEs. Adv. Health Sci. Educ. Theory Pract. 13(5):617-62.

Hargie, O., M. Boohan, M. McCoy and P. Murphy. 2010. Current trends in communication skills training in UK schools of medicine. Med. Teach. 32:385-391.

Hecker, K. G., C. L. Adams and J. B. Coe. 2012. Assessment of first-year veterinary students' communication skills using an objective structured clinical examination: The importance of context. J. Vet. Med. Educ. 39:304-310.

Hodges, B. D. 2006. The Objective Structured Clinical Examination: three decades of development. J. Vet. Med. Educ. 33:571-577.

Humphries, G. M. 2002. Communication skills knowledge, understanding and OSCE performance in medical trainees: a multivariate prospective study using structural equation modelling. Med. Educ. 36(9):842-852.

Jansen, J. 2010. Mastitis and Farmer Mindset: Towards Effective Communication Strategies to Improve Udder Health Management on Dutch Dairy Farms. PhD Thesis. Wageningen University, Wageningen, Netherlands.

Jansen, J., R. J. Renes and T. J. G. M. Lam. 2010b. Evaluation of two communication strategies to improve udder health management. J. Dairy Sci. 93:604-612.

Jansen, J., C. D. M. Steuten, R. J. Renes, N. Aarts and T. J. G. M. Lam. 2010a. Debunking the myth of the hard-to-reach farmer: effective communication on udder health. J. Dairy Sci. 93:1296-1306.

Kanji, N., J. B. Coe, C. L. Adams and J. R. Shaw. 2012. Effect of veterinarian-client-patient interactions on client adherence to dentistry and surgery recommendations in companion-animal practice. J. Am. Vet. Med. Assoc. 240:427-436.

Kleen, J. L., O. Atkinson and J. P. T. M. Noordhuizen. 2011. Communication in production animal medicine: modelling a complex interaction with the example of dairy herd health medicine. Ir. Vet. J. 64(1):8.

Kurtz, S. 2006. Teaching and learning communication in veterinary medicine. J. Vet. Med. Educ. 33:11-19.

Kurtz, S. M., J. Silverman and J. Draper. 2005. Teaching and Learning Communication Skills in Medicine. 2nd ed., Radcliffe Publishing Ltd., Abingdon, UK.

Lam, T. J. G. M., J. Jansen, B.H.P. van den Borne, R. J. Renes and H. Hogeveen. 2011. What veterinarians need to know about communication to optimise their role as advisors on udder health in dairy herds. N. Z. Vet. J. 59:8-15.

Lam, T. J. G. M., J. Jansen, J. C. L. Veersen and R. J. Renés. 2007. Making changes in improving udder health: A veterinary perspective. British Mastitis Conference 2007, Warwickshire, UK, 10th October 2007. 1-11.

Latham, C. E. and A. Morris. 2007. Effects of formal training in communication skills on the ability of veterinary students to communicate with clients. Vet. Rec. 160:181-186.

McManus, I. C., M. Thompson and J. Mollon. 2006. Assessment of examiner leniency and stringency ('hawk-dove effect') in the MRCP(UK) clinical examination (PACES) using multi-facet rasch modelling. BMC Med. Educ. 6:42.

Mills, J. N., P. Irwin, J. Baguley, M. Meehan, H. Austin, L. Fitzpatrick, B. Parry and T. Heath. 2006. Development of veterinary communication skills at Murdoch University and in other Australian veterinary schools. J Vet Med Educ. 33:93-99.

Mullan, B. A. and E. J. Kothe. 2010. Evaluating a nursing communication skills training course: The relationships between self-rated ability, satisfaction, and actual performance. Nurse Educ. Pract. 10:374-378.

Norman, G. R., C. Vleuten and D. Newble. 2002. International Handbook of Research in Medical Education. Norman, G. R., C. P. M. Van Der Vleuten, D. I. Newble eds. Kluwer Academic Publishers, Boston, MA, USA.

Parle, M., P. Maguire and C. Heaven. 1997. The development of a training model to improve health professionals' skills, self-efficacy and outcome expectancies when communicating with cancer patients. Soc. Sci. Med. 44:231-240.

Petrovski, K. R. and M. McArthur. 2015. The art and science of consultations in bovine medicine: use of modified Calgary-Cambridge-Guides. Maced. Vet. Rev. 38:137-147.

Quinn, C., M. J. Haber and Y. Pan. 2009. Use of the concordance correlation coefficient when examining agreement in dyadic research. Nurs. Res. 58:368-373.

Radford, A., P. Stockley, J. Silverman, I. Taylor, R. Turner and C. Gray. 2006. Development, teaching, and evaluation of a consultation structure model for use in veterinary education. J. Vet. Med. Educ. 33:38-44.

Ridge, S. E., I. M. Baker and M. Hannah. 2005. Effect of compliance with recommended calf-rearing practices on control of bovine Johne’s disease. Aust. Vet. J. 83:85-90.

Ritter, C., C. L. Adams, D. F. Kelton and H. W. Barkema. 2018. Clinical communication patterns of veterinary practitioners during dairy herd health and production management farm visits. J. Dairy Sci. 101(11):10337-10350.

Ritter, C., C. L. Adams, D. F. Kelton and H. W. Barkema. 2019. Factors associated with dairy farmers' satisfaction and preparedness to adopt recommendations after veterinary herd health visits. J. Dairy Sci. 102(5):4280-4293.

Roter, D. L., R. Wexler, P. Naragon, B. Forrest, J. Dees, A. Almodovar and J. Wood. 2012. The impact of patient and physician computer mediated communication skill training on reported communication and patient satisfaction. Patient Educ. Couns. 88:406-413.

Shaw, D. 2010. VCA 475 - client communication
pre & post rotation student surveys.

Shaw, D. H. and S. L. Ihle. 2006. Communication skills training at the Atlantic Veterinary College, University of Prince Edward Island. J. Vet. Med. Educ. 33:100-104.

Shaw, J. R. 2019. Evaluation of communication skills training programs at North American veterinary medical training institutions. J. Am. Vet. Med. Assoc. 255(6):722-733.

Shaw, J. R., C. L. Adams and B. N. Bonnett. 2004. What can veterinarians learn from studies of physician-patient communication about veterinarian-client-patient communication?. J. Am. Vet. Med. Assoc. 224:676-684.

Shaw, J. R., C. L. Adams, B. N. Bonnett, S. Larson and D. L. Roter. 2012. Veterinarian satisfaction with companion animal visits. J. Am. Vet. Med. Assoc. 240:832-841.

Shaw, J. R., G. E. Barley, K. Broadfoot, A. E. Hill and D. L. Roter. 2016. Outcomes assessment of on-site communication skills education in a companion animal practice. J. Am. Vet. Med. Assoc. 249:419-432.

Shaw, J. R., G. E. Barley, A. E. Hill, S. Larson and D. L. Roter. 2010. Communication skills education onsite in a veterinary practice. Patient Educ. Couns. 80:337-344.

Silverman, J., S. M. Kurtz and J. Draper. 2013. Skills for Communicating with Patients. 3rd ed. CRC Press, Taylor & Francis Group. Boca Raton, Florida, USA.

Sorge, U., D. Kelton, K. Lissemore, A. Godkin, S. Hendrick and S. Wells. 2010a. Attitudes of Canadian dairy farmers toward a voluntary Johne's disease control program. J. Dairy Sci. 93:1491-1499.

Sorge, U. S., J. Mount, D. F. Kelton and A. Godkin. 2010b. Veterinarian's perspective on a voluntary Johne's disease prevention program in Ontario and western Canada. Can. Vet. J. 51(4):403-405.

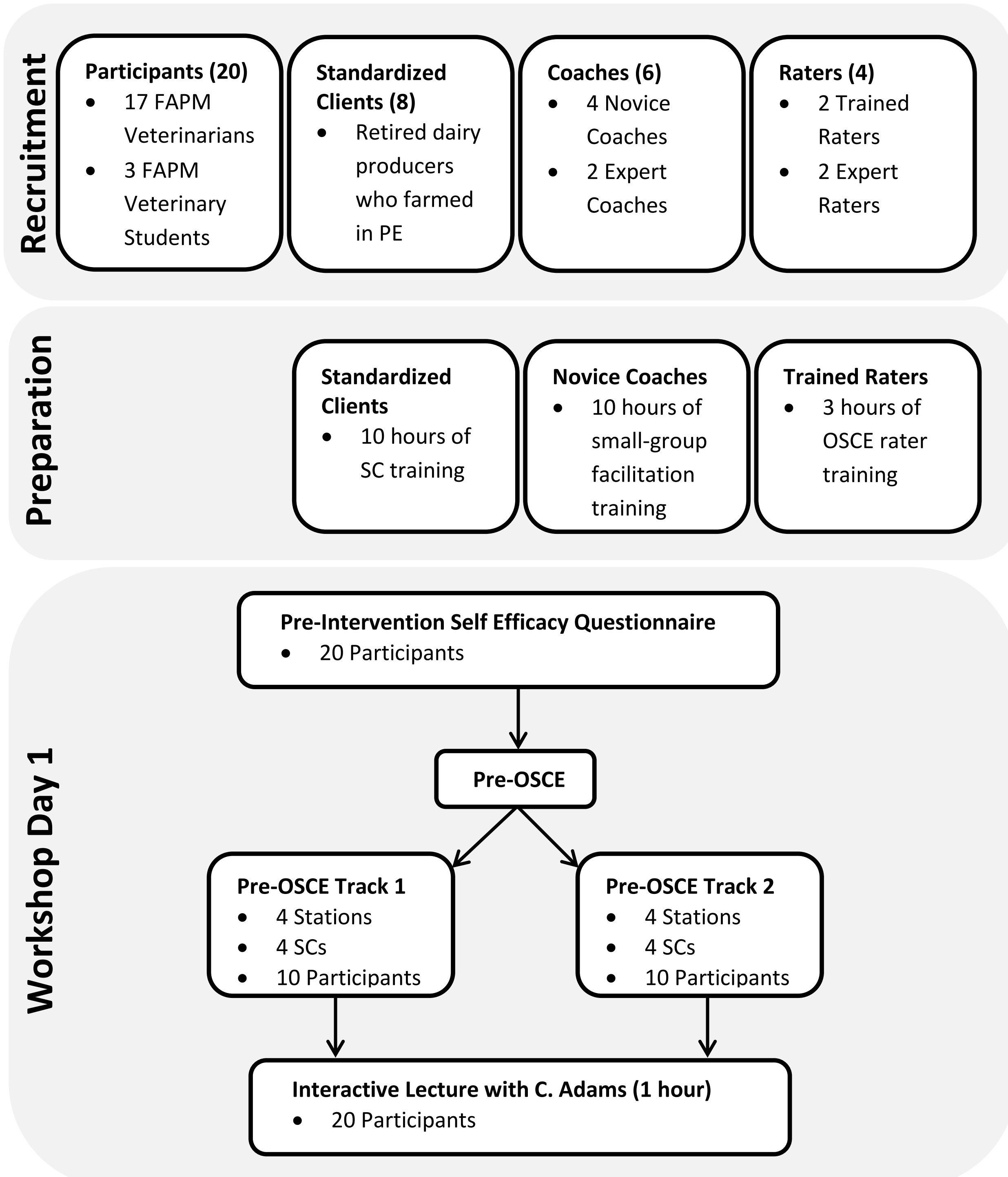
van Ginkel, J. R., K. Sijtsma, d. A. van and J. K. Vermunt. 2010. Incidence of missing item scores in personality measurement, and simple item-score imputation. Methodology. 6:17-30.

Wolf, R., H. W. Barkema, J. De Buck and K. Orsel. 2015. Factors affecting management changes on farms participating in a Johne's disease control program. J. Dairy Sci. 98:7784-7796.

World Organization for Animal Health. 2012. OIE recommendations on the competencies of graduating veterinarians ('Day 1 graduates') to assure National Veterinary Services of quality. OIE. Paris, France.

Wraight, M. D., J. McNeil, D. S. Beggs, R. K. Greenall, T. B. Humphris, R. J. Irwin, S. P. Jagoe, A. Jemmeson, W. F. Morgan, P. Brightling, G. A. Anderson and P. D. Mansell. 200. Compliance of Victorian dairy farmers with current calf rearing recommendations for control of Johne's disease. Vet. Microbiol. 77(3-4):429-442.

Figure 6.1 Layout of the Communication Skills Training Workshop for the 20 participants, 8 Standardized Clients, 6 Coaches and 4 Raters, in Atlantic Canada in 2014



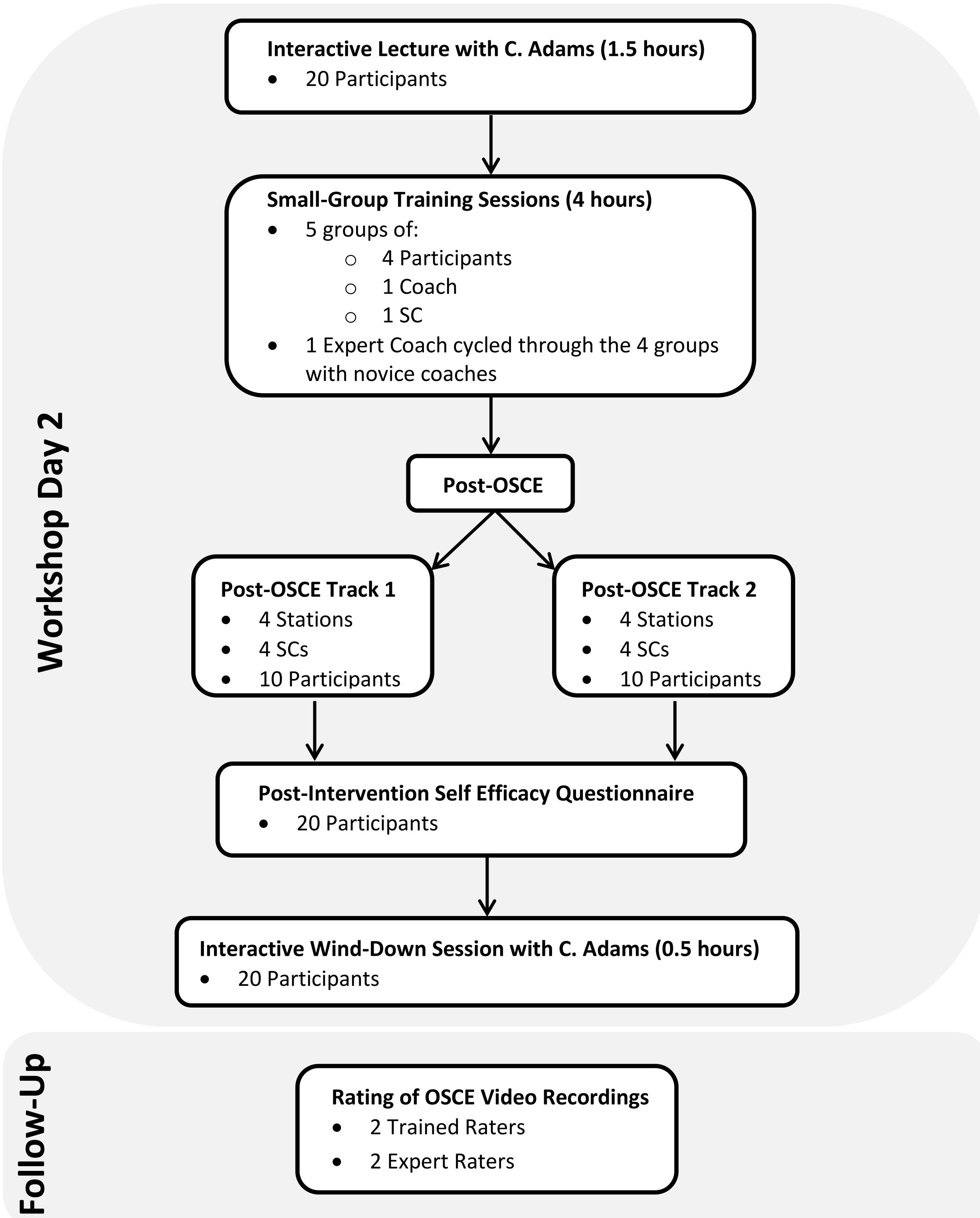

Workshop Day 2
Interactive Lecture with C. Adams (1.5 hours)
20 Participants
Small-Group Training Sessions (4 hours)
5 groups of:
4 Participants
1 Coach
1 SC
1 Expert Coach cycled through the 4 groups with novice coaches
Post-OSCE
Post-OSCE Track 1
4 Stations
4 SCs
10 Participants
Post-OSCE Track 2
4 Stations
4 SCs
10 Participants
Post-Intervention Self Efficacy Questionnaire
20 Participants
Interactive Wind-Down Session with C. Adams (0.5 hours)
20 Participants
Follow-Up
Rating of OSCE Video Recordings
2 Trained Raters
2 Expert Raters

Table 6.1 Descriptive statistics of the percentage scores and the global scores for the 20 participant pre- and post-intervention OSCEs, by trained raters, expert raters and the SCs, in Atlantic Canada in 2014

	Pre-Intervention OSCE		Post-Intervention OSCE	
	Mean % Score	Mean Global Score	Mean % Score	Mean Global Score
Trained Raters[a]	65.08 (63.01, 67.14[c]) [152[d]]	3.29 (3.17, 3.41) [152]	77.84 (76.07, 79.61) [146]	3.86 (3.73, 4.00) [146]
Expert Raters[a]	48.17 (46.23, 50.11) [151]	1.78 (1.65, 1.91) [150]	68.29 (65.89, 70.69) [146]	3.22 (3.05, 3.39) [145]
SCs[b]	80.13 (74.06, 86.20) [70]	1.67 (1.50, 1.85) [58]	92.71 (90.49, 94.93) [70]	1.98 (1.95, 2.00) [59]

[a] OSCE checklist
[b] SC Feedback Form
[c] 95% confidence interval
[d] Number of observations

Table 6.2 Descriptive statistics of task percentages for the 20 participant pre- and post-intervention OSCEs, by trained and expert raters, in Atlantic Canada in 2014

	Pre-Intervention OSCE		Post-Intervention OSCE	
	Trained Raters	Expert Raters	Trained Raters	Expert Raters
Initiating the Session	70.09 (67.77, 72.41[a]) [149[b]]	44.40 (41.47, 47.34) [143]	76.78 (74.50, 79.06) [146]	63.43 (59.92, 66.94) [142]
Gathering Information	72.17 (68.72, 75.62) [151]	60.54 (56.97, 64.11) [142]	89.72 (87.25, 92.19) [144]	79.94 (77.02, 82.86) [140]
Providing Structure	14.39 (10.34, 18.44) [150]	35.04 (30.37, 39.72) [141]	32.23 (26.87, 37.59) [144]	56.28 (50.98, 61.58) [136]
Building the Relationship	73.25 (69.20, 77.29) [152]	54.67 (51.28, 58.06) [141]	82.88 (79.28, 86.48) [146]	73.86 (70.22, 77.50) [141]
Explanation and Planning	77.53 (74.29, 80.77) [149]	47.16 (44.25, 50.06) [135]	89.55 (86.90, 92.21) [146]	69.05 (65.60, 72.50) [138]
Closing the Session	44.79 (39.43, 50.14) [148]	25.87 (21.47, 30.28) [142]	59.42 (54.27, 64.56) [146]	47.60 (41.62, 53.59) [142]

[a] 95% confidence interval

[b] Number of observations

Table 6.3 Results of G-studies for the checklist percentages for the trained raters from the 20 participant pre- and post-intervention OSCEs in Atlantic Canada in 2014

	Source	Variance ($\sigma 2$)	Variance (%)	G Coefficient ($E\rho^2$)
Pre-Intervention OSCE	R	37.37	45.85	0.60
	T	0.00	0.00	
	v:t	14.10	17.30	
	S	0.00	0.00	
	Rt	0.00	0.00	
	rv:t	11.58	14.21	
	Rs	0.14	0.17	
	Ts	0.00	0.00	
	v:ts	12.11	14.86	
	Rts	0.00	0.00	
	rv:ts, error	6.21	7.62	
	Total	81.51	100.00	
Post-Intervention OSCE	R	9.45	16.81	0.26
	T	16.08	28.60	
	v:t	5.14	9.14	
	S	1.38	2.45	
	Rt	0.00	0.00	
	rv:t	15.07	26.80	
	Rs	0.00	0.00	
	Ts	0.00	0.00	
	v:ts	2.37	4.21	
	Rts	0.00	0.00	
	rv:ts, error	6.74	11.99	
	Total	56.23	100.00	

r = rater; t = track; v = veterinarian; s = station
$\sigma^2_{(r)}$ = variance component for rater
$\sigma^2_{(t)}$ = variance component for track
$\sigma^2_{(v:t)}$ = variance component for veterinarian within track
$\sigma^2_{(s)}$ = variance component for station
$\sigma^2_{(rt)}$ = variance component for rater by track
$\sigma^2_{(rv:t)}$ = variance component for rater by veterinarian within track
$\sigma^2_{(rs)}$ = variance component for rater by station
$\sigma^2_{(ts)}$ = variance component for track by station
$\sigma^2_{(v:ts)}$ = variance component for veterinarian within tract by station
$\sigma^2_{(rts)}$ = variance component for rater by track by station
$\sigma^2_{(rv:ts,\ error)}$ = variance component for rater by veterinarian within track by station and error (residual)

Table 6.4 Results of D-studies using variance components from the G-study of checklist percentages for the trained raters from the 20 participant post-intervention OSCEs in Atlantic Canada in 2014

Raters[a]	Stations[b]	G Coefficient ($E\rho^2$)
1	1	0.15
1	4	0.15
2	4	0.26
2	40	0.41
6	40	0.51
8	40	0.58
9	4	0.61
9	10	0.61

[a] Number of random raters
[b] Number of fixed stations

Table 6.5 Results of G-studies for the checklist percentages for the expert raters from the 20 participant pre- and post-intervention OSCEs in Atlantic Canada in 2014

	Source	Variance (σ^2)	Variance (%)	G Coefficient ($E\rho^2$)
Pre-Intervention OSCE	R	0.00	0.00	0.68
	T	2.70	4.92	
	v:t	25.93	47.22	
	S	1.62	2.95	
	Rt	0.00	0.00	
	rv:t	7.96	14.50	
	Rs	0.29	0.53	
	Ts	0.00	0.00	
	v:ts	8.15	14.84	
	Rts	0.00	0.00	
	rv:ts, error	8.26	15.04	
	Total	54.91	100.00	
Post-Intervention OSCE	R	0.00	0.00	0.66
	T	23.73	21.85	
	v:t	33.55	30.89	
	S	0.00	0.00	
	Rt	7.33	6.75	
	rv:t	18.50	17.03	
	Rs	0.37	0.34	
	Ts	2.28	2.10	
	v:ts	16.04	14.77	
	Rts	0.00	0.00	
	rv:ts, error	6.80	6.26	
	Total	108.60	100	

r = rater; t = track; v = veterinarian; s = station
$\sigma^2_{(r)}$ = variance component for rater
$\sigma^2_{(t)}$ = variance component for track
$\sigma^2_{(v:t)}$ = variance component for veterinarian within track
$\sigma^2_{(s)}$ = variance component for station
$\sigma^2_{(rt)}$ = variance component for rater by track
$\sigma^2_{(rv:t)}$ = variance component for rater by veterinarian within track
$\sigma^2_{(rs)}$ = variance component for rater by station
$\sigma^2_{(ts)}$ = variance component for track by station
$\sigma^2_{(v:ts)}$ = variance component for veterinarian within tract by station
$\sigma^2_{(rts)}$ = variance component for rater by track by station
$\sigma^2_{(rv:ts,\ error)}$ = variance component for rater by veterinarian within track by station and error (residual)

Table 6.6 Results of D-studies using variance components from the G-study of global scores for the expert raters from the 20 participant post-intervention OSCEs in Atlantic Canada in 2014

Raters[a]	Stations[b]	G Coefficient ($E\rho^2$)
1	1	0.41
1	4	0.40
2	4	0.57
2	20	0.57
3	4	0.67

[a] Number of random raters
[b] Number of fixed stations

CHAPTER 7: SUMMARIZING AND INTEGRATING CONCLUSIONS

Johne's disease, also known as paratuberculosis, is a chronic infectious disease caused by *Mycobacterium avium* subspecies *paratuberculosis* (MAP) that is endemic among farmed cattle worldwide. The clinical signs of Johne's disease (JD) include severe watery diarrhea, progressive emaciation and diffuse edema (Sweeney et al., 2012). Johne's disease is an important production limiting disease in dairy cattle that causes substantial economic losses through decreased milk production and slaughter value, increased culling risk, mortality, treatment costs and reproductive loss (Chi et al., 2002; McKenna et al., 2006; Barkema et al., 2010; Wolf et al., 2014; McAloon et al., 2016, Rasmussen et al., 2020). Evidence suggesting a potential link between MAP and Crohn's disease in humans has also led to public health and food safety concerns, although a causal relationship has not been scientifically demonstrated (Naser et al., 2004; Abubakar et al., 2008; Barkema et al., 2011).

Currently, there is no ideal, cost-effective vaccine or treatment to control JD (Patton, 2011; Fecteau and Whitlock, 2011). The diagnosis of JD can also be challenging, particularly due to the long incubation period and poor sensitivity of diagnostic tests (Nielsen and Toft, 2008; McAloon et al., 2019). As such, prevention and control of JD is most commonly based on reducing MAP transmission (Pieper et al., 2015; Arango-Sabogal et al., 2017). Two fundamental approaches are used by effective JD control programs to reduce MAP transmission: implementation of best management practices to target infection routes and decrease calf exposure to all manure, and reduction of prevalent infections to limit the quantity of MAP shed into the environment (McKenna et al., 2006; Whitlock, 2010; Arango-Sabogal et al., 2017). Many regions and nations around the globe, including Canada, have implemented voluntary control and surveillance programs based on these approaches, using veterinarian-administered risk assessment (RA) to identify high risk management practices and to prompt changes in management behaviour (Kennedy and Allworth, 2000; Groenendaal et al., 2003; Nielsen, 2007; Collins et al., 2010; Barker et al., 2012).

In 2011, the Atlantic Johne's Disease Initiative (AJDI) was launched as part of control efforts in Canada. The AJDI combined a veterinarian-administered risk assessment and management plan (RAMP) with herd- and cow-level testing to reduce the impact and prevalence of MAP infection in the Atlantic provinces of Canada; specifically, New Brunswick (NB), Newfoundland and Labrador (NL), Nova Scotia (NS), and Prince Edward Island (PE).

Success of a RAMP-based control program depends upon the implementation and adherence of best management practices to reduce the risk of JD introduction and spread on-farm. Unfortunately, previous studies have indicated that management changes are not being made as recommended, particularly with increasing duration of participation in a control program (Wraight et al., 2000; Ridge et al., 2010; Sorge et al., 2010; Wolf et al., 2015a). Nonadherence to recommendations has been recognized as a considerable challenge within veterinary medicine, and important research has been done in this area. The aim of this thesis was to investigate and address factors potentially impacting adherence to control measures in the AJDI and its associated outcomes.

7.1 Atlantic Johne's Disease Initiative description

The AJDI was designed based upon four pillars often included in successful JD control programs: 1) education of producers, veterinarians and the public; 2) farm-specific veterinarian-administered RAMPs; 3) testing at the herd and/or cow level; and 4) applied research (Barker et al., 2012; Barkema 2018). When the AJDI was launched, the Atlantic Canadian dairy industry consisted of 664 herds. The goal was to recruit at least 60% of the herds to participate in the AJDI. Another goal was to train at least one veterinarian from each veterinary clinic providing service to the dairy herds of Atlantic Canada to function as certified AJDI veterinarians. Certification was achieved by the completion of an advanced education program designed by the AJDI that included in-person training (small groups or one-on-one) and web-based training and evaluation. Only the certified veterinarians were to provide the producers with MAP infection diagnostic test results or perform farm-specific RAMPs.

Following enrollment in the AJDI, herd-level MAP infection diagnostic testing was performed using an environmental culture (EC) procedure that tested six mixed fecal samples (EC-6) from prescribed locations in the herd environment, and with those results, categorized the herds as either EC-negative or EC-positive. During the herd visit to collect the EC-6 samples, trained AJDI technical staff completed a questionnaire with the producer(s) about herd demographics and their opinions about the AJDI.

Risk assessment workbooks, designed using the Canadian national standards for risk assessment, were used for the veterinarian-administered RAMPs (McKenna et al., 2006; Barker et al., 2012). Different risk assessment workbooks were designed for EC-neg and EC-pos farms. Workbooks for EC-neg herds assigned higher risk assessment scores to risk factors related to external biosecurity, notably animal purchase history.

Conversely, workbooks for EC-pos herds assigned higher risk assessment scores to management practices related to internal biosecurity, specifically the source of colostrum fed to calves and the exposure of pre-weaned calves to cow manure. Based on the herd's JD categorization and RA, and what could be practically achieved in the following 12 months, consensus between the veterinarian and producer identified up to a maximum of three management changes to be implemented to mitigate JD risk. Consensus management changes were also ranked in order of priority for JD control.

Herd categorization and veterinarian-administered RAMPs were fully funded by the AJDI. Herds categorized as EC-positive were also eligible for voluntary co-funded individual cow MAP infection diagnostic testing. From previous research, it was expected that the proportion of environmental fecal samples that tested positive for MAP out of the EC-6 set could be used to estimate the apparent within-herd prevalence of MAP (Lavers et al., 2013). As such, the AJDI recommended to selectively conduct individual cow diagnostic testing in EC-positive herds that had a high proportion of their environmental fecal samples positive per EC-6 set (i.e., more than 3 environmental fecal samples positive per EC-6 set). To be eligible for co-funding, herds had to test all lactating cows and could voluntarily test all dry cows.

Repetition of EC herd categorization and veterinarian-administered RAMPs was done for each herd annually, until they were EC-negative for 2 consecutive years. At that point, the EC and RAMP were repeated every other year, as long as the herd remained EC-negative. Herds that were categorized EC-negative were eligible to have their status voluntarily registered on the AJDI website (www.atlanticjohnes.ca; site is no longer active). There were 2 levels in the Registry: EC-Negative Level 1 (Entry Level) and EC-Negative Level 2 (Maintenance of Status).

7.2 Atlantic Johne's Disease Initiative outcomes

The focus of Chapter 2 was to describe the outcomes related to participation in the AJDI, herd categorization by EC, factors associated with herds that were EC-positive, individual cow MAP infection diagnostic testing results for EC-positive herds, and association between 305-day milk production and individual cow MAP infection status.

Participation in the AJDI was very high. Of the Atlantic Canadian dairy herds at the launch of the AJDI, 70% voluntarily participated in the initiative. The AJDI reached a higher percentage of its dairy herds than did the JD control programs in any other province in Canada and almost doubled the participation rate among Canadian dairy herds overall (Barkema, 2018). Involvement of the food animal production medicine (FAPM) veterinarians in Atlantic Canada also exceeded the AJDI goal, with a total of 55 veterinarians from 27 different veterinary clinics completing the advanced education program to become certified veterinarians.

The recruited herds became the study population during the 3 years of this study, 2011-2013. Following enrollment in the AJDI, herds moved through the control program as described in Section 7.1. Data collected through herd- and cow-level diagnostic testing, questionnaires completed during EC sample collection, and production and reproduction records in the regional dairy herd improvement (DHI) database (Valacta) were used for statistical analyses in this study.

Descriptive statistics calculated for EC questionnaires provided insight to AJDI herds. Involvement of FAPM veterinarians was considered to be crucial for the success of the AJDI (Barkema, 2018) and indeed, more than 75% of producers attributed their motivation to participate in the AJDI to their herd veterinarian. While almost all of the AJDI producers reported a positive experience with the AJDI and supported the establishment of a national program for the control of JD, they also most frequently ranked JD as the least important disease concern in their herd when compared to common disease problems such as infertility, mastitis and lameness.

Overall, a moderate apparent herd prevalence of MAP infection was detected in the AJDI, with 26.5% of herds testing EC-positive at least once during the study period. Almost all herds had enrolled in the AJDI early enough to have more than one EC conducted during the study. Of herds that were categorized EC-positive at least once (n=122), more than half were also misclassified as EC-negative at least once. This is similar to what was found by Lavers et al. (2013), who reported half of the MAP-positive herds in their study had at least one EC-negative test, and that the herds with inconsistent EC results had low apparent within-herd prevalence (aWHP) of MAP infection. The same study reported the sensitivity (Se) of EC was 71% but also demonstrated that Se varied depending upon the aWHP of MAP, such that the Se was relatively low at very low aWHP values (≤2% aWHP), and increased with increasing aWHP (Lavers et al., 2013). The misclassification of EC-positive herds in this study supports previous findings that repeated herd-level testing will maximize the identification of low-prevalence herds in control programs (Kalis et al., 2004; Lavers et al., 2013).

A herd-level generalized estimating equation (GEE) logistic regression model was developed with an exchangeable correlation structure and robust standard errors to evaluate if herd demographics or management factors were associated with herd-level

MAP infection from EC testing. The risk of herds being EC-positive was significantly associated with a number of herd demographic and management characteristics. Herds were more likely to be EC-positive with increasing herd size and if they planned to purchase cattle within the next year. The effect of herd size has also been reported in other studies but reasons for this effect have only been theorized (Wells and Wagner, 2000; Wolf et al., 2015b). Herds were also more likely to be EC-positive with increasing heifer problems, such as pneumonia and mortality, and if the EC sampling was conducted in the summer (July through September) as opposed to the winter or the spring. An effect of season has been observed in previous studies on MAP infection diagnostics but there are inconsistencies as to which season has the highest likelihood of test-positive results. McKenna et al. (2004) found the highest detection of MAP occurred in June, but Laurin et al. (2015) found detection in summer and fall was lower than in winter and spring. Further research to better understand the relationship between season of diagnostic testing and detection of MAP is recommended.

Among AJDI herds, the risk of being EC-positive also differed by province, with herds in NS less likely to be EC-positive than the other three Atlantic provinces. The effect of province was partially expected, as herds in different provinces had different cattle purchasing requirements. In particular, herds in NL purchased almost all of their replacement animals, and as such, had a high risk of bringing JD into their herds. Further investigation into provincial differences in dairy management or purchasing strategies is recommended.

Of the EC-positive herds, 34% (n=42) elected to conduct individual cow MAP infection diagnostics at least once during the study period. On average, the aWHP of

MAP infection within the EC-positive herds was very low at 5.5% [95% confidence interval (CI): 1.8-9.2%]. During design of the AJDI, it was anticipated that a larger number of EC-positive herds would elect to conduct co-funded individual cow testing. This result suggests that instead of test-and-cull strategies, best management practice implementation was prioritized to control JD in the AJDI. This prioritization was appropriate, especially given the very low aWHP that was detected. It would have been difficult to justify the expense of performing cow-level testing for most AJDI EC-positive herds with low aWHP. The apparent prevalence of MAP infection in Atlantic Canada had been previously estimated to be lower than for many of its neighbours (Tiwari et al., 2006; USDA-APHIS-VS-CEAH, 2008; Wolf et al., 2014b).

A mixed effect linear regression model with herd as a random effect was used to determine whether or not cow MAP infection was associated with reduced cow-level 305-day milk production as has been reported (VanLeeuwen et al., 2002). The predictor variables used in the model included: cow MAP infection status, cow lactation number, cow average somatic cell count linear score, and number of cows in the herd's DHI record for the study period. A significant association was detected between 305-day milk production and the latest cow MAP diagnostic test result: test-positive cows produced 682 kg of milk less than test-negative cows.

Findings from this study provide further evidence of the benefit of management practices that decrease the risk of JD introduction onto a farm, including closing the herd or purchasing replacement animals from MAP test-negative herds, and improving calf and heifer management that mitigate the risk of infectious disease transmission within a farm in general.

7.3 Risk assessment and management plan outcomes and adherence measurements

The focus for Chapter 3 was to describe outcomes of the veterinarian-administered RAMPs; specifically, findings of the risk assessments, the consensus management practice recommendations, and the measurements of adherence to the management plans. Perceptions of dairy producers about recommended best management practices that had less than ideal adherence were also examined.

Risk assessment workbooks, described in section 7.1, were used for the RAMP process. The RAMP was semi-quantitative, with high scores indicating high risk of MAP transmission. The RAMP contained 6 risk assessment sections: (1) general JD and biosecurity questions, (2) calving area risk management, (3) pre-weaned heifer risk management, (4) weaned heifer to first calving risk management, (5) dry cow risk management, and (6) lactating cow risk management. Scoring of risk by certified veterinarians was based on observed management practices, along with clarifying information from the producer. Based on the RA, up to 3 priority items were identified, and a consensus was built with the producer on action to be taken.

In this study, 894 RAMPs were conducted by AJDI-certified veterinarians on 457 dairy herds from 2012-2014. JD RA indicated that on average, the existing management practices had moderate potential to spread MAP between and within farms. Overall, JD RA scores were significantly lower for herds that were only EC-negative throughout the study period compared to herds that were EC-positive at least once. A difference in RA score by EC herd categorization was similarly reported by the Alberta Johne's Disease Initiative, which also used a RA that was developed using the Canadian national standards for risk assessment (Wolf et al., 2016).

The sections of the RAs that were apportioned the highest JD risk were the sections that evaluated general JD items and biosecurity and calving areas. Inadequacies in management practices within these sections could be especially detrimental to JD control for AJDI herds. The highest risk for MAP transmission exists for young calves (Windsor and Whittington, 2010) and it is critical to prevent MAP entry into herds that are not yet infected or have very low aWHP of MAP. Indeed, over half of all RAMPs in the AJDI recommended closing the herd or purchasing cattle from only lower risk herd(s). This recommendation was the most frequent top priority when it was a consensus management recommendation. For herds that were unable to cease cattle purchasing, producers were referred to the voluntary registry of EC-negative herds on the AJDI website.

Adherence to best management practices to control JD is necessary for RAMP-based control programs to be successful (Sorge et al., 2010). Three different adherence measures were used in this study, the producers' self-assessed adherence rating (AR-self), the certified veterinarians' adherence rating (AR-vet), and the reduction in RA score between the herds' first and second RAMPs (AR-RA). The level of adherence to the first RAMP that was conducted for all AJDI herds varied depending upon the measure of adherence used. AR-self indicated fair adherence, AR-vet indicated slight adherence and AR-RA showed improvements in JD risk scores that were statistically significant. AR-vet and AR-RA were correlated but AR-self had poor to slight agreement with the other two measures.

Even though the three assessment measures indicated some adherence overall, a substantial proportion of the AJDI herds did not adhere to the consensus recommendations in their first RAMP. Based upon AR-self, EC-positive herds were more than twice as likely to adhere as were EC-negative herds. This result is similar to the relationship previously described between MAP infection status and the likelihood of management improvement on farm (Wolf et al., 2015a). Investigations using herd demographic and management characteristics detected few additional associations with the adherence measures to adequately explain the adherence barriers in the AJDI.

In addition to the adherence measure AR-vet, producers were also asked to identify adherence impediments for any recommendations that the certified veterinarians did not consider appropriately implemented. Many of the impediments documented implied that the producers did not completely approve of the management changes recommended in the RAMP. Reasons for this incomplete acceptance could have been that true consensus on the management changes had not been reached, or that there was communication failure between the veterinarians and the producers during the RAMP. It is possible that deficits in the communication skills of the certified veterinarians impacted the adherence to the RAMP recommendations. Further research is needed to identify factors associated with nonadherence in the AJDI, including evaluation of the communication skills of the certified veterinarians.

7.4 Knowledge, attitudes, beliefs, and behaviours around Johne's disease control

The focus of Chapter 4 was assessing the knowledge, attitudes and beliefs of cow managers in the AJDI herds around JD control using a validated theory that explains people's behaviour. Socio-psychological theories suggest that behaviour is influenced by a complex set of factors, including both internal (e.g., attitude, personality, perception, beliefs, knowledge, learning preferences, skills), and external (e.g., policy, economics, penalties, incentives, input from social referents) factors (Janz and Becker, 1984; Roche et al., 2015; Ritter et al., 2015). Theoretical models have been developed to better understand behaviour, to investigate the effects of socio-psychological variables on decision-making, and to predict deliberate and planned behaviour. One model that has been extensively used in health research is the Theory of Planned Behaviour (TPB) (Ajzen, 1991). According to TPB, when people have the time to plan how they are going to behave, the best predictor for that behaviour is one's intention, which in turn is determined by three things: attitude, subjective norms, and perceived control (Ajzen, 1991). In other words, to predict whether a person intends to do a behaviour, one needs to know whether the person is in favor of doing it (i.e., attitude), how much the person feels social pressure to do it (i.e., subjective norm), and whether the person feels in control of it (i.e., perceived behavioural control) (Francis et al., 2004).

This study used TPB framework to design and administer a questionnaire to elicit and measure behavioural intent and intention determinants of cow managers. Cow managers were considered to be the people who made the animal health decisions for the herds. The aim was to better understand the cow managers' intention to utilize best management practices to control JD within the year following the first RAMP, and to identify behavioural determinants that could be targeted to increase adherence in the AJDI. Behavioural intention was measured using one intention performance statement; specifically, "we use strategies to prevent and control JD on our farm." Attitudes, subjective norms, and perceived behavioural control were all measured using indirect measurement of their beliefs and corresponding evaluations. Behavioural beliefs were measured for three different themes: (1) farm goals that could be negatively impacted by

JD and its best management practices, (2) reasons cows were culled from the herd, and (3) JD and its control. Normative beliefs were assessed by asking about the opinions of the following reference groups towards JD prevention and control: fellow producers, the herd veterinarian, dairy consumers, international dairy industry, and dairy processors. The control beliefs were related to self-reported JD knowledge and effectiveness of JD control strategies. Perceived behavioural control was also measured using direct measurement of the AJDI cow managers' confidence in their capability to implement JD best management practices and possible impediments of time, money and competing herd priorities. Other sections of the questionnaire included intention simulation scenarios, statements to measure JD knowledge and gather sources of JD information, and question to collect demographic information.

A total of 68 cow managers, from AJDI herds who had already done their first RAMP, completed in-person questionnaires from June 2012 to September 2013. On average, the cow managers had moderate positive intent to utilize strategies to prevent and control JD. They held strong positive attitudes towards JD, its prevention and control and moderate positive attitudes towards farm goals and herd culling reasons. The cow managers exhibited moderate knowledge scores about JD and felt a strong amount of social pressure to prevent and control JD from their herd veterinarian and dairy consumers. Nonetheless, they did not have strong confidence in their ability to effectively control JD on their farm. The TPB construct with the highest composite score in this study was attitude towards the control of JD. TPB components with such strength could be considered the most influential constructs and therefore be an intended target for interventions to increase adherence in the AJDI. On the other hand, with such strong attitudes about JD control, there may not be a lot of room for improvement in the strength of this attitude for the average cow manager.

Univariable analyses were used to estimate the impact of targeting specific behavioural determinants on the intent of the cow manager to utilize strategies to control JD in their herd. Of the behavioural determinants, the cow managers' attitudes toward the control of JD and their confidence in their ability to control JD (i.e., perceived behavioural control) were both significantly associated with the intent to utilize control measures. There was also a borderline association between the amount of social pressure felt by the cow managers to control JD and intent. These findings suggest that interventions to improve adherence in the AJDI will be most effective if they include strategies to assist the herd veterinarians to communicate farm-specific aspects of JD control, and to negotiate mutually acceptable plans to implement JD best management practices to prevent the spread of JD between and within herds.

While the behavioural intention measure used did have significant associations with some of the behavioural determinants measured in this study, the quality of this measure as a proxy for cow managers' adherence behaviour was specifically investigated. During questionnaire design, it seemed advantageous to use a single item to measure the behavioural intention score (Francis et al., 2004) and to be able to compare it to the herd's improvement in RAMP scores throughout AJDI participation; however, no correlation was detected between the intention scores and the RAMP improvement scores. The implementation of JD best management practices is a complex behaviour, and the intention to perform this behaviour may have been better captured using multiple items and the generalized intention method. For future research, it may be preferred to use the following three statements to measure this behavioural intention: I expect to use best management practices to prevent and control JD; I want to use best management practices to prevent and control JD; and I intend to use best management practices to prevent and control JD.

The TPB framework has also been used to assess producer behaviour regarding JD control in dairy herds in the Canadian province of Ontario (Roche et al., 2015). Interestingly, similar findings were described about the strengths of the three behavioural determinant constructs, even though the individual items that contributed to the overall determinant scores differed. The similarities in the behavioural determinants between producers in these two different dairy populations suggest that the attitudes and beliefs of the cow managers in the AJDI are not unique. Consequently, the proposal by Roche et al. (2015), to reframe the communication about JD control to be part of a good holistic approach to herd health may effectively influence management changes for herds in Atlantic Canada as well.

By using the TPB in this study, interventions aimed at improving the communication skills of herd veterinarians were identified as possible methods to strengthen behavioural intention determinants and, in turn, behavioural intent. Further research using the TPB alone or in combination with other health behaviour models would be beneficial to identify additional attitude and belief factors that may effectively influence management changes to control JD.

7.5 Risk assessment and management plan satisfaction and knowledge transfer

The focus of Chapter 5 was on the satisfaction of dairy producers with the veterinarian-administered RAMPs, producer knowledge, and knowledge transfer during the RAMP. Satisfaction is considered to be an important outcome in veterinary medicine and there is burgeoning research in this area (Woodcock and Barleggs, 2005; Coe et al., 2010; Shaw et al., 2012; Shaw et al., 2016). There is strong evidence in human medicine studies that patient satisfaction is linked to adherence (Larsen and Rootman, 1976; Bartlett et al., 1984; Bell et al., 2002) and similar evidence is emerging about client adherence in veterinary medicine studies (Wassink et al., 2010; Kanji et al., 2012; Ritter et al., 2019). In addition to adherence, measuring satisfaction in medicine has also been important to evaluate the quality of health care provided (Haya et al., 1993; Sitzia and Wood, 1997; Jackson et al., 2001; Bragadóttir and Reed, 2002), and to isolate and address problems in service delivery (Locker and Dunt, 1978; Jackson et al., 2001). To measure client satisfaction in companion animal practice, two questionnaires have been developed and validated, the Veterinary Service Satisfaction Questionnaire (VSSQ) (Woodcock and Barleggs, 2005) and the Client Satisfaction Questionnaire (CSQ) (Coe et al., 2010). The VSSQ was intended to assess clients' overall satisfaction with small animal veterinary services and the CSQ was intended to measure appointment-specific client satisfaction with veterinary care in companion animal practice (Woodcock and Barleggs, 2005; Coe et al., 2010). A recent study slightly modified the CSQ to be applicable to dairy farmers to elicit their satisfaction with veterinary advisors after herd health and production management farm visits (Ritter et al., 2019). Considering that formal research into client satisfaction in food animal production medicine is so limited, particularly for infectious disease control programs, additional research into producer satisfaction with the RAMP process in the AJDI was warranted.

Objectives for this study were to measure RAMP-specific satisfaction using a modified CSQ, adapted to veterinary-administered RAMPs in the AJDI, and to measure knowledge transfer during the RAMP. The questionnaire included nine RAMP-specific producer satisfaction items, one global RAMP satisfaction item, and 16 questions to assess producer knowledge and knowledge translation about JD, Bovine Viral Diarrhea (BVD) and Bovine Leukosis Virus (BLV) during the RAMP (BVD and BLV used for comparison purposes). Data about the herds' preceding RAMPs (JD herd categorization by EC, RAMP score, and number of RAMPs completed) and production data (where available) were combined with the questionnaire data for statistical analyses. To identify simple associations between the overall satisfaction score and the demographic and herd information variables, univariable analyses were conducted using linear mixed models with random effects at the veterinarian level. To further evaluate associations between the overall satisfaction score and the demographic and herd information variables, a multivariable linear mixed model with random effects at the veterinarian level was conducted.

A total of 133 dairy producers who completed a RAMP in the AJDI from July 2013 to March 2014 (79.6% response rate) answered the questionnaire by telephone. Findings demonstrated that RAMP-specific producer satisfaction was high in the AJDI. High satisfaction has similarly been reported for dairy farmers about their herd veterinarians' communication during herd health visits (Ritter et al., 2019). High RAMP satisfaction was shown using both an overall multi-item satisfaction measure and a global measure. There was a positive correlation detected between the overall satisfaction score and the global satisfaction score. This finding supports construct validity of the adapted

CSQ satisfaction measure. When the CSQ was developed, survey reliability and validity were formally assessed (Coe et al., 2010). Similar assessments of the instrument adapted to dairy production medicine, and to JD control programs, would be beneficial (Ritter, 2019).

Unlike previous satisfaction studies in human and veterinary medicine (Martin et al., 2004; Woodcock and Barleggs, 2005; Coe et al., 2010; Shaw et al., 2012; Ritter et al., 2019), factors that were associated with RAMP-specific producer satisfaction were not detected in this study. Satisfaction results were not found to differ based on EC status or the gender of the producer. Other factors that had been shown to have significant associations with client satisfaction (e.g., client age, client education, length of relationship with the veterinarian, veterinarian communication skill) (Martin et al., 2004; Woodcock and Barleggs, 2005; Coe et al., 2010; Shaw et al., 2012; Ritter et al., 2019) were not available in this study. However, through the use of the multi-item satisfaction measure in this study, problem areas in the veterinarian-administered RAMPs were identified. During the RAMP, certified veterinarians' discussions of costs and the producers' understanding of the management options for JD on their farm were not highly satisfactory. It has been shown in previous research and in Chapter 4 of this thesis that dairy producers are concerned with the overall economic impact of JD, and they have identified financial cost as a key issue to increase their prioritization of JD prevention and control (Sorge et al., 2010). Additionally, considering that the AJDI is a RA-based control program, the appropriate implementation of management practices is essential for success of the initiative.

Knowledge scores and evidence of knowledge transfer in this study were mixed. JD knowledge score indicated moderate knowledge while BVD and BLV knowledge score indicated fair knowledge. BVD knowledge scores were not found to differ based on whether or not the certified veterinarian discussed BVD during the preceding RAMP but BLV knowledge scores were significantly higher among dairy producers that discussed BLV during the preceding RAMP. These problem areas likely represent communication failure between the certified veterinarians and the producers. Improving communication skills of the certified veterinarians would likely enhance knowledge transfer during the RAMP, improve the producers' understanding of JD control options, and encourage client participation, negotiation, and shared decision making for best management practice changes to be implemented on-farm (Shaw et al., 2016). Additional research to investigate factors related to RAMP-specific producer satisfaction would also be beneficial to improve quality of JD control program delivery and adherence in JD control programs.

7.6 Communication skills training and assessment

The focus of Chapter 6 was on communication skills training and assessment for FAPM veterinarians who were part of the AJDI. Skilled communication is a requisite to the practice of effective and compassionate veterinary medicine (Adams and Kurtz, 2017). There is an expanding body of evidence in veterinary medical literature to demonstrate that communication competence is related to more efficient and satisfying consultations for both clients and veterinarians and improved outcomes of care, specifically satisfaction and adherence (American Animal Hospital Association, 2009; Coe et al., 2010; Kanji et al., 2012; Shaw et al., 2012; Adams and Kurtz, 2017; Ritter et al., 2019). Studies in FAPM and the previous chapters of this thesis have shown that communication skills of veterinary practitioners appear to be suboptimal (Jansen, 2010; Cipolla and Zecconi, 2015; Ritter et al., 2018; Ritter et al., 2019). As such, the goals for this study were to assess communication skills of FAPM veterinarians in the AJDI and to develop, implement and assess a communication skills training workshop for the veterinarians.

A communication skills training workshop was held in the winter of 2014 over 1 ½ days (13 hours in total). In human medicine, communication training programs were found to improve communication skills if they lasted for at least one day (Berkhof et al., 2011). The intervention included two interactive lectures (1 hour on the first day and 1 ½ hours on the second day) and small-group training sessions, where each participant spent a minimum of 45 minutes practicing their communication skills with a standardized dairy production client (SC) and received individualized feedback and active coaching. Workshop participants included 20 veterinarians who completed the communication training, 6 coaches who facilitated the small-group training sessions, and 8 retired dairy producers who acted as SCs. Prior to the workshop, 1 ½ days of training were provided to 4 of the 6 workshop coaches who were new to small-group facilitation of communication skills and the 8 SCs. During the workshop, interactive lectures were facilitated by a member of the Faculty of Veterinary Medicine at the University of Calgary (UCVM) who had significant experience in teaching communication skills. The Calgary Cambridge Guides (CCG) was used as a framework for the interventions (Kurtz et al., 2005). The CCG delineates 73 core, evidence-based communication process skills and organizes the medical consultation into a framework of 6 communication domains and objectives (Adams and Kurtz, 2012; Silverman et al., 2013).

The communication skills of the veterinarians were assessed using three different tools: Objective Structured Clinical Exam (OSCE), SC feedback and self-efficacy. One of the primary ways of assessing communication skills of undergraduate students is through an OSCE (Hodges, 2006; Davis et al., 2006; Hecker et al., 2012; Artemiou et al., 2013). During an OSCE, the learner interacts with SCs, who are trained to portray a client's concerns in a standardized manner (Adams and Ladner, 2004; Barton et al., 2006; Artemiou et al. 2014). Pre- and post-intervention OSCEs were designed and used to assess the veterinarians' competence in communication and to evaluate the effectiveness of the communication skills training workshop. For time efficiency, two OSCE tracks were run simultaneously with the same 4 cases being portrayed in each track. The OSCEs were video-recorded and the recordings were rated by 4 independent raters (2 expert rates and 2 novice raters) following the workshop. The raters used an OSCE checklist to score how each communication skill was demonstrated (checklist item scores were totalled and converted to a checklist percentage score) and to give a global rating score for their impression of the participant's overall communication performance. Following each OSCE consultation, the SCs also completed a SC Feedback Form on the participants' communication performance. To the author's knowledge, an OSCE has not been used with communication training for veterinary practitioners.

Self-efficacy questionnaires, which represent an individual's self-evaluation on successfully performing a specified task such as communication skills, is another tool that has frequently been used in human medicine (Ammentorp et al., 2007; Mullan and

Kothe, 2010; Roter et al., 2012; Gulbrandsen et al., 2013). Use of self-efficacy assessment in conjunction with outcome measures, such as an OSCE, has not been reported in veterinary communication skills training. All participants completed a self-efficacy questionnaire before and after the workshop.

Study results showed that prior to training, communication skills of the veterinarians had significant limitations, including skill deficits in communication tasks strongly associated with adherence to veterinary recommendations. Based on the 3 assessment tools, communication skills of participating veterinarians significantly improved with the training provided, including stronger communication process skills that are likely to improve client adherence.

Reliability of the OSCEs, inter-rater agreement and variance components for all the main and interaction effects were assessed using generalizability theory, which accounts for several sources of measurement error (e.g., error due to raters, OSCE station, checklist items, etc.) (Goodwin, 2001). For the reliability studies, all were three-facet fully-crossed designs where each of the 4 raters independently rated the 20 participants in all 4 stations in both OSCE tracks. The participants were nested within 2 tracks (10 participants in each track).

For expert raters, the largest source of variance for both OSCE global scores and OSCE checklist percentage scores was reflective of differences in communication skill development by participating veterinarians. For trained raters, the same was found for OSCE global scores; however, for OSCE percentage scores in the pre-intervention OSCE, the largest source of variance was from rater. This result indicates that significant portions of the differences in OSCE scores from trained raters were due to rater variability and there was likely an issue with rater training.

The within-rater reliability of the OSCEs ranged from 0.26 to 0.78 and varied between pre- and post-intervention OSCEs, OSCE scores, and rater (trained or expert). The acceptable reliability range for education research is 0.60 to 0.80 (Norman et al., 2002). Within-rater reliability was lowest for post-intervention OSCE percentage scores from trained raters and highest for pre-intervention OSCE global scores from expert raters. Considering only 4 OSCE stations were used for this study, within-rater reliability lower than the acceptable range is not unexpected. Two studies that used OSCE assessment of veterinary student communication were also 4-station OSCEs and had similar within-rater reliabilities (Hecker et al., 2012; Artemiou et al., 2013).

The inter-rater reliabilities of the OSCEs in this study followed a similar trend as the within-rater reliabilities. In reliability studies using OSCE percentage scores, trained raters had much lower inter-rater reliabilities than expert raters. This result indicated that rater experience likely had a significant impact on the ability of raters to reliably assess participants using checklist items. Other factors that may alter the degree of rater stringency/leniency include: their expertise, expectation and standards, and ethnicity (Harasym et al., 2008). The inter-rater reliability reported for a study that used OSCE assessment of veterinary student communication was higher than observed in our study (Hecker et al., 2012).

In OSCE studies, there is a perennial issue of rater training (Hecker et al., 2012). Given the difficult nature of assessing communication skills, some papers have concluded that it is important when training on this topic to emphasize communication skills spotting (Hecker et al., 2012) however, other studies have concluded that thorough selection, monitoring and training did not eliminate examiner stringency/leniency effect (McManus et al, 2006). In this study, differences in variance, within-rater reliability and inter-rater reliability between trained and expert raters demonstrates that rater experience likely had a significant impact rater's ability to reliably assess communication skills in an OSCE. Further research into rater training to facilitate a fair assessment of communication skills is recommended.

The preparation, cost, and in-person time required for training, conducting and completing this communication skills training workshop was considerable. Some solo practitioners were unable to attend because they couldn't leave their practice for the length of the workshop, and multi-veterinarian clinics could only send some, rather than all, veterinarians in order to maintain clinic operations. An alternative training format would be to incorporate web-based communication interventions into a communication skills workshop for FAPM veterinarians. Research has found that web-based communication training was an effective communication training method (Roter et al., 2012; Artemiou et al., 2013; Artemiou et al., 2014). Web-based communication training could be a particularly useful tool to introduce communication theory and describe the necessary communication skills prior to the workshop. This would allow more time for participants to practice communication skills during the in-person workshop (using small-group training and video skill-spotting exercises), and would likely lead to less workshop fatigue. Web-based resources could also be useful for continued communication practice and learning after the workshop intervention. While resources needed for this communication skills training workshop were high, it can be justified by creation of a base of coaches, SCs, and training material appropriate for FAPM. This can be used in future communication skills training and assessment programs for students and practitioners in Atlantic Canada.

Based on this study, development and implementation of communication skills training such as face-to-face interactive lectures and small-group training sessions increases the communication competency of FAPM veterinarians. This training would be particularly relevant for those veterinarians involved in infectious disease control programs.

7.7 Research integration and future directions

This research, through description and evaluation of the AJDI and its outcomes, exploration of factors potentially affecting adherence to JD control measures, and development and implementation of communication skills training and assessment for FAPM veterinarians, offered new information to assist in the prevention and control of JD. The research also uncovered more unanswered questions that would benefit from further investigation to enhance the management of this complex infectious disease and mitigate its effect within the dairy industry.

In Chapter 2, patterns of MAP detection using EC differed by season of diagnostic testing and province. AJDI herds were more likely detected as EC-positive if EC sampling was conducted in the summer (July through September) as opposed to the winter or the spring. An effect of season has been observed in previous studies on MAP infection diagnostics but there are inconsistencies as to which season has the highest likelihood of test-positive results. McKenna et al. (2004) found the highest detection of MAP occurred in June but Laurin et al. (2015) found detection in summer and fall was lower than in winter and spring. Further research to better understand the relationship between season of diagnostic testing and detection of MAP is recommended.

The higher likelihood of MAP detection in the province of NL was understandable due to higher cattle purchasing requirements. However, the lower likelihood of MAP detection in NS was not expected. Differences in dairy management or cattle purchasing strategies are not documented for NS compared to the other Atlantic Provinces; therefore, further investigation is needed to explain this observation.

It was clearly demonstrated by this research that FAPM veterinarians practicing in Atlantic Canada are invested in controlling JD in the region and are essential to a successful control program. Participation rates in the AJDI of both veterinarians and herds were strengths in this research. The number of veterinarians who volunteered to undergo advanced training to function as certified AJDI veterinarians exceeded program goals and the majority of farmers who indicated their motivation to participate in the AJDI attributed their participation to their herd veterinarian. The certified veterinarians sampled individual cows for testing, delivered diagnostic test results to producers, performed farm-specific RAMPs annually, assessed adherence to management plan recommendations and indicated impediments to adoption of best management practices. From this research, it was determined that cow managers felt strong social pressure to prevent and control JD from their herd veterinarian and satisfaction with the veterinary-administered RAMP was high. However, adherence ratings signified there were difficulties with the adherence to management plan recommendations for a substantial proportion of AJDI herds.

Adherence with best management practices to control JD is necessary for RA-based control programs to be successful (Sorge et al., 2010). Investigations into adherence in Chapter 3, using herd demographic and management characteristics, detected too few associations with the adherence measures to adequately explain the adherence barriers in the AJDI. Previous studies have identified a number of reasons for nonadherence with on-farm recommendations to control JD in Canadian dairy populations that did not include Atlantic Canada. Sorge et al. (2010) reported that respondents did not believe a change was necessary. Roche (2014) reported that there were both physical resource barriers (i.e., time, money, and infrastructure) and intrinsic barriers (i.e., perceived priority of JD, motivation, and perceived practicality of JD control recommendations) to adoption of on-farm management practices. Further research is needed to confirm why these reasons for nonadherence were not identified in the present study and what the main reasons in this region of Canada were.

Chapter 4 described additional efforts to identify factors associated with adherence in the AJDI, using TPB framework to assess knowledge, attitudes and beliefs of cow managers in the AJDI. While the behavioural intention measure did have significant associations with some of the behavioural determinants measured in this study, the quality of this measure as a proxy for cow managers' adherence behaviour was questioned. For future research, it may be preferred to use the following three statements to measure this behavioural intention: I expect to use best management practices to prevent and control JD; I want to use best management practices to prevent and control JD; and I intend to use best management practices to prevent and control JD. Further research using TPB in a larger proportion of AJDI herds, or in combination with other health behaviour models (e.g., HBM) (Roche et al., 2015; Ritter et al., 2017), may also be beneficial to identify additional attitude and belief factors that may effectively influence management changes to control JD.

Chapter 5 measured RAMP-specific satisfaction in the AJDI through the adaption of a questionnaire developed to measure client satisfaction in companion animal practice, the CSQ (Coe et al., 2010). Satisfaction is considered an important outcome of veterinary medical encounters and is associated with adherence to health care regimes and recommendations (Wassink et al., 2010; Kanji et al., 2012; Ritter et al., 2019). Findings demonstrated that RAMP-specific producer satisfaction was high in the AJDI, which was supported by similar findings in satisfaction research for dairy farmers in other parts of Canada about their herd veterinarians' communication during herd health visits (Ritter et al., 2019). Unlike previous satisfaction studies in human and veterinary medicine (Martin et al., 2004; Woodcock and Barleggs, 2005; Coe et al., 2010; Shaw et al., 2012; Ritter et al., 2019), factors that influenced RAMP-specific producer satisfaction were not detected in this study. Additional research to investigate factors related to RAMP-specific producer satisfaction would be beneficial to improve quality and adherence in JD control programs. When the CSQ was developed for companion animal practice, survey reliability and validity were formally assessed (Coe et al., 2010). Future research to conduct similar reliability and validity assessments of the instrument adapted to dairy production medicine, and to JD control programs would also be beneficial (Ritter et al., 2019).

For RAMP recommendations where veterinary-assessed adherence ratings indicated nonadherence, producers frequently indicated they did not approve of the management plan recommendation (Chapter 3). Some producers also identified a satisfaction problem during veterinary-administered RAMPs resulting from a lack of understanding of management options to control Johne's disease on their farm (Chapter 5). This suggests that when management options were being chosen in RAMPs, producers' perspectives were not adequately understood or their opinions and preferences were not sufficiently incorporated into the decision making process. Communication failure between the veterinarians and producers could have contributed to these problems.

Skilled communication is a requisite to the practice of effective and compassionate veterinary medicine and is related to improved outcomes of care, specifically satisfaction and adherence (American Animal Hospital Association, 2009; Coe et al., 2010; Kanji et al., 2012; Shaw et al., 2012; Adams and Kurtz, 2017; Ritter et al., 2019). To evaluate and address potential limitations in communication skills of AJDI certified veterinarians, a communication skills training and assessment workshop specific to FAPM veterinarians was developed and implemented and is described in Chapter 6. This study confirmed that communication skills of participating FAPM veterinarians had limitations and communication skills significantly improved following intervention. Issues were identified with the ability of trained raters to reliably assess communication skills in this study. In addition, resources needed for this workshop were high. Research into alternative training formats to incorporate less resource intense interventions into communication skills training for FAPM veterinarians is recommended (e.g., incorporation of web-based communication interventions). Further research into rater training and preparation to facilitate a fair assessment of communication skills would also be beneficial.

Research is ongoing into the control of endemic pathogens and the adoption of best management practices to prevent their spread between and within farms. Based on a literature review, Ritter et al. (2017) recommended that when attempting to facilitate the development and implementation of voluntary prevention and control programs for livestock diseases, certain approaches, such as participatory group learning or individual communication, are preferred. Based on the findings from Chapter 6, communication skills training was deemed to be required for FAPM veterinarians to improve their communication and their ability to influence adherence among dairy producers. Future research that combines efforts to improve communication skills of farm advisors with participatory approaches recommended by Ritter et al. (2017) may provide the necessary formula to successfully control infectious diseases such as JD.

7.8 References

Abubakar, I., D. Myhill, S. H. Aliyu and P. R. Hunter. 2008. Detection of *Mycobacterium avium* subspecies *paratuberculosis* from patients with Crohn's disease using nucleic acid-based techniques: A systematic review and meta-analysis. Inflamm. Bowel Dis. 14(3):401-410.

Adams, C. L. and L. Ladner. 2004. Implementing a simulated client program: Bridging the gap between theory and practice. J. Vet. Med. Educ. 31(2):138-145.

Adams, C. L. and S. M. Kurtz. 2017. Skills for Communicating in Veterinary Medicine. Dewpoint Publishing, Parsippany, NJ, USA.

Adams, C. L. and S. Kurtz. 2012. Coaching and feedback: Enhancing communication teaching and learning in veterinary practice settings. J. Vet. Med. Educ. 39:217-228.

Ajzen, I. 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50:179-211.

American Animal Hospital Association. 2009. Compliance: Taking Quality Care to the Next Level: A Report of the 2009 AAHA Compliance Follow-Up Study. AAHA Press, Lakewood, Colorado, USA.

Ammentorp, J., S. Sabroe, P. Kofoed and J. Mainz. 2007. The effect of training in communication skills on medical doctors' and nurses' self-efficacy. A randomized controlled trial. Patient Educ. Couns. 66:270-277.

Arango-Sabogal, J., J. Pare, O. Labrecque, G. Cote, J. P. Roy, S. Buczinski, V. Wellemans and G. Fecteau. 2017. Incidence of fecal excretion of *Mycobacterium avium* subspecies *paratuberculosis* in dairy cows before and after the enrolment in the Quebec voluntary program. Prev. Vet. Med. 148:94-105.

Artemiou, E., C. L. Adams, L. Toews, C. Violato and J. B. Coe. 2014. Informing web-based communication curricula in veterinary education: A systematic review of web-based methods used for teaching and assessing clinical communication in medical education. J Vet Med. Educ. 41:44-54.

Artemiou, E., C. L. Adams, A. Vallevand, C. Violato and K. G. Hecker. 2013. Measuring the effectiveness of small-group and web-based training methods in teaching clinical communication: A case comparison study. J. Vet. Med. Educ. 40:242-251.

Barkema, H. W., S. Hendrick, J. M. Buck, S. Ghosh, G. G. Kaplan and K. P. Rioux. 2011. Crohn's disease in humans and Johne's disease in cattle - linked diseases?. Zoonotic Pathogens in the Food Chain. D. O. Krause and S. Hendrick eds. CAB International, Cambridge, MA, USA.

Barkema, H. W., J. W. Hesselink, S. L. B. McKenna, G. Benedictus and H. Groenendaal. 2010. Global prevalence and economics of infection with *Mycobacterium avium* subspecies *paratuberculosis* in ruminants. Paratuberculosis: Organism, Disease, Control. M. Behr and D. M. Collins eds. CAB International, Boston, MA, USA.

Barkema, H. W. 2018. Lessons learned from the Canadian Johne's disease programs. WCDS Advances in Dairy Technology. 30:309-318.

Barker, R. A., H. W. Barkema, G. Fecteau, G. K. Keefe and D. F. Kelton. 2012. Johne's Disease Control in Canada - Coordinated Nationally - Delivered Provincially. Proc. 3rd ParaTB Forum, Sydney, Australia. 45-51.

Bartlett, E. E., M. Grayson, R. Barker, D. M. Levine, A. Golden and S. Libber. 1984. The effects of physician communications skills on patient satisfaction; recall, and adherence. J. Chronic Dis. 37:755-764.

Barton, K., C. D. Cunningham, G. T. Jones and P. Maharg. 2006. Valuing what clients think: standardized clients and the assessment of communicative competence. Clinical Law Review. 13(1):1-65

Bell, R. A., R. L. Kravitz, D. Thom, E. Krupat and R. Azari. 2002. Unmet expectations for care and the patient-physician relationship. J. Gen. Intern. Med. 17(11):817-24.

Berkhof, M., H. J. van Rijssen, A. J. M. Schellart, J. R. Anema and d. B. van. 2011. Review article: Effective training strategies for teaching communication skills to physicians: An overview of systematic reviews. Patient Educ. Couns. 84:152-162.

Bragadóttir, H. and D. Reed. 2002. Psychometric instrument evaluation: The pediatric family satisfaction questionnaire. Pediatr. Nurs. 28:475-484.

Chi, J., J. A. VanLeeuwen, A. Weersink and G. P. Keefe. 2002. Direct production losses and treatment costs from bovine viral diarrhoea virus, bovine leukosis virus, *Mycobacterium avium* subspecies *paratuberculosis*, and Neospora caninum. Prev. Vet. Med. 55:137-153.

Cipolla, M. and A. Zecconi. 2015. Short communication: Study on veterinarian communication skills preferred and perceived by dairy farmers. Res. Vet. Sci. 99:60-62.

Coe, J. B., C. L. Adams, K. Eva, S. Desmarais and B. N. Bonnett. 2010. Development and validation of an instrument for measuring appointment-specific client satisfaction in companion-animal practice. Prev. Vet. Med. 93:201-210.

Collins, M. T., V. Eggleston and E. J. B. Manning. 2010. Successful control of Johne's disease in nine dairy herds: Results of a six-year field trial. J. Dairy Sci. 93:1638-1643.

Davis, M. H., G. G. Ponnamperuma, S. McAleer and V. H. M. Dale. 2006. The objective structured clinical examination (OSCE) as a determinant of veterinary clinical skills. J. Vet. Med. Educ. 33:578-587.

Fecteau, M. E. and R. H. Whitlock. 2011. Treatment and chemoprophylaxis for paratuberculosis. Vet. Clin. North Am. Food Anim. Pract. 27:547-557.

Francis, J. J., M. P. Eccles, M. Johnston, A. Walker, J. Grimshaw, R. Foy, E. F. S. Kaner, L. Smith and D. Bonetti. 2004. Constructing Questionnaires Based on the Theory of Planned Behaviour:A Manual for Health Services Researchers. University of Newcastle, United Kingdom, Europe.

Goodwin, L. D. 2001. Interrater agreement and reliability. Meas. Phys. Educ. Exerc. Sci. 5:13-34

Groenendaal, H., M. Nielen and J. W. Hesselink. 2003. Development of the Dutch Johne's disease control program supported by a simulation model. Prev. Vet. Med. 60:69-90.

Gulbrandsen, P., B. F. Jensen, A. Finset and D. Blanch-Hartigan. 2013. Long-term effect of communication training on the relationship between physicians' self-efficacy and performance. Patient Educ. Couns. 91:180-185.

Harasym, P. H., W. Woloschuk and L. Cunning. 2008. Undesired variance due to examiner stringency/leniency effect in communication skill scores assessed in OSCEs. Adv. Health Sci. Educ. Theory Pract. 13(5):617-62.

Haya R., R., G. Barbara, R. William H., K. Mark, M. Colleen A. and W. John E. 1993. Patients' ratings of outpatient visits in different practice settings: Results from the medical outcomes study. JAMA. 270(7):835-840.

Hecker, K. G., C. L. Adams and J. B. Coe. 2012. Assessment of first-year veterinary students' communication skills using an objective structured clinical examination: The importance of context. J. Vet. Med. Educ. 39:304-310.

Hodges, B. D. 2006. The objective structured clinical examination: Three decades of development. J. Vet. Med. Educ. 33:571-577.

Jackson, J. L., J. Chamberlin and K. Kroenke. 2001. Predictors of patient satisfaction. Soc. Sci. Med. 52:609-620.

Jansen, J. 2010. Mastitis and Farmer Mindset: Towards Effective Communication Strategies to Improve Udder Health Management on Dutch Dairy Farms. PhD Thesis. Wageningen University, Wageningen, Netherlands.

Janz, N. K. and M. H. Becker. 1984. The health belief model: A decade later. Health Educ. Q. 11:1-47.

Kalis, C. H. J., M. T. Collins, H. W. Barkema and J. W. Hesselink. 2004. Certification of herds as free of *Mycobacterium paratuberculosis* infection: Actual pooled faecal results versus certification model predictions. Prev. Vet. Med. 65:189-204.

Kanji, N., J. B. Coe, C. L. Adams and J. R. Shaw. 2012. Effect of veterinarian-client-patient interactions on client adherence to dentistry and surgery recommendations in companion-animal practice. J. Am. Vet. Med. Assoc. 240:427-436.

Kennedy, D. J. and M. B. Allworth. 2000. Progress in national control and assurance programs for bovine Johne's disease in Australia. Vet. Microbiol. 77:443-451.

Kurtz, S. M., J. Silverman and J. Draper. 2005. Teaching and Learning Communication Skills in Medicine. 2nd ed., Radcliffe Publishing Ltd. Abingdon, UK.

Larsen, D. E. and I. Rootman. 1976. Physician role performance and patient satisfaction. Soc. Sci. Med. 10:29-32.

Laurin, E. L., M. Chaffer, J. T. McClure, S. L. B. McKenna and G. P. Keefe. 2015. The association of detection method, season, and lactation stage on identification of fecal shedding in *Mycobacterium avium* subspecies *paratuberculosis* infectious dairy cows. J. Dairy Sci. 98:211-220.

Lavers, C. J., S. L. B. McKenna, I. R. Dohoo, H. W. Barkema and G. P. Keefe. 2013. Evaluation of environmental fecal culture for *Mycobacterium avium* subspecies *paratuberculosis* detection in dairy herds and association with apparent within-herd prevalence. Can. Vet. J. 54:1053-1060.

Locker, D. and D. Dunt. 1978. Theoretical and methodological issues in sociological studies of consumer satisfaction with medical care. Soc. Sci. Med. 12:283-292.

Martin, F., K. L. Ruby, T. M. Deking and A. E. Taunton. 2004. Factors associated with client, staff, and student satisfaction regarding small animal euthanasia procedures at a veterinary teaching hospital. J. Am. Vet. Med. Assoc. 224:1774-1779.

McAloon, C. G., S. Roche, C. Ritter, H. W. Barkema, P. Whyte, S. J. More, L. O'Grady, M. J. Green and M. L. Doherty. 2019. A review of paratuberculosis in dairy herds - Part 2: On-farm control. Vet. J. 246:54-58.

McAloon, C. G., P. Whyte, S. J. More, M. J. Green, L. O'Grady, A. Garcia and M. L. Doherty. 2015. The effect of paratuberculosis on milk yield: A systematic review and meta-analysis. J. Dairy Sci. 99:1449-1460.

McManus, I. C., M. Thompson and J. Mollon. 2006. Assessment of examiner leniency and stringency ('hawk-dove effect') in the MRCP(UK) clinical examination (PACES) using multi-facet rasch modelling. BMC Med. Educ. 6:42

McKenna, S. L. B., G. P. Keefe, H. W. Barkema, J. McClure, J. A. VanLeeuwen, P. Hanna and D. C. Sockett. 2004. Cow-level prevalence of paratuberculosis in culled dairy cows in Atlantic Canada and Maine. J. Dairy Sci. 87:3770-3777.

McKenna, S. L. B., G. P. Keefe, A. Tiwari, J. VanLeeuwen and H. W. Barkema. 2006. Johne's disease in Canada part II: Disease impacts, risk factors, and control programs for dairy producers. Can. Vet. J. 47:1089-1099.

Mullan, B. A. and E. J. Kothe. 2010. Evaluating a nursing communication skills training course: The relationships between self-rated ability, satisfaction, and actual performance. Nurse Educ. Pract. 10:374-378.

Naser, S. A., G. Ghobrial, C. Romero and J. F. Valentine. 2004. Culture of *Mycobacterium avium* subspecies *paratuberculosis* from the blood of patients with Crohn's disease. Lancet. 364(9439):1039-1044.

Nielsen, S. S. 2007. Danish control programme for bovine paratuberculosis. Cattle Pract. 15:161-168.

Nielsen, S. S. and N. Toft. 2008. Ante mortem diagnosis of paratuberculosis: A review of accuracies of ELISA, interferon-γ assay and faecal culture techniques. Vet. Microbiol. 129:217-235.

Norman, G. R., C. Vleuten and D. Newble. 2002. International Handbook of Research in Medical Education. Norman, G. R., C. P. M. Van Der Vleuten, D. I. Newble eds. Kluwer Academic Publishers, Boston, MA, USA.

Patton, E. A. 2011. Paratuberculosis vaccination. Vet. Clin. North Am. Food Anim. Pract. 27:573-580.

Pieper, L., U. S. Sorge, T. J. DeVries, A. Godkin, K. Lissemore and D. F. Kelton. 2015. Evaluation of the Johne's disease risk assessment and management plan on dairy farms in Ontario. J. Dairy Sci. 98(10):6792-6800.

Rasmussen, P., H. W. Barkema, S. Mason, E. Beaulieu and D. C. Hall. 2020. Economic losses due to Johne's disease (paratuberculosis) in dairy cattle. J. Dairy Sci. 104:3123-3143.

Ridge, S. E., C. Heuer, N. Cogger, A. Heck, S. Moor, I. M. Baker and S. Vaughan. 2010. Herd management practices and the transmission of Johne's disease within infected dairy herds in Victoria, Australia. Prev. Vet. Med. 95:186-197.

Ritter, C., G. P. S. Kwong, R. Wolf, C. Pickel, M. Slomp, J. Flaig, S. Mason, C. L. Adams, D. F. Kelton, J. Jansen, J. De Buck and H. W. Barkema. 2015. Factors associated with participation of Alberta dairy farmers in a voluntary, management-based Johne's disease control program. J. Dairy Sci. 98(11):7831-7845.

Ritter, C., C. L. Adams, D. F. Kelton and H. W. Barkema. 2019. Factors associated with dairy farmers' satisfaction and preparedness to adopt recommendations after veterinary herd health visits. J. Dairy Sci. 102(5):4280-4293.

Ritter, C., C. L. Adams, D. F. Kelton and H. W. Barkema. 2018. Clinical communication patterns of veterinary practitioners during dairy herd health and production management farm visits. J. Dairy Sci. 101(11):10337-10350.

Ritter, C., J. Jansen, S. Roche, D. F. Kelton, C. L. Adams, K. Orsel, R. J. Erskine, G. Benedictus, T. J. G. M. Lam and H. W. Barkema. 2017. Invited review: Determinants of farmers' adoption of management-based strategies for infectious disease prevention and control. J. Dairy Sci. 100(5):3329-3347.

Roche, S. M., A. Jones-Bitton, M. Meehan, M. Von Massow and D. F. Kelton. 2015. Evaluating the effect of focus farms on Ontario dairy producers' knowledge, attitudes, and behavior toward control of Johne's disease. J. Dairy Sci. 98:5222-5240.

Roche, S. 2014. Investigating the role of agricultural extension in influencing Ontario dairy producer behaviour for Johne's disease control. PhD Thesis. Department of Population Medicine. University of Guelph, Ontario, Canada.

Roter, D. L., R. Wexler, P. Naragon, B. Forrest, J. Dees, A. Almodovar and J. Wood. 2012. The impact of patient and physician computer mediated communication skill training on reported communication and patient satisfaction. Patient Educ. Couns. 88:406-413.

Shaw, J. R., C. L. Adams, B. N. Bonnett, S. Larson and D. L. Roter. 2012. Veterinarian satisfaction with companion animal visits. J. Am. Vet. Med. Assoc. 240:832-841.

Shaw, J. R., G. E. Barley, K. Broadfoot, A. E. Hill and D. L. Roter. 2016. Outcomes assessment of on-site communication skills education in a companion animal practice. J. Am. Vet. Med. Assoc. 249:419-432.

Silverman, J., S. M. Kurtz and J. Draper. 2013. Skills for Communicating with Patients. 3rd ed. CRC Press, Taylor & Francis Group. Boca Raton, Florida, USA.

Sitzia, J. and N. Wood. 1997. Patient satisfaction: A review of issues and concepts. Soc. Sci. Med. 45:1829-1843.

Sorge, U., D. Kelton, K. Lissemore, A. Godkin, S. Hendrick and S. Wells. 2010. Attitudes of Canadian dairy farmers toward a voluntary Johne's disease control program. J. Dairy Sci. 93:1491-1499.

Sweeney, R. W., M. T. Collins, A. P. Koets, S. M. McGuirk and A. J. Roussel. 2012. Paratuberculosis (Johne's disease) in cattle and other susceptible species. J. Vet. Intern. Med. 26(6):1239-1250.

Tiwari, A., J. A. VanLeeuwen, S. L. B. McKenna, G. P. Keefe and H. W. Barkema. 2006. Johne's disease in Canada Part I: Clinical symptoms, pathophysiology, diagnosis, and prevalence in dairy herds. Can. Vet. J. 47:874-882.

USDA-APHIS-VS-CEAH, 2008. Johne's disease on US dairies, 1991-2007. Accessed June 11. 2021. www.aphis.usda.gov/animal_health/nahms/dairy/downloads/dairy07/Dairy07_is_Johnes_1.pdf.

VanLeeuwen, J. A., G. P. Keefe and A. Tiwari. 2002. Seroprevalence and productivity effects of infection with bovine leukemia virus, *Mycobacterium avium* subspecies *paratuberculosis*, and Neospora caninum in Maritime Canadian dairy cattle. Bov. Pract. 36:86-91.

Wassink, G. J., T. R. N. George, J. Kaler and L. E. Green. 2010. Footrot and interdigital dermatitis in sheep: Farmer satisfaction with current management, their ideal management and sources used to adopt new strategies. Prev. Vet. Med. 96:65-73.

Wells, S. J. and B. A. Wagner. 2000. Herd-level risk factors for infection with *Mycobacterium paratuberculosis* in US dairies and association between familiarity of the herd manager with the disease or prior diagnosis of the disease in that herd and use of preventive measures. J. Am. Vet. Med. Assoc. 216:1450-1457.

Whitlock, R. H. 2010. Paratuberculosis control measures in the USA. Paratuberculosis: Organism, Disease, Control. M. Behr and D. M. Collins eds. CAB International, Boston, MA, USA.

Windsor, P. A. and R. J. Whittington. 2010. Evidence for age susceptibility of cattle to Johne's disease. Veterinary Journal. 184:37-44.

Wolf, R., H. W. Barkema, J. DeBuck and K. Orsel. 2016. Dairy farms testing positive for M*ycobacterium avium* ssp. *paratuberculosis* have poorer hygiene practices and are less cautious when purchasing cattle than test-negative herds. J. Dairy Sci. 99:1-11.

Wolf, R., H. W. Barkema, J. De Buck and K. Orsel. 2015a. Factors affecting management changes on farms participating in a Johne's disease control program. J. Dairy Sci. 98:7784-7796.

Wolf, R., H. W. Barkema, J. De Buck and K. Orsel. 2015b. Sampling location, herd size, and season influence *Mycobacterium avium* subspecies *paratuberculosis* environmental culture results. J. Dairy Sci. 98:275-287.

Wolf, R., H. W. Barkema, J. De Buck, M. Slomp, J. Flaig, D. Haupstein, C. Pickel and K. Orsel. 2014b. High herd-level prevalence of *Mycobacterium avium* subspecies *paratuberculosis* in Western Canadian dairy farms, based on environmental sampling. J. Dairy Sci. 97:6250-6259.

Wolf, R., F. Clement, H. W. Barkema and K. Orsel. 2014a. Economic evaluation of participation in a voluntary Johne’s disease prevention and control program from a farmer's perspective - The Alberta Johne’s Disease Initiative. J. Dairy Sci. 97:2822-2834.

Woodcock, A. and D. Barleggs. 2005. Development and psychometric validation of the veterinary service satisfaction questionnaire (VSSQ). J. Vet. Med. A Physiol. Pathol. Clin. Med. 52(1):26-38.

Wraight, M. D., J. McNeil, D. S. Beggs, R. K. Greenall, T. B. Humphris, R. J. Irwin, S. P. Jagoe, A. Jemmeson, W. F. Morgan, P. Brightling, G. A. Anderson and P. D. Mansell. 2000. Compliance of Victorian dairy farmers with current calf rearing recommendations for control of Johne’s disease. Vet. Microbiol. 77(3-4):429-442.

APPENDIX A – CHAPTER 2

A.1 Environmental culture sampling protocol

For each herd categorization, six mixed manure samples were collected from prescribed locations by trained AJDI technical staff, including two samples from manure storage areas and 4 samples from mature cow concentration areas. Manure storage samples were collected from the liquid manure storage or the manure pile. If these sites were unavailable, the samples were collected from the site of manure exit from the barn (reception pit or barn cleaner boom) or from the manure spreader. The cow concentration sample collection protocol depended upon type of cow housing. In free-stall barns, 2 samples were collected from each the cross-over alleys and the area adjacent to waterer or feed stations. If the waterer or feed stations were located in cross-over alleys, these sites were excluded and 1 sample was collected from each the sick cow pen and the alley floor immediately behind the stalls. If less than 6 sick cows had been in the sick cow pen since it was cleaned, this site was excluded and an additional sample was collected from the cross-over alleys. In tie-stall barns, 1 sample was collected from the sick cow pen and 3 samples were collected from the manure gutters (corners, crevices, turn wheels, and paddle tips of stable-cleaners). If less than 6 sick cows had been in the sick cow pen since it was cleaned, this site was excluded and an additional sample was collected from the manure gutters. In bedded-pack barns, 2 samples were collected from the area adjacent to waterer and feed stations and 1 sample was collected from each the pack holding area and the sick cow pen. If the pack holding area was cleaned daily, this site was excluded and 1 sample was collected from the manure pack. If less than 6 sick cows had been in the sick cow pen since it was cleaned, this site was excluded and 1 sample was collected from the manure pack (if not already collected) or an additional sample was collected from the area adjacent to the waterer and feed stations. To create the cow concentration, manure pile and manure spreader samples, 8 subsamples were collected. Four subsamples were collected to create the liquid manure storage and the manure exit from barn samples. Subsamples from each sample location were initially collected into a clean, disposable paper bowl. Once the complete number of subsamples had been collected, the sample was thoroughly mixed and a 50-100ml portion of the mixed sample was placed into a clean, labelled specimen container. Each sample was collected using clean latex or nitrile gloves and clean plastic sleeves. Samples were kept cool during transport to the laboratory.

A.2 Environmental culture questionnaire structure

The questionnaires were developed in consultation with veterinarians specialized in dairy production medicine. The first year EC questionnaire differed from the EC questionnaire used for the second and third EC. The questionnaires consisted of 15 or 19 questions related to topics such as herd size and type of housing, heifer inventory and health, disease importance rankings, future herd plans, and an evaluation of the AJDI experience.

A.3 Environmental Culture Questionnaires

A.3.1 Entry Survey (Year 1 Environmental Culture Survey)

Owner Name:
Farm Name:
Address:
Phone
Fax:
Email:
AJDI Johne's Certified Veterinarian:

Johne's Disease Knowledge Base and Attitudes:

1. How much knowledge do you have about Johne's Disease (JD)? Please circle one:
   I had never heard of JD before applying for the program
   I have heard other producers discussing JD
   I have seen information about JD in the media (i.e. newsletters, magazines etc.)
   I actively sought out information about JD (i.e. read journal articles, internet searches etc.)
   I discussed JD control with my veterinarian

2. How did you hear about the Atlantic Johne's Disease Initiative (AJDI)? Circle all that apply:

   Fellow Producer(s)
   Media Reports (i.e. newsletters, magazines etc.)
   Mail Out Information from AJDI
   AJDI Website
   Own Veterinarian

3. What motivated you to volunteer to participate in the AJDI? Please circle one:

   Fellow Producer(s)
   Media Reports
   Mail Out Information from AJDI
   AJDI Website
   Own Veterinarian
   Other:

4. AJDI is a voluntary long-term farm strategy to reduce JD.

   Do you think that there should be a national program for JD?
   Yes No

   If Yes, do you think this program should be (please circle one):
   Voluntary Mandatory

General Herd Information:

5. Herd Size Today (please estimate numbers):

# lactating cows	_____	# heifers 12 months to calving	_____
# dry cows	_____	# bull calves	_____
# 0-6 month old heifers	_____	# breeding bulls	_____
# 7-12 month old heifers	_____		

6. Herd Production:

   Volume of milk shipped last shipment __________ (litres)

7. Barn Characteristics:

   a) Housing for LACTATING Cows (please circle one):

      Free-stall Tie-stall Bedded Pack*

   * Bedded pack is when the cattle are in the milking area (tie-stall or parlour) for <6hrs and have access to a bedded pack

   b) Housing for DRY cows (please circle all that apply):

      Free-stall Tie-stall Bedded pack

   c) Location of LACTATING cows in summer:

      Percent of time inside _____
      Percent of time outside in yard** _____
      Percent of time on pasture*** _____

   ** Yard is when there is not substantial nutrition from pasture (ration does not change for more than 6 weeks because animals go outdoors)

   *** Pasture is when the ration changes for greater than 6 weeks because they do receive substantial nutrition from pasture

d) Location of LACTATING cows in winter:

Percent of time inside _____
Percent of time outside in yard _____

8. Water source for cows (please circle all that apply):

Well Water (Municipal) | Pond/Reservoir | City Water

Calf Information:

9. What is the total number of heifer calves born in the last 6 months? _____

Of these heifer calves, what is the:

a) Number of deaths in calves: >12 hours to 7 days of age _____
Between 7 days to 1 month of age _____
Between 1 month to 4 months of age _____

b) Number of scouring calves (whether treated or not) _____

c) Number of calves with pneumonia (whether treated or not) _____

General Herd Health Information:

10. Please rank, in order of importance, the herd disease concerns that are experienced on your farm (ranking of 1 is considered most important):

Mastitis _____
JD _____
Lameness including Strawberry Foot Rot _____
Retained Placenta and Uterine Infections _____
DA (twisted stomach) and ketosis (off feed cows) _____
Other (please describe below) _____

____

11. Do you administer Rumensin to the cattle? Yes No

If Yes, to which animals and in what form? (circle all that apply):

Lactating cows	Feed Premix	Boluses
Dry cows	Feed Premix	Boluses
Heifers	Feed Premix	Boluses

12. Before you buy an animal, do you ask about any of the following?

Seller's herd, general disease history?	Yes	No
Seller's herd, bulk tank SCC?	Yes	No
Seller's herd, cow SCC?	Yes	No
Seller's herd, vaccination history?	Yes	No
Seller's herd, status for JD?	Yes	No
Seller's herd, the cow's status for JD?	Yes	No

Future Farm Plans:

13. Do you plan to purchase animals within the next year? Yes No

If Yes, from which group(s) do you plan to purchase? (circle all that apply):

Calves Heifers Cows Bulls (herd sires)

14. What is your plan for the next 5 years?

Maintain herd size	Yes	No
Increase herd size >10% but <25%	Yes	No
Increase herd size >25%	Yes	No
Not be farming	Yes	No

15. What is your plan for the next 10 years?

Maintain herd size	Yes	No
Increase herd size >10% but <25%	Yes	No
Increase herd size >25%	Yes	No
Not be farming	Yes	No

A.3.2 Environmental Culture Survey for Years 2 and 3

Owner Name:
Farm Name:
Address:
Phone
Fax:
Email:
AJDI Johne's Certified Veterinarian:

Should the Environmental Culture of your farm be negative, do you wish to be listed on the register of Environmental Culture Negative Herds?

Yes **No**

Signature: ____

Section 1: This first section is to gather updated information on your herd and cow facilities.

16. Herd Size Today (please estimate numbers):

# lactating cows	_____	# heifers 12 months to calving	_____
# dry cows	_____	# bull calves	_____
# 0-6 month old heifers	_____	# breeding bulls	_____
# 7-12 month old heifers	_____		

17. Volume of last milk shipment in liters: ______

18. In the past year, have there been changes in the cow facilities or the time cows spend in the barn versus outside (circle one)?
Yes No

If No, please skip to question 4.

b) Housing for LACTATING Cows (please circle one):
Free-stall
Tie-stall
Bedded Pack*

c) Housing for DRY cows (please circle all that apply):
Free-stall
Tie-stall
Bedded pack*

* Bedded pack is when the cattle are in the milking area (tie-stall or parlour) for <6hrs and have access to a bedded pack.

d) Location of LACTATING cows in summer:
Percent of time inside ______
Percent of time outside in yard** ______
Percent of time on pasture*** ______

e) Location of LACTATING cows in winter:
Percent of time inside ______
Percent of time outside in yard*** ______

** Yard is when there is not substantial nutrition from pasture (ration does not change for more than 6 weeks because animals go outdoors)	*** Pasture is when the ration changes for greater than 6 weeks because they do receive substantial nutrition from pasture

19. Water source for cows (please circle all that apply):

Well Water   Pond/Reservoir/SpringCity Water (Municipal)

20. What is the total number of heifer calves born in the last 6 months? _____

Of these heifer calves, what is the:

a) Number of deaths in calves: >12 hours to 7 days of age _____
Between 7 days to 1 month of age _____
Between 1 month to 4 months of age _____

b) Number of scouring calves (whether treated or not) _____

c) Number of calves with pneumonia (whether treated or not) _____

Section 2: This purpose of this section is to describe herd health and management.

21. Do you administer Rumensin® (monensin) to the cattle?

Yes No Don't Know

If Yes, to which animals and in what form (circle all that apply):

Lactating cows	Feed Premix	Boluses	Pressed Block
Dry cows	Feed Premix	Boluses	Pressed Block
Heifers	Feed Premix	Boluses	Pressed Block

22. Please rank the following disease concerns in order of importance to your farm: **Rank of 1 represents the most important disease concern.**

Mastitis	______
Johne's Disease	______
Lameness (including Strawberry Foot Rot)	______
Retained Placenta and Uterine Infections	______
Off Feed Cows (e.g. DA = twisted stomach, ketosis, etc.)	______
Other (please describe on line below)	______

____

23. Do you plan to purchase cattle within the next year? Yes No

If No, please skip to question 9.

b) From which group(s) do you plan to purchase (please circle all that apply):

Calves Heifers Cows Bulls (herd sires)

c) Before you buy an animal, do you ask about any of the following?

General disease history of seller's herd	Yes	No
Bulk tank somatic cell count (SCC) of seller's herd	Yes	No
The cow's somatic cell count	Yes	No
Vaccination history of the seller's herd	Yes	No
Johne's disease status of the seller's herd	Yes	No
The cow's Johne's disease status	Yes	No

9. Within the next 5 years, what are your herd size goals (circle one):

    Decrease
    Maintain
    Increase ≤10%
    Increase >10% but <25%
    Increase >25%

10. Within the next 10 years, what are your herd size goals (circle one):

    Decrease
    Maintain
    Increase ≤10%
    Increase >10% but <25%
    Increase >25%

Section 3: This final section is to evaluate your experience with the AJDI.

11. Completing the risk assessment with our certified veterinarian was easy.

    Completely disagree 1 2 3 4 5 6 7 Completely agree

12. The time required to complete the risk assessment and management plan with our certified veterinarian was worthwhile.

    Completely disagree 1 2 3 4 5 6 7 Completely agree

13. The Johne's disease management plan was reasonable.

    Completely disagree 1 2 3 4 5 6 7 Completely agree

14. The Johne's disease management plan also helps manage other diseases (e.g. calf scours, pneumonia, etc.).

    Completely disagree 1 2 3 4 5 6 7 Completely agree

15. It took a lot of discussion/debate with our certified veterinarian to agree on the Johne's disease management plan that would be implemented on our farm.

    Completely disagree 1 2 3 4 5 6 7 Completely agree

16. We implemented the Johne's disease management plan on our farm.

    Completely disagree 1 2 3 4 5 6 7 Completely agree

17. I learned a lot about Johne's disease by completing the Johne's disease risk assessment and designing the management plan with our certified veterinarian.

Completely disagree	1	2	3	4	5	6	7	Completely agree

18. My experience with the AJDI has been positive.

Completely disagree	1	2	3	4	5	6	7	Completely agree

19. Do you have any ***additional comments*** regarding your first year experience with AJDI?-

____

____

____

Thank you for your time and participation in the AJDI!

APPENDIX B – CHAPTER 3

B.1 Certified Veterinarian Management Plan Implementation Survey

Farm Name: ____

Owner Name: ____

Certified Veterinarian: ____

Date (dd/mm/yyyy): ____

Dairy Board Number: ____

Environmental culture has been completed for this farm. As such, the RAMP is due within the next 60 days. While completing the RAMP, please answer the following questions to indicate if the previous management plan recommendations were adopted and rigorously applied. The previous RAMP has been attached for your reference.

1. The management plan recommendation previously ranked as most important was adopted and rigorously applied on the farm.

   Completely disagree 1 2 3 4 5 6 7 Completely agree

   a. If rated below 5, please indicate the impediment(s) that prevented adoption of this best management practice. Circle all that apply:

      Farmer viewed as low priority
      Farmer viewed as not practical
      Farmer viewed as too costly
      Not compatible with other management practices on the farm
      Other: ____

   b. If rated below 5, will the recommendation be implemented in the coming year?

      Yes No

2. The management plan recommendation previously ranked second most important was adopted and rigorously applied on the farm. If not applicable (only one recommendation made previously), please circle: N/A

   Completely disagree 1 2 3 4 5 6 7 Completely agree

   a. If rated below 5, please indicate the impediment(s) that prevented adoption of this best management practice. Circle all that apply:

      Farmer viewed as low priority

Farmer viewed as not practical
Farmer viewed as too costly
Not compatible with other management practices on the farm
Other: ____

b. If rated below 5, will the recommendation be implemented in the coming year?

Yes No

3. The management plan recommendation previously ranked third most important was adopted and rigorously applied on the farm. If not applicable (only two recommendations made previously), please circle: N/A
Completely disagree 1 2 3 4 5 6 7 Completely agree

a. If rated below 5, please indicate the impediment(s) that prevented adoption of this best management practice. Circle all that apply:

Farmer viewed as low priority
Farmer viewed as not practical
Farmer viewed as too costly
Not compatible with other management practices on the farm
Other: ____

b. If rated below 5, will the recommendation be implemented in the coming year?

Yes No

4. Were there additional Johne's disease best management practices implemented on the farm beyond the three recommended in the management plan?

Yes No

   a. If yes, circle the most appropriate RAMP category for the additionally implemented best management practice(s) (numbers correspond to management plan recommendations in Risk Assessment Workbook):

General Johne's and Biosecurity:	1.1		1.3	1.4			
Calving Area Risk Management:	2.1	2.2	2.3	2.4	2.5	2.6	2.7
Pre-Weaned Heifer Risk Management:	3.1	3.2	3.3	3.4	3.5	3.6	
Weaned Heifer to First Calving Risk Management:	4.1	4.2	4.3	4.4			
Dry Cow Risk Management:	5.1	5.2	5.3				
Lactating Cow Risk Management:	6.1	6.2	6.3				

5. Do you have any ***additional comments*** regarding the implementation of the previous management plan recommendations?

____
____
____
____

APPENDIX C – CHAPTER 4

C.1 Johne’s Disease Attitudes and Awareness Questionnaire

Farm Name: ____

Owner Name: ____

Interviewee: ____

Interviewer: ____

Date of Interview: ________________ Dairy Producer Number: ________

Informed Consent:

I understand that this survey focuses on Johne’s disease attitudes and awareness in Atlantic Canadian dairy producers. Approximately 80 producers will be surveyed and the questionnaire will take approximately 1 hour to complete. I understand my participation in the survey is voluntary. By answering the survey questions, I realize that I may become more aware of my own personal attitudes and beliefs. If this makes me uncomfortable, I know that I am free to withdraw at any time. I understand that any information I provide will be kept confidential. My identity will not be revealed in any publications that result from this survey. Also, questionnaires and individual data will be stored securely, only used for research purposes and only presented grouped with other data to prevent indirect identification of my farm. By signing below, I am consenting to participate in this survey.

Interviewee Signature: ________________________ Date: ________________

Response Scales:

In this questionnaire, two different response scales are used. Depending upon the concept to be measured, the response scale will be 1 to 7 or -3 to +3. During the survey, we will draw your attention to the places where the response scales switch.

Section 1: The intention of this first section is to better understand your farm and farm goals.

1	Milk production is high on our farm	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
2	Cows on our farm have high classification. If not applicable, circle → N/A	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
3	Cows from our farm compete successfully at shows. If not applicable, circle → N/A	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
4	Cow longevity is good on our farm	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
5	Herd fertility is good on our farm	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
6	We have adequate disease prevention strategies on our farm	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
7	Fresh cows rarely become ill on our farm	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
8	Farm management is simple on our farm	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
9	Our farm is very profitable	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
10	Our farm has little debt	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
11	Our farm is preparing to transfer from one generation to the next	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
12	Our farm has a large land base	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
13	The facilities on our farm are very clean	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

14	Our farm is a closed herd (no cattle purchased including bulls)	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
15	We always fill our quota credits	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
16	An important farm goal is high milk production per cow	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
17	An important farm goal is to have cows that have high classification	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
18	An important farm goal is to have cows that compete in shows successfully	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
19	An important farm goal is to increase cow longevity	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
20	An important farm goal is to increase the herd fertility	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
21	An important farm goal is to prevent infectious disease introduction and spread	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
22	An important farm goal is to minimize fresh cow illness	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
23	An important farm goal is to keep farm management simple	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
24	An important farm goal is to maximize profit	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
25	An important farm goal is to reduce debt	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
26	An important farm goal is to be able to transfer the farm to the next generation	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
27	An important farm goal is to increase the farm land base	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
28	An important farm goal is to maintain facility cleanliness	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important

29	An important farm goal is to have a closed herd (no cattle purchased including bulls)	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
30	An important farm goal is to fill our quota credits	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important

Section 2: The focus now shifts from farm goals to the reasons cows are culled on your farm.

31	We often cull cows due to fertility problems	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
32	We often cull cows due to mastitis	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
33	We often cull cows due to metabolic disease (e.g. displaced abomasum/DA, milk fever, ketosis, etc.)	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
34	We often cull cows due to lameness problems	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
35	We are unable to cull as many cows for low milk production as we would like	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
36	Decreasing the number of cows culled due to fertility problems on our farm is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
37	Decreasing the number of cows culled due to mastitis on our farm is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
38	Decreasing the number of cows culled due to metabolic disease (e.g. displaced abomasum/DA, milk fever, ketosis, etc.) on our farm is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
39	Decreasing the number of cows culled due to lameness problems on our farm is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
40	Increasing the number of cows we can cull due to low milk production is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important

Section 3: In this section, we wish to understand your perceptions about Johne’s disease.

41	Johne’s disease has been reported all over the world	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
42	In the environment, Johne’s disease bacteria can survive for one year or longer	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
43	The best way to prevent Johne’s disease introduction into a herd is to avoid purchasing cattle	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
44	Housing heifers of 6 months of age or less near maternity pens or adult cows has no impact on Johne’s disease transmission	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
45	Johne’s disease bacteria are not shed into milk or colostrum	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
46	Adult cattle with Johne’s disease can have normal manure and look healthy	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
47	Infection with Johne’s disease occurs primarily within the first few days of life	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
48	Johne’s disease can be cured with antibiotics	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
49	A cow with Johne’s disease sheds the bacteria in their manure	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
50	Newborn calves may remain with their dam for a longer period of time if the dam is young and appears healthy	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
51	Cattle with Johne’s disease have reduced milk production	Definitely false	-3	-2	-1	0	1	2	3	Definitely true

52	The risk of a newborn calf becoming infected with Johne's disease increases as they are exposed to more cows in the calving area	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
53	Johne's disease in cattle has no reproductive effects	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
54	Bulls do not shed Johne's disease bacteria	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
55	Johne's disease increases the risk of culling	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
56	Signs of Johne's disease begin shortly after infection occurs	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
57	In adult cattle with Johne's disease, illness or moving to a new group impacts the number of Johne's disease bacteria shed	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
58	Cleanliness in the maternity pen is crucial for decreasing Johne's disease transmission	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
59	Animals with Johne's disease tend to lose their appetite	Definitely false	-3	-2	-1	0	1	2	3	Definitely true
60	When purchasing cattle, the best protocol to prevent Johne's disease introduction is to test the animal prior to purchase	Definitely false	-3	-2	-1	0	1	2	3	Definitely true

Section 4: For this section, we want to hear your thoughts about Johne's disease.

61	I am concerned about Johne's disease	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
62	We use strategies to prevent and control Johne's disease on our farm	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
63	I am concerned about the costs of Johne's disease	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

64	I am concerned about the possible human health risks of Johne's disease	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
65	I was eager to participate in the AJDI	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
66	I know a lot about Johne's disease, its prevention and control	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
67	I think Johne's disease prevention and control strategies are very effective	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
68	Being concerned about Johne's disease is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
69	The prevention and control of Johne's disease on our farm is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
70	Minimizing financial losses due to Johne's disease is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
71	Minimizing the potential impact of Johne's disease on human health is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
72	Having an industry wide Johne's disease prevention and control program in Atlantic Canada is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
73	Having knowledge about Johne's disease, its prevention and control is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
74	Having effective Johne's disease prevention and control strategies are:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important

Section 5: The purpose of this section is to identify your Johne's disease information sources.

75	I have learned about Johne's disease from our veterinarian	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
76	I have learned about Johne's disease from fellow producers	Strongly disagree	1	2	3	4	5	6	7	Strongly agree

77	I have learned about Johne's disease from other herd service providers (e.g. nutritionist, dairy management specialists)	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
78	I have learned about Johne's disease from the AJDI website (www.atlanticjohnes.ca)	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
79	I have learned about Johne's disease from other Johne's disease websites	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
80	I have learned about Johne's disease from mailings from the Dairy Board or AJDI	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
81	I have learned about Johne's disease from presentation(s) about Johne's disease	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
82	I have learned about Johne's disease from trade magazines (e.g. Hoard's Dairyman, Milk Producer)	Strongly disagree	1	2	3	4	5	6	7	Strongly agree
83	Johne's disease information from our veterinarian is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
84	Johne's disease information from fellow producers is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
85	Johne's disease information from other herd service providers (e.g. nutritionist, dairy management specialists, etc.) is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
86	Johne's disease information from the AJDI website (www.atlanticjohnes.ca) is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
87	Johne's disease information from other Johne's disease websites is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
88	Johne's disease information from mailings from the Dairy Board or AJDI is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important

89	Johne's disease information from presentation(s) is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important
90	Johne's disease information from trade magazines (e.g. Hoard's Dairyman, Milk Producer) is:	Extremely unimportant	-3	-2	-1	0	1	2	3	Extremely important

Section 6: The next few questions deal with the opinions and actions of others.

91	Fellow producers think it is important to prevent and control Johne's disease	Strongly disagree	-3	-2	-1	0	1	2	3	Strongly agree
92	The majority of dairy producers in Atlantic Canada prevent and control Johne's disease	Strongly disagree	-3	-2	-1	0	1	2	3	Strongly agree
93	Our herd veterinarian thinks it is important to prevent and control Johne's disease	Strongly disagree	-3	-2	-1	0	1	2	3	Strongly agree
94	Dairy consumers would approve of how we prevent and control Johne's disease	Strongly disagree	-3	-2	-1	0	1	2	3	Strongly agree
95	The international dairy industry thinks it is important to prevent and control Johne's disease	Strongly disagree	-3	-2	-1	0	1	2	3	Strongly agree
96	Dairy processors think it is important to prevent and control Johne's disease	Strongly disagree	-3	-2	-1	0	1	2	3	Strongly agree
97	Colleague approval matters to me	Not at all	1	2	3	4	5	6	7	Very much
98	It is important to me to do what the other Atlantic Canadian dairy producers are doing	Not at all	1	2	3	4	5	6	7	Very much
99	What our veterinarian thinks I should do matters to me	Not at all	1	2	3	4	5	6	7	Very much

100	Consumer approval of our herd management is important to me	Not at all	1	2	3	4	5	6	7	Very much
101	It is important to conform to international dairy industry expectations	Not at all	1	2	3	4	5	6	7	Very much
102	It is important to conform to the expectations of the dairy processors	Not at all	1	2	3	4	5	6	7	Very much

Section 7: At this time, you will be presented with a number of scenarios, which may or may not be true. The purpose is to gauge which issues about Johne's disease are important enough to you to change the prioritization of Johne's disease in your herd and to determine how difficult it was for you to make your decision.

Context: Milk processors require dairy farms to test for Johne's disease annually.										
Scenario 1: *If a herd has cows that test positive for Johne's disease, the positive animal(s) must be culled from the herd. Otherwise, the farm will be unable to ship milk*										
103	Does this change how you will prioritize the prevention and control of Johne's disease?	No changes in priority	1	2	3	4	5	6	7	Major changes in priority
104	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult
Scenario 2: *If all cows two years of age and older test negative for Johne's disease, the herd will receive a cash bonus of $0.50 per hectolitre*										
105	Does this change how you will prioritize the prevention and control of Johne's disease?	No changes in priority	1	2	3	4	5	6	7	Major changes in priority
106	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult

Context: An economic analysis of Atlantic Canadian dairy herds has been conducted. The annual financial cost of Johne's disease for a herd of 100 cows was determined to be:										
Scenario 1: *$20,000 per year (if 5 cows in the herd test positive for Johne's disease)*										
107	Does this change how you will prioritize the prevention and control of Johne's disease?	No changes in priority	1	2	3	4	5	6	7	Major changes in priority
108	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult
Scenario 2: *$10,000 per year (if 5 cows in the herd test positive for Johne's disease)*										
109	Does this change how you will prioritize the prevention and control of Johne's disease?	No changes in priority	1	2	3	4	5	6	7	Major changes in priority
110	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult
Scenario 3: *$5000 per year (if 5 cows in the herd test positive for Johne's disease)*										
111	Does this change how you will prioritize the prevention and control of Johne's disease?	No changes in priority	1	2	3	4	5	6	7	Major changes in priority
112	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult

Context: New methods have been developed to assist in the prevention and control of Johne's disease in Atlantic Canada.										
Scenario 1: *A 60-day oral treatment with a pro-biotic is effective at preventing 75% of the Johne's disease infections in calves. The cost of treatment is $2.00 per day.*										
113	Does this change how you will prioritize the prevention and control of Johne's disease?	No changes in priority	1	2	3	4	5	6	7	Major changes in priority
114	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult
Scenario 2: *A newly developed Johne's disease diagnostic test identifies 90% of infected cows and calls no non-infected cows positive. The cost of the test is $10.00.*										
115	Does this change how you will prioritize the prevention and control of Johne's disease?	No changes in priority	1	2	3	4	5	6	7	Major changes in priority
116	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult

Context: There is concern about a link between Johne's disease bacteria and human health problems including Crohn’s disease, which is a chronic bowel disease with similarities to Johne’s disease.										
Scenario 1: *A medical journal reports that researchers are able to cause Crohn's disease in mice by exposing them to milk containing the Johne’s disease bacteria*										
117	Does this change how you will prioritize the prevention and control of Johne’s disease?	No changes in priority	1	2	3	4	5	6	7	Major changes in priority
118	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult
Scenario 2: *A medical journal reports that Johne’s disease bacteria are found 2.5 times more frequently in people with Crohn’s disease than the normal population*										
119	Does this change how you will prioritize the prevention and control of Johne’s disease?	No changes in priority	1	2	3	4	5	6	7	Major changes in priority
120	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult

Context: Managing on-farm risks of Johne’s disease through a farm-specific risk assessment and management plan effectively prevents and controls Johne’s disease.										
Scenario 1: *After a management plan was implemented, the risk of new test positive cows was decreased by 30% after 3 years, 40% after 4 years and 60% after 5 years compared to farms without management plans*										
121	Does this change how you will prioritize the prevention and control of Johne’s disease?	No changes changes in priority	1	2	3	4	5	6	7	Major in priority
122	How difficult was it to make a decision for this scenario (e.g. did it take you a lot of thought)?	Not at all difficult	1	2	3	4	5	6	7	Extremely difficult

Section 8: This section will determine how feasible you think it is to use best management practices to prevent and control Johne's disease on your farm.

123	I can prevent and control Johne's disease on our farm if I wanted to	Strongly Disagree	1	2	3	4	5	6	7	Strongly agree
124	Implementing Johne's disease best management practices is easy	Strongly Disagree	1	2	3	4	5	6	7	Strongly agree
125	I have too little time to implement Johne's disease best management practices	Strongly Disagree	1	2	3	4	5	6	7	Strongly agree
126	Implementing the best management practices to prevent and control Johne's disease is not entirely up to me	Strongly Disagree	1	2	3	4	5	6	7	Strongly agree
127	I am unable to fully implement Johne's disease best management practices because I would need to do things that are too expensive	Strongly Disagree	1	2	3	4	5	6	7	Strongly agree
128	I am unable to fully implement Johne's disease best management practices because of other herd priorities (e.g. need to buy cattle, don't like milk replacer, like letting the cow lick the calf dry, etc.)	Strongly Disagree	1	2	3	4	5	6	7	Strongly agree

Section 9: This final section is to gather baseline information on your herd, the people working on your herd, your veterinarian and you as the person who makes the animal health policy decisions for your herd (referred to as cow manager).

129. Number of cows milked today (per milking) ______

130. Cow manager's year of birth ______

131. Cow manager's highest level of education completed (circle one):

University Undergraduate Degree

College Diploma

High School Graduate/Equivalent (GED)

Some High School or less

Other: ____

132. Number of farm personnel or family members that work with cows ______

(any person ≥12 years old working ≥5 hours per week with cows/heifers/calves including; milking, feeding, bedding, driving TMR mixer, etc. but not field work)

133. Number of full time personnel equivalents that work with cows ______

(number of full time people that would be required to do the cow/heifer/calf work including; milking, feeding, bedding, driving TMR mixer, etc. but not field work)

134. Estimate the percentage of the gross farm income from dairy production ______

(e.g. milk sales, heifer sales, embryos, bob calves, etc. but not crops, eggs, etc.)

135. How many different vets have worked on your herd in the past year? ______

136. Average number of vet sick cow visits per ***month*** *or* ***year*** (circle one) ______

(Average for the time period including calls for calvings, illnesses, traumas, etc.)

137. Average number of vet herd healths per ***month*** *or* ***year*** (circle one) ______

138. Dr. ___________________________________ is our regular herd veterinarian.

139. Within the next 5 years, what are your quota goals (circle one):

Decrease

Maintain

Increase ≤10%

Increase >10% but <25%

Increase >25%

140. Within the next 10 years, what are your quota goals (circle one):

Decrease
Maintain
Increase ≤10%
Increase >10% but <25%
Increase >25%

THANK YOU FOR YOUR PARTICIPATION

APPENDIX D – CHAPTER 5

D.1 Knowledge transfer questions in the Producer Satisfaction Questionnaire for the Risk Assessment and Management Plan (RAMP) in the Atlantic Johne's Disease Initiative

Johne's disease (JD):

1. Variable Name: **Age Susceptibility**
   At which stage of life do most cattle become infected with the Johne's bacteria?
   - ◯ Pre-weaned calf
   - ◯ Weaned calf
   - ◯ Breeding-age heifer
   - ◯ Bred heifer
   - ◯ Cow

2. Variable Name: **Prevalence_JD**
   How common is Johne's disease in Atlantic Canada?
   - ◯ Less than 1/3 of the herds tested positive
   - ◯ 1/3 to 2/3 of the herds tested positive
   - ◯ More than 2/3 of the herds tested positive

3. Variable Name: **Transmission_JD**
   Can a healthy looking cow be infected and transmit Johne's disease to other animals?
   ◯ Yes ◯ No ◯ I'm uncertain

4. Variable Name: **Diarrhea_JD**
   Do most cattle with Johne's disease have watery diarrhea?
   ◯ Yes ◯ No ◯ I'm uncertain

5. Variable Name: **Diagnostics_JD**
   Do Johne's disease tests reliably find the positive animals?
   ◯ Yes ◯ No ◯ I'm uncertain

Bovine Viral Diarrhea (BVD):

6. Variable Name: **Discuss_BVD**
   Did the vet discuss Bovine Viral Diarrhea or BVD with you at your last Johne's RAMP?
   ◯ Yes ◯ No ◯ I'm uncertain

7. Variable Name: **Abortion**
   Can BVD cause abortion?
   ◯ Yes ◯ No ◯ I'm uncertain

8. Variable Name: **Diarrhea_BVD**
   Do most infections with BVD result in severe diarrhea?
   ◯ Yes ◯ No ◯ I'm uncertain

9. Variable Name: **Persistent Infection**
   Can a calf be born as a carrier of BVD?
   ◯ Yes ◯ No ◯ I'm uncertain

10. Variable Name: **Vaccination**
    Is vaccination a good method to control BVD?
    ◯ Yes ◯ No ◯ I'm uncertain

Bovine Leukosis Virus (BLV):

11. Variable Name: **Discuss_BLV**
    Did the vet discuss Bovine Leukosis or BLV with you at your last Johne's RAMP?
    ◯ Yes ◯ No ◯ I'm uncertain

12. Variable Name: **Prevalence_BLV**
    How common is Leukosis in the Maritimes?
    ◯ Less than 1/3 of the herds have a cow(s) with Leukosis
    ◯ 1/3 to 2/3 of the herds have a cow(s) with Leukosis
    ◯ More than 2/3 of the herds have a cow(s) with Leukosis

13. Variable Name: **Masses**
    Is a sign of Leukosis the formation of tumors?
    ◯ Yes ◯ No ◯ I'm uncertain

14. Variable Name: **Transmission_BLV**
    Can Leukosis be transmitted directly between animals through milk or colostrum?
    ◯ Yes ◯ No ◯ I'm uncertain

15. Variable Name: **Diagnostics_BLV**
    Can blood or milk tests be used to accurately diagnose Leukosis?
    ◯ Yes ◯ No ◯ I'm uncertain

16. Variable Name: **Cure**
    Once a cow has Leukosis, can it be treated to remove the infection?
    ◯ ◯ ◯

APPENDIX E – CHAPTER 6

E.1 Communication skills training and assessment workshop consent form, Atlantic Canada in 2014

Vet Name (please print):

To help us assess the effectiveness of this workshop, we will be recording the pre-OSCE (Thursday evening) and the post-OSCE (Friday afternoon) with video cameras. These recordings are for research purposes only. They will be stored securely. They will not be shown in any publications or presentations that result from this research. By signing below, you are consenting to the recording.

Signature: ____

Date: ____

E.2. Objective Structured Clinical Exam (OSCE) Task Sheet Example for the Communication Skills Training and Assessment Workshop, in Atlantic Canada in 2014

Post-OSCE Station 1A

O'Halloran Johne's: O'Halloran Farm

VET INSTRUCTIONS

You are out today for the annual visit to do the Johne's disease risk assessment and management plan (RAMP) for the third year. The herd has all 6 environment cultures (EC) positive for Johne's disease again.

Dr. Smith did the previous RAMPs. At last year's RAMP, David O'Halloran agreed to a set of 3 management changes and to conduct some individual cow testing via milk ELISA.

This is your first time to the farm. Dr. Smith does the biweekly herd healths on this farm and is concerned that there has been limited implementation of the recommendations and no testing.

With the Calgary-Cambridge Guide in mind, your task is to:

- **meet David O'Halloran**
- **gather information**
- **build a relationship**
- **arrive at a mutually agreed upon plan**

You have 10 minutes for the discussion.

E.3 Standardized Producer Feedback Form for the Communication Skills Training and Assessment Workshop pre- and post-intervention Objective Structured Clinical Exams (OSCEs), in Atlantic Canada in 2014

Initiation, Gathering Information, Relationship Development	**Yes**	**Yes But**	**No**
Were your main concerns addressed today? (Exploring your story, screening, using open-ended questions, silence, etc.)			
Did this vet understand the importance of your reason for calling them to the farm today? (Reflective listening/paraphrasing, clarifying questions)			
Do you think the vet understood you today? (Acknowledging your perspective, empathy, non-judgmental, empathetic statements)			
Were you satisfied with the discussion of the concern/problem? (Partnership statements, explored your ideas and concerns)			
Were you satisfied with the opportunity to ask questions?			
Did the vet explore your expectations and your ideas? (Explored your expectations)			
Was the vet successful in communicating that s/he cares about you as a person? (Authenticity, respect, empathy, supportive statements)			
Did the vet follow up on clues you dropped? (e.g. You mentioned you were worried that disease. Can you tell me more)?			
Explanation and Planning Phase - Did the vet :			
Assess your starting point (asks for your prior knowledge early on when giving information, discovers your wish for information)			
Give information at the appropriate time			
Organize the explanation			
Relate explanation to your perspective (to your beliefs, concerns, values, expectations, reactions, feelings)			
Involve you (offers suggestions and choices versus directives)			
Explore and negotiate a management plan with you			
Closing – Did the vet:			
Contract with you regarding next steps?			
Summarize the session?			
Perform a final check? (Your comfort level, last questions or other items to discuss)?			
Would you use this person as your veterinarian? (yes, yes but, no)			

E.4 Pre-intervention self-efficacy questionnaire for the Communication Skills Training and Assessment Workshop, in Atlantic Canada in 2014

1. My prior communication training has been	Poor Below Average Fair Good Excellent
Please list any prior communication classes/training:	
2. My knowledge of communication skills is:	Poor Below Average Fair Good Excellent
3. My listening skills are:	Poor Below Average Fair Good Excellent
4. My ability to accurately identify non-verbal communication is:	Poor Below Average Fair Good Excellent
5. My written communication skills are:	Poor Below Average Fair Good Excellent
6. My general oral communication skills are:	Poor Below Average Fair Good Excellent
a. My ability to get an accurate history is:	Poor Below Average Fair Good Excellent
b. My ability to establish rapport with my clients is:	Poor Below Average Fair Good Excellent
c. My ability to build a relationship with my clients is:	Poor Below Average Fair Good Excellent

d. My ability to explain things to and develop a plan with my clients is:	Poor	Below Average	Fair	Good	Excellent
7. My complex medical communication skills (i.e. bad news, euthanasia, angry clients, etc.) are:	Poor	Below Average	Fair	Good	Excellent
8. My communication skills with other veterinary healthcare providers is:	Poor	Below Average	Fair	Good	Excellent
9. My team skills are:	Poor	Below Average	Fair	Good	Excellent
10. My primary reason for attending this workshop is:					
11. My goal (s) for this workshop is/are:					
12. Topics I'm particularly interested in are:					
Signature: ____	Date: February 13, 2014				

E.5 Post-intervention self-efficacy questionnaire for the Communication Skills Training and Assessment Workshop, in Atlantic Canada in 2014

13. My knowledge of communication skills is:	Poor	Below Average	Fair	Good	Excellent
14. My listening skills are:	Poor	Below Average	Fair	Good	Excellent
15. My ability to accurately identify non-verbal communication is:	Poor	Below Average	Fair	Good	Excellent
16. My general oral communication skills are:	Poor	Below Average	Fair	Good	Excellent
a. My ability to get an accurate history is:	Poor	Below Average	Fair	Good	Excellent
b. My ability to establish rapport with my clients is:	Poor	Below Average	Fair	Good	Excellent
c. My ability to build a relationship with my clients is:	Poor	Below Average	Fair	Good	Excellent
d. My ability to explain things to and develop a plan with my clients is:	Poor	Below Average	Fair	Good	Excellent
17. My complex medical communication skills (i.e. bad news, euthanasia, angry clients, etc.) are:	Poor	Below Average	Fair	Good	Excellent
18. My communication skills with other veterinary healthcare providers is:	Poor	Below Average	Fair	Good	Excellent
19. My team skills are:	Poor	Below Average	Fair	Good	Excellent

20. The three most useful skills/concepts I learned in this workshop are:
21. Other communication skills/concepts I'd still like to learn about are:
22. Ways to improve this workshop are:
Signature: ______________________________ Date: February 14, 2014

E.6 Objective Structured Clinical Exam (OSCE) Checklist for the Communication Skills Training and Assessment Workshop pre- and post-intervention OSCEs, in Atlantic Canada in 2014

COMMENTS	COMMUNICATION SKILL	“YES”	“YES BUT”	NO”
	Initiating the Session			
	1. Greets client	○	○	○
	2. Introduces self and role	○	○	○
	3. Asks an open-ended question to identify problem or producer’s issues	○	○	○
	4. Listens without interrupting	○	○	○
	5. Negotiates the agenda for the discussion	○	○	○
	Gathering Information			
	6. Encourages producer to tell story (2 open-ended questions = “yes”)	○	○	○
	7. Asks questions, appropriately moving from open to closed	○	○	○
	8. Listens attentively	○	○	○
	9. Facilitates producers responses verbally and non-verbally (eye contact, uses encouragement and facilitative responses i.e. ok, go on, uh huh, etc.) (2 items used = “yes”)	○	○	○
	10. Clarifies producer’s statements as needed (1 reflective statement = “yes”)	○	○	○
	11. Actively determines and appropriately explores producer’s ideas, concerns and expectations	○	○	○
	Providing Structure			
	12. Uses internal summarizing (1 internal summarizing = “yes”)	○	○	○

	13. Progresses using signposting (1 signpost = “yes”)	○ ○ ○
	Building the Relationship	
	14. Demonstrates appropriate non-verbal behaviour (eye contact, facial expression, body language etc.)	○ ○ ○
	15. Demonstrates appropriate confidence	○ ○ ○
	16. Empathizes and supports client (1 empathetic statement = “yes”)	○ ○ ○
	Explanation and Planning	
	17. Provides information in manageable chunks and checks for understanding	○ ○ ○
	18. Uses easily understood language	○ ○ ○
	19. Negotiates mutually acceptable plan with producer	○ ○ ○
	20. Checks producer’s understanding and concerns	○ ○ ○
	Closing the Session	
	21. Agrees on next steps with producer	○ ○ ○
	22. Safety nets with producer	○ ○ ○
	23. Did the veterinarian run out of time before doing the Explanation and Planning skills?	○ ○ ○

OVERALL IMPRESSION **(***CIRCLE ONE)*	**Excellent** **5**	**Good** **4**	**Average** **3**	**Fair** **2**	**Poor** **1**
Additional Comments					