Approach for designing appropriate Johne's disease control programs on the farm

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Johne's disease (*Mycobacterium paratuberculosis)* is well documented to be an insidious disease that is widely distributed in domestic and wild ruminants. Studies, diagnostic lab submissions, and impressions of veterinarians suggest that Johne's disease problems are increasing in dairy and beef, as well as in sheep, goats, deer, and other confined exotic species. Today, a significant proportion of clients in most food animal practices are likely to have Johne's disease infection in their herds. Although definitive costs associated with different levels of endemic herd infection have not been quantified, those associated with clinical Johne's disease are most prominent including value and production of animals lost,[1,2,46,56] calves lost, replacement costs[20,37] and reduced salvage value. The impact of involuntary culling for Johne's disease on culling rate and or policy, [20,37] plus the last lactation production loss (5-15%) associated with subclinical infection[1,2,31,46] may have additional significant effects in some situations. Lost genetics and marketing options can significantly impact breeding stock operations. As herd infection increases, losses compound as the number of cases increases, and age affected declines.

Uncertainties, however, in the understanding of Johne's disease make the pursuit of disease control confusing for producers and veterinarians. As a consequence, early sentinel Johne's disease cases are frequently dismissed, and infection and economic effects in herds increase, particularly when significant risk factors for spread exist. However, misguided or inappropriate responses to Johne's disease problems can further frustrate or overwhelm producers and may stimulate excessive and unnecessary costs of "control" i.e.. new facilities, equipment, culling of productive animals, extra inefficient efforts etc. Generic control recommendations often fail because they do not account for uncertainties inherent in control recommendations, nor the unique circumstances of individual farms; they appear impractical, may be unnecessary, and often are not implemented.[4,9,16,26,28,35,51,58] This paper is a response to this dilemma and hopes to encourage veterinarians and producers to give more timely and appropriate attention to Johne's disease problems.[33] It outlines a systematic and pragmatic approach to adapt the principles of Johne's disease control to the individual farm circumstances, and to integrate Johne's management into the general farm management plan.

The control of Johne's disease is complicated by several issues. The subclinical and chronic nature of the infection makes recognizing the disease and estimating it's cost difficult and herd level control a lengthy process.[11] Early control, when it is easier and inexpensive, is not usually pursued, yet compounded effort and commitment is required to control endemic infection.

Understanding of the pathogenesis and epidemiology of infection is inadequate to definitively predict the relative importance of transmission routes (manure ingestion, in utero, colostrum, and milk), as they occur naturally on the farm, as control points. [15,36,43,44,48,49] Information is also lacking about factors (effective dose, age, genetics, nutrition, immune status, etc) that affect host susceptibility and influence the acquisition and outcome of infection. Thus it is difficult to choose the most effective control measures or confidently predict their success.

The time lag for control and the uncertain economics of Johne's disease (effect of clinical and subclinical infection on individual and herd productivity, herdlife, herd cull rate, replacement needs) make it difficult to predict the economic return from long term control efforts and thus the resources that should be committed.

Regulatory, ethical and economic considerations accompany the marketing or showing of animals known to be infected or exposed to Johne's disease, although most States do not restrict movement of infected or exposed animals (a few states encourage culture positive animals be sold to slaughter only). Thus buyers should beware, and sellers should consider their liability and reputation. Producers contemplating voluntary testing must choose between the benefits of knowing their herd's status and the risks if Johne's disease is diagnosed in the herd.

Individual farm variation in operational goals and the availability and flexibility of resources such as skills and management, labor, finances, and facilities complicate control proscriptions as well.

As a consequence of these matters, control strategies that are likely to be most appropriate i.e. practical and effective, are not simple or clear; strict control guidelines become difficult to justify and apply appropriately, and no single control formula applies in every case. To ensure that control programs can be implemented, specific control plans must be designed to complement the resources available.

Testing is a critical tool in controlling Johne's disease. However, the limitations and options associated with commonly used tests can create confusion about herd testing as a part of a control program. Rational test choices can be made by veterinarians and producers with a basic understanding of the tests available, what they do, what results mean, and how results can be appropriately used. Understanding the tests underlies their usefulness. The issues that influence choice of commonly used tests and test strategies include basic performance characteristics (sensitivity, specificity, predictive value), cost, interpretation of results, herd test strategies (frequency, portion of herd tested, one or combination of tests), and action to be taken based on test results. These issues preclude a generic proscription for the most appropriate test scheme. Instead, each should be weighed in the context of the farm situation to determine the most appropriate strategy for their control program.

In spite of uncertainties, enough is known to suggest the major steps needed to control Johne's disease.[3,14,16,22,26,32,35] Evidence and experience also supports that establishing a control plan to control or prevent increasing prevalence is merited by economic returns.[30,34,35,50] But, tailoring successful on-farm control programs necessitates that veterinarians possess a sound working knowledge of the epidemiology of Johne's disease and the availability and use of diagnostic tests. This includes familiarity with the *basic* test performance characteristics including ***sensitivity***, ***specificity*** , ***apparent test prevalence*** (determined by testing) verses ***true prevalence*** of infection, and the marked influence of prevalence of infection on the predictive value (likelihood that it is actually correct) of a positive or negative test result. It is beyond the scope of presenting this approach to review the epidemiology and diagnosis of Johne's disease. The reader is encouraged to refer to several articles that address these issues.[13,14,17,38,41,42,45,47,54] Contact the author if they are not accessible. Veterinarians should know the tests and costs available through their routine labs. Johne's disease testing is not standardized across laboratories.[7,53,54] To ensure accurate results, consider using the labs that are validated to perform the standard tests. Several labs were accredited in 1995-96 by the USDA, APHIS, National Veterinary Services Laboratory, Ames, Iowa, to perform fecal culture and ELISA testing for the National Johne's Disease Certification Program,[29] established through USAHA in 1993. Contact NVSL for information on these labs.

Developing farm specific control programs

Successful farm control plans have more dimensions than generic recommendations[9,28,41,50,51,58] suggest. Instead, control options must be weighed in the context of the specific farm situation to arrive at the best decision for the farm. Management systems, disease progression, and the priorities for Johne's disease interventions are unique to each farm. Thus Johne's disease control programs need to be developed on an individual basis[16,30,35] and are unlikely to be implemented, or sustained if the unique farm situation is not incorporated into the plan.

Comprehensive and systematically constructed control programs are more effective and should ensure that three tasks are accomplished in the design process:

1. Collecting adequate information concerning farm/family background, management system, operation objectives, herd health, preliminary assessment of the extent of Johne's disease, assessment of the farms specific risk areas for spread, and farm resources and constraints.
2. Educating personnel about Johne's disease and control options.
3. Planning and implementing the program.

This approach is presented as an *eight point process* of investigation/discussion on the farm. It is intended to facilitate farm owners and personnel, veterinarians, and other farm advisors to review information together, integrate related issues, and arrive at a well thought out plan.

The *eight point process*

Eight points are presented in a logical order to discuss on the farm, but it is most important not to overlook any points. The veterinarian and the people who will execute the control plan should be involved to develop the best plan. The eight points include:

1. Compiling background information on the farm operation.
2. Compiling probable Johne's history and prevalence.
3. Identifying the farm's specific risks for spreading Johne's disease
4. Examining control options for identified risks.
5. Considering herd testing strategies
6. Defining control objectives and time frames.
7. Characterizing the intensity expected from control efforts
8. Planning, implementing, and evaluating the control program.

Point One. **Farm background information.**

The process should begin with a review of essential aspects of the farm operation to understand decisions facing the producer and the context within which Johne's disease control will be established. This is an excellent opportunity for veterinarians and clients if they haven't recently reviewed the overall status of the operation. Four main areas include:

1. Type of operation; short (1-2 yr.) and long term (2-10 yr.) farm goals for commercial performance and/ or marketing of breeding stock, cash flow, profit, herd size, facilities, capital expenses, business future to incorporate partners or sell, etc.
2. Management characteristics. Identify strengths, challenges, and existing priorities in the management. Review status of production, cull rate, replacements, reproduction, feed program, facilities, husbandry of key animal groups, etc.
3. Resources. Summarize flexibility and constraints on resources, especially labor, facilities, and finances.
4. Animal health. Review the status of other animal health issues including mastitis, lameness, and infectious and metabolic disease. This helps prioritize Johne's disease economically relative to other diseases and will help optimize the choices for return on "disease control" dollars available.

Point Two. **Disease history and prevalence.**

An assessment of the history of Johne's disease in the herd (with or without herd test information) can reveal how and when Johne's was introduced, and an estimate of the prevalence, endemicity, and economic impact of Johne's in the herd. This information is essential to understanding Johne's disease as a priority on the farm and making control decisions. History can be constructed from previous test results, and recall of diagnosed and suspect clinical cases, and introduced animals in the past.

The following information is useful to compile first, to assess herd prevalence, incidence of cases, direct losses due to Johne's, and endemic nature of infection:

1. Recent herd test data if available; list of test positive animals
2. List of diagnosed clinical cases and or unconfirmed clinical suspects removed from the herd in the last 6-12 months.

Obtain for each: date of birth, raised on the farm or purchased, purchase source, age at diagnosis/disease, signs of Johne's disease, date removed, lactation no., lactation production data, DIM, body condition score at removal, salvage value.

Herd testing gives the best estimate of apparent[38] prevalence of infection in the herd. An estimate of the true prevalence of infection in the herd is obtained for fecal culture or serology by dividing the test prevalence by the sensitivity (.30-.50) of the test. Prevalence can also be characterized by the incidence of clinical disease in the herd in the last 6 to 12 months: number of suspect (producer is reasonably certain were Johne's disease) and diagnosed clinical cases divided by number of mature animals through the herd. Rule of thumb in a herd with endemic (established) infection is that every home raised clinical case represents 10 to 20 other (raised) animals that are infected - "the tip of the iceberg". The estimates may be lower in herds with established management and cull control programs. In addition, the manifestation of clinical Johne's disease may vary between herds, which may be related to factors linked to nutrition, health, immune system, nutrition, quality of management, stress, and genetic susceptibility. From the history, herd prevalence can be categorized as low moderate or high. The categories aren't rigorous but are useful to describe the likely severity of infection in the herd. Table 1 summarizes historical criteria useful to categorize herd prevalence.

Table 1. *Point Two:* Historical criteria to categorize Johne's disease herd prevalence.

Low	➤ no or isolated clinical cases in raised animals, only older (i.e. > 4 yrs of age) ➤ isolated diagnosis or clinical cases in purchased animal(s) only ➤ < 3 % [§] *positive* [‡] on herd test ; older animals only (i.e. > 3 yrs) ➤ management history suggests generally low risks for spread i. e. good hygiene in calving areas, minimal contact between younger and mature animals (see Point Three. Table 2 . Checklist for risks for spread)
Moderate	➤ occasional clinical cases in raised animals, generally older (i.e. > 3 yrs) ➤ increasing cases and or decreasing age (i.e. < 3 yrs) ➤ occasional clinical cases may be in acquired animals ➤ recall animals that possibly introduced Johne's disease in the past (i.e. 5-20 yrs) ➤ 3-10 % *positive* [‡] on herd test ; generally older, may be an occasional younger animal (2-3 yrs of age) ➤ management history suggests some risks for spread in the past: i.e. calving area hygiene, some contact between ➤ younger and mature animals, manure contamination of feed
High	➤ frequent clinical cases or groups in raised animals ➤ pattern of progression : increase in number of cases in last 2 to several years; decrease in age of cases: cases in 2 yr olds or less ➤ significant economic losses due to animals culled ➤ cases may also be in acquired animals ➤ may have acquired several animals of unknown status in past (i.e. 5-20 yrs. in the past) ➤ recall animals introduced, prior to early cases , who possibly introduced Johne's disease (i.e. 5-20 yrs in the past) ➤ 10 - 20% *positive* [‡] on herd test ; some older , many younger (2-3 yrs of age) ➤ several risks for spread existed in the past : i.e. poor hygiene in calving area , calves nursed cows, regular contact of youngstock with mature animals or manure, manure contamination of feed , etc

‡ test prevalence using fecal culture or single cut-off ELISA; assuming sensitivity approximately 30-50%, specificity 99-100%.
§ ranges are arbitrary from experience and are intended to conceptually characterize severity of herd infection not be rigorously interpreted.
¶ see *Point Three*, Table 2, On-farm checklist for identifying risks for spread

The extent to which Johne's is endemic in the herd can be further determined from the ages of cases and or asymptomatic test positive animals, and whether they were raised on the farm. Infection is likely more widespread in the herd where younger (replacement heifers, first or second lactation animals) raised animals are test positive or develop clinical disease. These animals were likely heavily exposed to *Mycobacterium paratuberculosis* at a young age. Actual clinical disease in immature animals suggests severe herdwide infection or that a particular group or age cohort was at higher risk for some reason. Prevalence of infection in animals that were raised on the farm compared to purchased also indicates endemic or acquired infection.

However, it is difficult to assume the source of infection in outside animals that have resided for months or years in an already endemically infected herd.

Severity of the Johne's problem is usually associated with the prevalence and the endemic extent of herd infection. Severity also usually reflects the cost of Johne's disease to the farm and how aggressive a control program may *need* to be. The direct losses due to clinical Johne's disease for 6-12 months can be estimated from the number, production or value of animal lost,[1,2,31,46,56] salvage value, replacement cost, and the impact of involuntary culling for Johne's disease on culling policy and rate.[20,37] Losses can be expected to increase if Johne's is spreading in the herd.

The following additional history should be reconstructed to help explain the current level of herd infection i.e. source(s) of infection, and years and rate of spread, and to identify current animals at high risk of infection from past exposures such as to clinical cases, *Mycobacterium paratuberculosis* in manure in the environment, or familial association.

1. Date, age, and source of first suspected clinical Johne's case
2. Notable history of animals added to the herd, prior and subsequent to initial cases, to suggest when Johne's was introduced: number, date, source, subsequent performance.
3. Number, date, age, and source of subsequent cases remembered; dates of clusters of cases; approximate number of clinical cases per year(s).
4. Note possible associations between history/location of past clinical cases and birth dates of subsequent cases or test positives.
5. Recall obvious past conditions (risk factors) that may have enhanced spread, i.e. thin nurse cows or their milk used for calves, calving in freestall alleys, youngstock exposure to manure of cows, etc.
6. Date of occurrence and age of oldest and youngest cases.

How and when Johne's disease was probably introduced and patterns in clinical cases can reveal the rate with which Johne's disease has spread in the herd and where the herd is on the disease continuum. History often demonstrates the slow progression over 5-20 years. A history that suggests rapid progression i.e. less than 5 years warns that conditions that significantly promote spread did and may still exist.

Point Three. Identifying specific risks.

A grasp of the severity and source of infection provides the context to assess the actual *current* and *previous* conditions (risks) for spreading Johne's disease. Identifying risks that exposed younger animals in the past is crucial to help explain the level of disease currently observed in the adult herd, and to indicate risks that have already been eliminated, or have been recently introduced. Knowing what has happened in the past is essential to determine which existing risks are most important in continuing to spread infection and should be targeted in the control plan .

Risk conditions to identify on the farm are those that promote spread of Johne's disease by one of four known transmission routes:

1. Ingestion of manure from infected animals.
2. Ingestion of milk and colostrum from, or contaminated by, infected animals.
3. In utero transmission from infected dams.
4. Introduction of infected animals from the outside.

To be thorough, risks for spreading Johne's disease should be assessed systematically.

All facilities and management areas should be reviewed in a group walk-about, in a logical order, from youngest to adult, beginning with the calving area. Alternative and seasonal housing or management also needs to be considered.

The magnitude of each risk as a hazard for spreading Johne's should be characterized as low, medium or high or on a scale i.e. 1-10, by taking into account three factors:

1. ***age** of animal exposed:* younger animals are more susceptible
2. *degree of **exposure:*** a function of
   dose - infective dose largely unknown under natural conditions, particularly for utero, milk, and colostrum. One must assume risk due to the latter three is significant 10-25% of the time, increasing with advanced infection.[36,43,44,48,49]
   frequency - duration and frequency exposure occurs i.e.. multiple times daily, weekly, seasonal, sporadic event, etc.
   density - intensity of exposure in general increases with animal density.
3. *herd **prevalence:*** degree of exposure for same risk increases with prevalence.

The checklist in Table 2 can be used to identify specific risk areas and rate their magnitude, which indicates their relative importance to be addressed in the control program.

Current risks for spread in each age group should be compared to the risks that current known infected cows were exposed to, for example compared to the specific risks that existed when a recent 3 yr. old clinical case was raised. Comparing the magnitude of current and past risks helps anticipate the extent to which the present level of infection in mature animals may be expected to increase or decrease in the succeeding

Table 2.1 *Point Three.* Checklist - Special risk areas for spreading Johne's disease. Risk importance is a function of age, dose, frequency and herd prevalence. Rate current and past risks from 1 to 10 (minimal to extremely high). Specific farm plan should target current risks. Note herd prevalence: Low - Mod - High.

I. Special risks:	Risk (1-10)	Current management	Risk	Past conditions
Calving: youngest age - highest risk				
common area - crowded, too many cows				
manure build-up - not well bedded, clean, dry				
calves born in gutter/free stall/holding area, no bedding				
used for "sick cows" (possibly Johne's)				
clinical suspects, test positives also in these areas				
newborn calves stay with cow or in maternity area				
calves nurse cows				
calves fed colostrum from possibly infected dam (s)				
dam(s) of calves had clinical signs or high risk on test				
dam(s) of calves assymptomatic but test positive /likely infected				
other				
Calves: youngest age - highest risk				
calves fed pooled colostrum - including from infected cows				
calves fed pooled milk - including from infected cows				
milk or colostrum contaminated w/ manure in handling				
calves housed *near* cows - *indirect* contact w/ manure (splatter)				
calves housed with *direct* contact w/ cows or manure				
calf feed contaminated w/ manure (boots, equipment, splatter)				
other				

Table 2.2 *Point Three.* Checklist - Common risk areas / acquired animal risks for spreading Johne's disease (cont). Rate the level of current and past risks from 1 to 10 (minimal to extremely high). Note age or mgmt group at risk.

II. Common risks - risk declines with maturity	Risk	Current management/ groups at risk	Risk	Past conditions
Weaned (high risk) to mature (low to moderate risk)				
direct contact w/ cows or manure				
direct ingestion of manure from mature (infectious) animals:				
contaminated feed stoage area - traffic, equip, boots, cows				
contaminated feed in bunk or manger - equip, cows, boots				
contaminated waterers				
share feed, water, lot, facilities w/ cows - co-mingle, separately				
drink water from cow yard runoff, contaminated still water				
share same pasture w/ cows - co-mingle, separately				
manure spread on pasture and grazed same season				
manure spread on grass forage harvested same growing period				
excess manure build-up - common facilities, areas				
manure contaminated equipment/loader used to move feed				
other				
III. Acquired animals (variable risk):				
animals of unknown or suspect status co-mingled with youngstock				
history or source suggests risk of Johne's				
suggested "collective" risk - number and age of animals acquired				
risk of acquired animals is higher (or lower) than home herd?				
other				

generations. Herd prevalence, thus exposure, given constant risk conditions, usually increases with time, but may have been offset by changes in management such as moving calves away from dry cows, to hutches. Frequently, significant Johne's disease control practices have already been established in the course of general farm management improvements, which is important to recognize.

The checklist in Table 2 first lists the special high risks associated with the calving period, followed by more common risks (associated with feed, water and hygiene) that occur and can be assessed similarly across other age groups. Introduced animals of unknown disease status are the third risk to evaluate. Identified risk areas provide the basis for *Points Four* and *Five* which is to consider options for reducing these risks with preventive management and/or testing strategies.

***Point Four*: Consider Johne's disease control options for identified risks.**

Identifying risks enables producers to clarify the extent of their Johne's disease problem and the control points where interventions will be most effective or necessary. By applying the following principles of Johne's disease control, risk by risk, in each management age group, management options that would reduce risk can be generated and considered with the producer.

The basic Johne's disease control strategy. There are two main objectives to Johne's disease control. Specific measures should attempt to accomplish one or both:

1. Prevent animals from ingesting *Mycobacterium paratuberculosis* in manure, milk, colostrum, or the special case of in utero infection. Younger animals are most susceptible, thus controlling exposure of younger animals is most important.
2. Reduce contamination of the environment to decrease exposure to *Mycobacterium paratuberculosis.*

Similarly, control programs have two major components:

1. Preventive management and hygiene to reduce animal exposure to manure and *Mycobacterium paratuberculosis.*
2. Culling or managing known infectious animals to reduce premise contamination.

A variety of management options should be entertained that would apply the control principles to the farm's situation. The goal is to identify a combination of preventive management practices that will *collectively* reduce exposure. Practical, creative measures that will fit into the routine are important. The ultimate utility of the options can be weighed by three additional criteria :

1. *To what degree is risk reduced?* The importance of a management option in controlling the Johne's will depend on magnitude of the risk and extent to which it can be reduced. For example a new facility may offer complete separation for older youngstock, whereas, moving youngstock further away in the same barn and adding a solid partition may offer less but adequate control, if coupled with good hygiene.
2. *How practical is the control measure?* Options are only useful if they can be implemented with exist-

ing resources and routines. For example, the expense and justification for new facilities should be contrasted with more feasible solutions such as rearranging pens and/or increasing labor to improve sanitation in a problem area.

3. *What other benefits may result from the intervention?* Johne's disease is controlled largely by good management practices, which provide other benefits sooner than they control Johne's disease. The additional health and production benefits that can result in other priority areas on the farm should be considered as part of the value of Johne's management options. For example the value of timely removal of calves and optimal management of the calving area includes improvements in calf and fresh cow health and performance that are likely to result.

Discussion of control options naturally develops as risks are identified during the farm walk-about. However, to ensure that control possibilities are fully reviewed, time should be taken to summarize considerations for control for each risk. The discussion of control options at this point should be instructive not conclusive. A variety of management control options to consider are provided in Table 3. ***The control plan should not be formulated until the benefits of testing, and objectives and intensity of control efforts are assessed*** in the following sections (*Points Five, Six* and *Seven*).

Vaccination in the control program. Vaccination in conjunction with a management and or testing approach may be an appropriate third component in a Johne's disease control strategy for high prevalence herds to help reduce the economic impact of clinical disease.[23,24,27] Vaccination does not provide immunity against infection. Effective control is not achieved or sustained without concurrent reduction in exposure by other management control measures[9,18,22,23,24,27,59] and can fail completely in its absence. Other disadvantages include interference with serologic tests for Johne's disease and TB caudal fold skin test, granulomas at the vaccination site in cattle, severe tissue reactions from self-injection, and effects take not experienced until vaccinated calves are mature (usually >2 years). Only a few states in the US permit use of the one killed product that is approved (Mycopar™, Solvay Animal Health, Mendotta Hts, Mn). Veterinarians or producers interested in vaccination should obtain more information on advantages and disadvantages for their situation and state's policy on its use.

Table 3.1 *Point Four:* Management objectives / options to control spread of Johne's disease.

Review a range of possible control options for each risk area identified on the farm (*Point Three*. Table 2) i.e. youngest high risk animals to older. Consider benefits of testing - test strategies, how results could be used to enhance control measures, cost.

I. Special risks -- youngest high risk animals

Management objective:	Possible options
Calving area: *clean, dry calving area*	• use for calving only • adequate size to maintain low cow density • bed routinely between calvings • remove manure ‡ before rebedding • use wide grates and bedding over gutters in standing stalls • if outside lot, remove manure, grade, remove surface seasonally • establish separate calving pastures or lots to make fresh (uncontaminated) areas available
Calf at calving: *prevent ingestion of M. paratuberculosis*	• clip, clean udder and teats before calving • remove calf immediately from cow and calving area • do not let calf search for udder or nurse; attend while cow licks calf, then remove • make easy for all employees to remove calves when seen by moving calves to temporary holding area ("Motel Six") until able to process them properly; construct from straw bales or solid sides; must be easy to move, accessiible, in dry, easy to clean area; can locate "close" to dam
minimize feeding of infective colostrum and milk	• use hygienic milking procedures on clean dry udder and teats • feed 4 qts of colostrum in 2 hrs to all calves *Risk of infection from colostrum and milk from infected cows increases with stage of infection(43,47). Exact risk is unknown, but high in symptomatic animals, significantly lower if assymptomatic, thus:* • do not feed colostrum or milk from animals in advanced infection (clinical signs of Johne's, moderate or many CFUs on fecal culture, higher ELISA OD values): --do not feed to offspring that must be kept as replacements; do not add to pool ed colostrum; • avoid feeding colostrum from *test positive* assymptomatic dams • avoid feeding milk from animals with advanced infection or test positive; do not add to pooled milk • pasteurizing colostrum not practical - too high temperature required to kill *M. paratuberculosis* • freeze colostrum from recent test negative cows ¶ , older healthy cows if untested, to feed to replacements • feed milk replacer or bulk tank milk • prevent manure contamination of stored milk or colostrum: cover in clean containers, in clean area
raise uninfected calves	*Risk of in utero infection is also unclear, but likely high in symptomatic animals (i.e. 25%), thus:* • do not raise replacements from dams with clinical signs, or in advanced infection based on test results • raise replacements from *test negative* animals and born under clean conditions • if raising replacements from infected animals: manage all calving aggressively, feed low risk colostrum • if high prevalence, not raising replacement animals until prevalence reduced can be considered
Calf housing : *minimize exposure when housed*	• house calves in separate facility/location removed from cows, manure, traffic • in same facility as cows, separate calves by distance/ clean buffer zone from cows, manure, traffic • prevent direct contact from manure or splatter w/ solid barriers i.e. plywood (don't impair ventilation) • prevent manure contamination of feed from splatter, traffic, equipment tires, etc • use clean boots and equipment only in calf area • use bootbaths to encourage awareness and hygiene

‡ manure from infectious (shedding *M. paratuberculosis)* is most important source infection. In endemically infected herds all manure should be considered to be infective.

¶ the accuracy of a negative test: declines with time since performed; is lower with increasing prevalence of herd infection (predictive value)

Table 3.2 *Point Four:* Management objectives / options to control spread of Johne's disease (con't).

II. Common risk areas -- youngstock to mature animals
Risk of infection from exposure to *M. paratuberculosis* increases with younger ages, repeated expsoure and higher herd prevalence.

Management objective:	Possible options
Housing/facilities: *prevent exposure to infective animals and manure*	• house youngstock in totally separate facility • do not co-mingle youngstock with mature animals • do not allow youngstock contact w/ mature cows, pens, lots, or manure • prevent contact or manure splatter by distance or solid barrier(s) • locate "upstream" of manure drainage / run-off/ or scrape patterns from older animals • group or segregate test *positive* animals in separate pens, pastures, calving areas, etc. -- contains infective manure, facilitates removal, improves observation, isolates highest risk areas
Feed and water: *prevent manure contamination of feed*	• do not use common feed bunk and waterers for youngstock and mature animals • do not use same loader to clean manure and move feed --obtain second bucket for feed only --wash out and disinfect (note: washing is often impractical) • keep feed handling equipment clean • elevate or curb bunk walls or mangers • clean feed bunks/ mangers daily • keep animals out of feed mangers/bunks • do not refeed adult animal feed that may be contaminated with infectious manure: --feed to older animals if necessary --discard contaminated feed from center of drive thru feed alleys, edges of flat mangers • do not drive thru feed, feed alleys, feed mangers with manure on tires -- clean feed loading pads, cross alleys, equipment, tires -- re-route traffic patterns • do not walk in feed areas/mangers with dirty boots
forage and pasture	*M. paratuberculosis survives (but does not multiply) months to years in soil and environment but is diluted over time if not recontaminated by sun, drying , freezing, turning under*, etc. • do not spread manure on hay growth and graze or harvest in same growing period or season; cut longer if must minimize risk of harvesting manure *Risk of spreading infection in rotational grazing systems is unknown; let common sense prevail:* • minimize conditions that promote ingestion of manure: -- reduce prevalence of infection in herd -- keep stocking rates low / do not over graze -- keep clinical suspects off pasture used by rest of herd -- if prevalence is not low , do not graze young animals after mature animals -- do not comingle young and mature -- keeping test *positive* animals off pasture or separate • evaluate feed programs, feed balanced rations, implement good feeding management
prevent contaminated water or access	• do not use common waterers for youngstock and mature animals • elevate, curb or protect waters from manure contamination • keep water clean: drain and clean waterers routinely • prevent manure build-up around waterers, provide drainage • prevent access to natural water , wet areas that collect manure or runoff from adults: -- remove, drain, regrade, fence off mud holes; remove shade -- fence animals out of slow or stagnant water that is easily contaminated

Table 3.3 *Point Four:* Management objectives / options to control spread of Johne'sdisease (con't).

III. Manure and animal risks	
Management objectives	Possible options
Manure management: *minimize contamination of premises*	• keep facilities and premises free of manure build-up • remove manure more often • haul , store, away from feed, water and young animal facilities; restrict direct access by animals • remove manure from contaminated lots, remove top surface , regrade • assume "all manure is guilty" if moderate or high prevalence of infection • use tuberculocidal (phenolic or cresylic base) disinfectants to clean surfaces after manure has been removed (organic matter inactivates disinfectants); use bootbaths
Replacement heifers: *recognize increased risk of shedding*	• in high prevalence situations heavily exposed youngstock may shed: -- prevent contamination of feed bunks, mangers, waterers with own manure -- clean more often; more thoroughly; prevent manure build-up -- consider not raising replacements until prevalence reduced
Mature animals: *eliminate high risk animals* *manage test positive animals*	• segregate, test, and / or cull all animals with clinical signs of Johne's ASAP • manage known assymptomatic infected animals to reduce premise contamination: -- visibly identify test *positive* animals -- target to cull *subclinical* test *positive* animals as soon as justified, before infection is advanced -- designate test *positive* animals as Do Not Breed • in high prevalence herds consider grouping : -- group test test positives and cows to be culled -- segregate test *negative*, low risk animals from rest of herd • monitor infection: record number, age of clinical cases • monitor cow/calving area exposure: newborn calf contact (time), assess exposure observed
Acquired animals: *"Buyer beware"* *minimize risk of introducing infected animals*	*Buyers should beware . Producers and veterinarians should to use several measures to minimize the risk of introducing Johne' s disease, and encourage others to do so as well. Excluding risk is difficult; management to prevent transmission in the herd should prevail.* • inquire about source, general management, hygiene and health of herd(s) of origin • inquire about history or suspicion of Johne's disease: when, number cases, raised/purchased, ages, methods of diagnosis • assess risk in own herd first - are introduced or raised animals higher risk? • look for individual herds, or a few known sources, that are lower risk for significant infection: -- certified repeated test negative herds (29,38) -- herds with a current or previous negative herd test -- herds with low prevalence on a herd test, no history of clinical disease, or only isolated cases in older or purchased animals, and practicing preventive management -- herds with no history of Johne's, or isolated older cases, practicing preventive management *Serology and fecal culture have poor sensitivity in immature animals unless heavily exposed. Single negative tests in individuals provide little assurance of infection status. Testing a group of animals or the herd with same farm background yields a profile of exposure that may be valuable.* • prior to purchase: --screen individuals or groups w/ serology; if high don't buy --test by fecal culture, make sale contingent on negative result • on arrival : -- "segregate"/ prevent oral-fecal contact with young animals -- test immediately; all introduced animals should ultimately be tested by culture and serology
Additional benefits of Johne's management to the herd:	Management options to control risks for spreading Johne's disease such as strict calving and manure management, improved calf and heifer managment, better feed management, closer observation etc, can be targeted to enhance other priorities as well , such as mastitis contol , cleaner facilities and cows, improved calf and heifer health and growth , improved dry matter intakes etc., and thus promote desired improvements in overall herd health and performance.

Point Five. Consider herd testing options.

Despite the limitations associated with the performance, interpretation and cost of Johne's tests, herd testing is useful to control the disease and/or certify herds to have a significance assurance of being free of infection (National Certification Program).[29] The most effective control programs employ both preventive management and testing strategies. Individual farm control plans should attempt an appropriate balance between the two. As prevalence increases, management and testing approaches will need to be more aggressive to establish control. Testing with culling or segregation of infected animals is the second, and potentially a powerful component of Johne's disease control programs. It is the means for most rapidly reducing the prevalence of infectious animals and contamination of the environment (control objective 2.). Consequently, the effectiveness of ALL preventive management measures is enhanced by testing, and removing, segregating, or managing known infected animals.

Testing strategies can be flexible, although options and limitations can make test decisions confusing. Several issues influence choice of herd testing strategies: type or combination of tests; frequency; use of test results (to cull, segregate, or manage positive or negative animals or groups differently); determining animals to be tested (herd, groups, introduced animals, age); cost of testing.

How herd testing could be used to reduce the number of infectious individuals, their contamination of the environment, and enhance preventive management should be considered for each risk area during the discussion of management options. Testing is not required to control Johne's disease, however, without it, stricter preventive management options will need to be considered to achieve a degree of control similar to that possible from the two approaches combined. The benefits of testing, the commonly used tests, and several herd test strategies that should be considered are summarized under the following questions.

What are the benefits of testing? Several benefits justify the investment in herd testing, at some point, in most earnest control efforts. Test results provide an estimate of the prevalence[a] and extent of infection in the herd, which is important in judging the effort needed for control. Result profiles by age, origin of the individual, or magnitude of antibody or shedding reveals patterns and clues about herd infection and assists interpretation of results in individuals. Test status can be used to target culling and management decisions. Repeated testing is a more sensitive monitor of infection than incidence of clinical disease. Herd testing is an educational process, such that producers and veterinarians understand Johne's disease and the objectives and means for control in their operations better as a result. A strategy based on fecal culture and/or ELISA serology can be chosen to cost-effectively assist any producer desiring to control the spread of Johne's disease.[30]

What tests are used for herd testing? At present, ELISA serology[6,13,17,19,42,54] and fecal culture[8,25,41,52,54,55] are most commonly used for herd testing. The sensitivity (proportion of infected animals the test correctly detects) of the two tests is comparable, approximately 40-50%; (a single test fails to detect half or more of the infected animals in a herd.) The two tests, however, are different:[13,17,54] ELISA measures antibody (indirect) response to infection and is quick and less expensive ($4-8); fecal culture detects shedding of the *Mycobacterium paratuberculosis* organism (direct) in feces, requires 8 to 12 weeks for a culture result, and is more expensive ($7 - 25). ELISA and fecal culture detect partly different groups of infected animals. Both tests detect animals in advanced stages of infection, but they correlate less well in mid - stages of infection. Early subclinical infection in adults and young (less than 18 months) animals are likely to be missed by both. Fecal

[a]true prevalence of infection is approximately equal to herd test prevalence divided by the sensitivity of the test used; true prevalence is therefore more than twice the test prevalence by ELISA on fecal culture.[38]

culture methods utilizing centrifugation of samples[8,25,47,54,55,57] detect earlier stages of infection, in which animals are shedding relatively few organisms (10-10^2 Colony Forming Units/gm (CFU)) and do not have antibody responses detectable by ELISA. Fecal culture has an advantage when detecting infected animals is a high priority.[19,47]

The sensitivity of both tests will be greater in high prevalence herds where more animals are in later stages of infection. However aggressive early control of Johne's disease is limited by the generally low sensitivity of the tests and inability to detect subclinically infected animals without repeated testing.

The specificity (proportion of non-infected animals the test detects correctly as negative) of is considered 100% for fecal culture and 99% for ELISAs, based on the reported positive/negative interpretation.[a 6] Both tests carry a high degree of confidence that test positives are infected. False positives (i.e. 1/100 tested) can occur with the ELISA, resulting in a low predictive value of positive tests when actual herd prevalence is low. The 100% specificity of fecal culture is an advantage for identifying animals in earlier stages of infection and low prevalence situations.

Laboratories routinely report results for ELISA and culture as "positive" or "negative" however, quantitative results provide more information and a profile of herd infection.[13,19,47,54,57] Colony forming units/gm (CFUs) and an interpretation i.e.. few, moderate, or many should be requested for culture. Numeric optical density (OD) values (reflecting magnitude of antibody), and the OD cut-off value[b] for the standard interpretation, should be requested for ELISA. Numeric OD values require more judgement to use but can be interpreted relative to the standard cut-off.[19,54] The probability the animal is infected increases with increasing OD values and declines as OD units get lower, which gives producers knowledge about animals with elevated OD values that are below the standard "positive" cut-off.

Which animals should be tested? Testing the mature herd gives the most efficient complete information about herd status and a context for interpreting individual results. Infection is unlikely to be detected in immature animals (<18 months) unless infection is severe. The herd can be tested all at once; or in groups, intending to test the entire herd over time. Considerations may be convenience or utility of results at a particular time i.e. calving, pasture, breeding or culling times. A subsample of the herd may be tested which represents animals at higher risk or to be managed differently such as individuals or age cohorts exposed to infected animals or their environments, individuals with clinical signs, animals from a suspect source, or animals to be segregated as lowest or highest risk. One caution is that infection is often clustered by age, exposure, time, or familial association, depending on how the disease has spread, and herd infection may not be adequately represented in a particular or statistical subsample. If Johne's disease control is in place in the herd, producers should beware when adding animals from the outside and take steps to reduce the risk of introducing new infection, by obtaining a history on the source ahead of time and testing.[5,39] All entering animals (unless from a certified negative herd) should be tested with ELISA serology and fecal culture, prior to or shortly after entry, and segregated from youngstock.

How often should the herd be tested? Testing should be undertaken as needed depending on objectives. A typical approach is to test the herd once initially to estimate prevalence, impact, distribution, and the need to control infection. Subsequently, preventive management may provide adequate control. The alternative is repeated herd testing, which is recommended for any aggressive control program. Updated test information permits control decisions to be more current and effective, and infection in individuals and the herd to be tracked. Reasonable intervals between herd tests may range from 2-3 times per year to every 2-3 years, based on goals and resources. A third strategy is no herd testing, but control is more difficult to target without knowing the extent of the problem. Accurately monitoring suspect and clinical cases is a more crude but valuable indicator for tracking Johne's disease. Whether herd testing or not, **all** farms should record **all** suspect and clinical cases and pursue adequate diagnostics to clarify the incidence.

What do results mean? Interpreting and deciding actions to take based on ELISA or fecal culture results can be confusing. Judgement is required to use tests in best accordance with the expectations of each situation. On a herd test, ELISA positive (single cutoff) and fecal culture moderate/many CFUs results will identify a majority of the most infectious animals, who are in "later" stages of infection and more likely to develop clinical disease within weeks to 1-2 years. Decisions to cull or segregate these animals for the purpose of control can be made with confidence. However, due to the prolonged subclinical course of the disease, lower values on either test do not characterize as well the extent to which animals may be infectious (shedding), likely to develop clinical Johne's disease, or tolerate or resolve their infection. The majority of these animals are likely to appear healthy and productive at the time. Quantitative results, multiple tests, and repeated testing is necessary to know more about the status of these individuals. Thus, risk and economic factors must be considered in prioritizing decisions about test positive animals. Since their course is unclear, ac-

[b]Reported sensitivity and specificity are based on using a single optimal cutoff to categorize the ELISA result as positive or negative. An optimal OD value is used that gives the best sensitivity and minimal false positive results (best specificity). This is the standard reporting method for the IDEXX *Mycobacterium paratuberculosis* ELISA test kit which has a sensitivity of 40-50% and a specificity of 99%. This is a USDA licensed test kit performed by many laboratories (IDEXX Labs Inc., Westbrook, Me.)[6]

tion on animals suggested to be in "earlier" stages of infection should be decided with caution. Whitlock[57] documented that less than thirty percent of fecal "light shedders" became clinical in a two to four year period, and some appeared to have resolved the infection. These animals would not be expected to have antibody.[19,47] Interpretation of test negative animals as uninfected is also difficult due to the low sensitivity of the tests. Assurance increases only with repeated negative tests and or low herd prevalence situations.

How can results be used? Test positive animals can be handled in three ways: either culled, managed differently, or not managed any differently.

Testing and culling of infected animals, especially with advanced infection, has a potent effect on Johne's disease control by immediately reducing the prevalence of animals that are multiplying *Mycobacterium paratuberculosis* and spreading the infection. Animals detected in "later" stages of infection are likely to be shedding billions (10^5 to 10^{12}) of organisms[3] per gram of manure, log quantities greater than animals with less advanced infection (10 to 10^2).[57] These and other test positive animals should be culled ***before*** they develop advanced infection (the point at which they cull themselves) and segregated if not culled. This should be the minimal test and cull policy in any herd. Offspring of animals with advanced infection should not be used as replacements due to high risk of infection due to inutero, colostral or oral-fecal routes.[35,36,44,48,49] Waiting to remove animals until clinical signs are advanced has little control impact and forfeits salvage value. When preventive management is in place, control of Johne's disease will be more rapid and efficient to the extent infected animals that are actively spreading infection are removed.

Despite its effectiveness, the test and cull approach to Johne's control is frequently limited by short term economics, where production losses and replacement costs are prohibitive. However, in the long run, test and cull in addition to preventive management will establish Johne's disease control most rapidly.

Thus, post-test decisions frequently include some culling, combined with managing the remaining positive animals in a variety of ways to reduce spread of the infection. Physically segregating test positives, particularly those that are more likely to be shedding, in the same or a different facility, or on a separate pasture contains infectious manure and reduces exposure to other animals. Segregation may be impractical for some management systems, or there may be too few positives to make a group.

Early removal of Johne's test positive animals from the herd can be facilitated by other means including visibly identifying positives, using test status to prioritize earlier culling, and not re-breeding. Management of offspring by the test status of the dam may be appropriate such as culling offspring and feeding colostrum (and freezing extra) and milk from test negative animals only. One caution is that test status must be kept up to date (every 6-12 months) for these interventions to remain effective, particularly in higher prevalence herds. Producers must avoid the trap of focusing on known positives and overlooking the risks associated with undiagnosed infected animals the herd. In higher prevalence herds, it is more accurate to regard **all** animals as possibly infected and shedding.

It can be expected that often no specific action to aid Johne's control is taken on test positives that are productive, less infectious according to test results (few on fecal culture or moderately elevated ELISA), or that leave the herd for other reasons. On the other hand, if test status is *never* used to remove test positive animals from the herd earlier, the utility of testing in the control program is negligible.

What test or combination of tests to use? ELISA serology or fecal culture can be used alone for herd testing. The choice depends on the issues mentioned here and the producer's objectives (*Point Six* and *Seven*). The tests can also be used together. When used at the same time (in parallel), sensitivity (approximately 70%),[13,35,38,54] characterization of stage of infection in the individual, and expense is greatest. The two tests can also be used in sequence (in series). For example, the mid-expense option on the New York State Paratuberculosis Program includes an ELISA screen of the whole herd followed by fecal culture of animals with elevated ELISA ODs, who considered at higher risk of advanced infection.[19] Infection is better characterized for animals receiving the two tests, which helps prioritize decisions. Serology and culture may also be alternated every other herd test to average the cost and detect a slightly different population of infected animals each test.

Are the costs of herd testing justified? Herd testing is expensive and likely to be the biggest cash cost in a Johne's control program. Fecal culture is 2-3 more times more expensive than ELISA, thus performance aside, cost is the major factor complicating the choice of tests. Furthermore, repeated herd testing is desirable for more rapid success of any serious control program. Returns on testing may not be recovered until prevalence and cost of disease declines, i.e. in 2-5 years. However, in higher prevalence herds, return on testing may be recovered in the short term in salvage value alone if test results are used to remove suspect animals in good condition. Owners of large and small herds often view the immediate cash cost as prohibitive, however, appropriately designed control programs are justified by the longer term returns in health and production. Collins' economic decision analysis illustrated that test and cull was profitable at a prevalence of 5%

taking into account expected losses in production and salvage, and replacement and test costs.[10] Although effective use of test strategies to reduce contamination enhances the effects of preventive management, some producers' objectives may not may not justify costs. The eight point approach is intended to help producers and veterinarians determine the value of Johne's control and the resources that should be dedicated. Several good reviews compare tests and their costs.[10,13,17,54]

In addition to test performance, interpretation, and use, the choice of the most appropriate test for the farm depends on the objectives (*Point Six*) and intensity of the control program (*Point Seven*), and the effort the producer wants to commit (Point Eight). These last steps attempt to match expectations with building a control plan that is realistic.

***Point Six.* Identify objectives and timeline for Johne's disease control programs.**

By this point the producer should be able to specify the objective (preferably measurable) that he or she wants to accomplish with regard to Johne's disease control. Producers must "own" their objectives for Johne's control if they are going to sustain the prolonged effort and commitment required to be successful. Control objectives will vary with the farm depending on the perceived or predicted impact of the disease on farm objectives, thus the perceived need and benefits from control, and available resources. Objectives may range from a desire to increase awareness to aggressive eradication.

Less-aggressive control objectives i.e. to increase awareness, confirm the diagnosis, prevent increased spread, may have minimal impact on disease but may be appropriate starting points for low prevalence, commercial or uncertain farm business situations. More aggressive control objectives may include to reduce spread, prevalence, clinical disease, and/or associated costs and would require changing the pattern of infection. They may be appropriate goals for varied sizes and types of operations i.e. purebred, commercial, dairy, beef, etc. Aggressive control goals may target the practical elimination of infection, or test negative certification and might be adopted by operations with strict objectives i.e., to market uninfected animals or close the herd. The producer's objectives should be a key determinant in deciding the testing, culling, and management elements of the control plan.

Secondly, the producer should estimate the time in which he or she wants to achieve the Johne's control objectives i.e. before passing the farm on to children, expanding the herd, selling breeding stock. Although time (years) required to control Johne's disease is difficult to anticipate, the desired time frame will influence how aggressive the control program needs to be. Alternatively, the time will be shorter or longer depending on the prevalence and how effective the control program actually is. Table 4 illustrates example objectives and time ranges that might be expected[11,12,26,30,34,35,50] to achieve them in a herd with moderate endemic infection.

Table 4. Example control objectives and expected time to achieve

Typical Johne's disease control objectives	Time to achieve
Practical control program to reduce to low prevalence	3-7 yrs
Eliminate infection and reduce prevalence to zero	7-15 yrs
Reduce and eventually eliminate clinical Johne's disease	2-5 yrs
Maintain status quo prevalence or slightly reduce	ongoing, indefinite

***Point Seven.* Considering the "intensity" desired of the Johne's control program.**

The answer to the question of what a producer should do to control Johne's disease depends on the intensity or scope of the control effort that will be required to meet the needs of the producer and situation. Four elements dictate the intensity of the control program that the producer might desire (whether or not is it feasible with the resources):

1. estimated ***prevalence and endemicity*** of Johne's disease in the herd (i.e. characterized as low, medium or high)
2. magnitude of Johne's disease ***exposure risks*** in the farm's management that require control (characterized as low, medium or high)
3. producer's ***control objectives*** (characterized as non, moderately or very aggressive)
4. ***time frame*** to accomplish control objectives (short, intermediate or long term).

Taking these elements into account the intensity or scope of the desired control program can be characterized as low, moderate, or high. It is a useful exercise for the producer to consider the intensity the control program might require to meet their objectives and farm's circumstances which have been illuminated in *Points One* to *Six*.

Intensity characterizes the level of control specific measures in the control program need to accomplish. Ultimately, the intensity of the final Johne's control plan will be dictated by the resources and management effort the producer is able or willing to commit. Frequently however, no analysis is given to whether expectations or the needed intensity match with resources, which makes success even less probable when they do not. Comparing intensity to resources as the farm plan is constructed in *Point Eight* should serve as a feasibility check on the expectations for Johne's control plans. Producers expectations must be realistic with regard to resources to be committed or the expected intensity and/or the resources should be reconsidered. Producers' objectives and time frames are most flexible to change, whereas herd prevalence and risk conditions have a more fixed influence on efforts required to control Johne's. This reinforces the value of knowing the herd prevalence to more accurately anticipate the intensity required and develop more efficient control plans. For example, high intensity control will be indicated when control objectives are aggressive, herd prevalence is high, time frame is short, and/or the number of risk conditions is great. The intensity (and feasibility) of control required will be considerably less for the high prevalence situation if control objectives are more moderate, time frame is longer and/or risk conditions are fewer.

***Point Eight.* Design, implement and evaluate the Johne's disease control plan.**

Designing the farm plan. Characterizing the farm and understanding Johne's disease and the farm situation has been an essential preliminary to defining the appropriate control measures. The following considerations guide the process of choosing the specific measures to be included in the final control plan:

1. ***Characterize the intensity*** desired from the control plan and match to the resources and efforts to be committed.
2. ***Choose a herd testing strategy*** . Frequency can be decided based on results, intensity desired and resources.
3. ***Decide how test results will be used*** to cull, segregate or manage.
4. ***Pick the best management control options for each risk.*** Weigh effectiveness, practicality to implement, and other health and performance priorities that will benefit . Table 3 lists possible options to consider.
5. ***Identify specific resources*** including management skills, labor of individuals, facilities, and finances, and testing required to implement each measure. Confirm that adequate resources are available.
6. ***Balance testing, management, and culling with intensity and resources.*** Test and cull programs permit more rapid and effective control of Johne's disease by reducing prevalence. However, at the level where test and culling is not economically feasible, management measures form the major component of the control program. Control programs with no or minimal testing must rely on preventive management, and monitoring and managing clinical disease.

Management systems dictate the balance. For example, the emphasis in a beef herd may be to reduce prevalence by testing and strategic culling, followed by cleanup of high density contaminated premises and use of segregated pastures. Commercial dairies may enhance existing management routines to control the highest risks such as calving pens and practices, and feed contamination, and may make additional improvements in areas where they are generally overdue such as heifer facilities. Herd prevalence also influences the balance. Control using testing, culling and reducing exposure risks is quick when prevalence is low, and prolonged when it is high. In high prevalence herds, test and cull or management alone is less likely to control the disease; aggressive measures such as depopulation of the herd or high risk groups, or not raising replacement heifers may need to be options for intensive control. Table 5 illustrates example control measures for different intensity control programs.

Table 5. *Point Eight:* Examples of specific control measures that might be used in farm control programs of different intensities

Control program components	Intensity of farm control program (‡)		
	Low	**Moderate**	**High**
Test selection **Test strategy**	• lower Se/Sp, less expensive test • initial mature herd screen, partial herd (high risk animals) • monitor clinical suspects	• 1-2x/yr >20-24 mos of age • serology, fecal culture; serial or alternating • clinical suspects	• 2-3 X/yr > 18 -24 mos of age • multiple tests; maximize sensitivity, specificity
Test result use: ***Culling***	• clinical suspects • high risk test *positives*	• clinical suspects immediately • subclinical test *positives* priority by test result, other problems, production, economics • consider for offspring of clinical dams	• clinical suspects immediately, segregate prior to decision • aggressive early culling of subclinical *positives* before infection advanced or clinical disease • consider for offspring of test *positive* dams • consider not raising replacements until prevalence is reduced
Manage test positive animals	• monitor *positives* for signs • use for culling criteria	• identify • segregate or group • do not feed milk or colostrum, consider replacer • do not breed higher risk *positives*	• same as for moderate, more aggressively • based on updated test results • separate calving area
Management	• calving area density /hygiene • remove newborn calves • prevent young stock contact with adults and manure • minimize feed and water contamination	• calving area density/hygiene • remove newborn calves immediately • separate youngstock and adults w/ barrier or in separate facility • prevent feed, water, equipment contamination	• superior calving mgmt. and hygiene • remove all newborn calves immediately • separate young stock from adults completely • feed banked colostrum from test *negative* animals to offspring of subclinical of *positives*, if raised • feed replacer or milk from *negative* cows only • eliminate feed, water and equipment contamination
Coordinate w/ other management priorities	• improve general mgmt in priority areas: dry cows, calving , heifers, nutrition	• focus mgmt to improve performance in related areas: dry cow nutrition, calving, calves, heifers, mastitis, reproduction, cow comfort	• improve health and performance in other areas for quicker response; offset effects of Johne's i.e. mastitis, reproduction, nutrition • optimize management i.e. feeding and nutrition, dry cows and calving, heifers • minimize stress, improve comfort

‡ Intensity (*Point Seven*) or scope desired in the farm control programs is determined by: prevalence and endemicity of Johne's disease , magnitude of exposure risks, producer control objectives and time frame, and commitment and allocation of resources.

7. ***Coordinate Johne's control with good management practices in related areas.*** The Johne's plan should include in its' priority list, improvements that are needed in related high priority areas such as feed quality and feed programs, mastitis control, cow comfort, lameness problems, etc. Returns from these efforts as improved animal health, productivity and profit will occur more rapidly than reductions in Johne's disease, while healthier animals will help minimize the impact

of Johne's disease infection. Johne's disease can be the extra incentive to generally improve the level of management in several areas.

8. ***Write the plan down.*** A simple written plan launches action, reminds, and can be evaluated and modified. Well designed Johne's plans are useful for a long time.

Implementing the plan. A team of people responsible for the daily management of the farm should be involved in developing, implementing, and monitoring the farms Johne's plan i.e. the owner, family members, farm personnel, veterinarian, nutritionist and other valued advisors. An individual should be responsible for implementing and monitoring each control measure, and standard practices should be established and posted.

It is usually practical to implement the plan in steps. Control measures should be prioritized by the importance of the risk to be controlled, ease and cost to implement, effectiveness, other health and production incentives to implement, etc. For example, reconstructing the calving area may be most important in the long run but be prioritized after easier effective measures, such as acquiring a second skid loader bucket to use for feed only, constructing a solid wall between dry cows and heifers, or creating a temporary holding pen to make it easy to remove newborn calves from the calving area.

Evaluating the plan. Well designed Johne's disease control plans remain applicable for a long time but should be periodically evaluated.

Initially, the team should be responsible to assure that measures are implemented, standard practices become routine, and problems are identified so that plans can be modified accordingly. In addition, a system should be set up to record the following information (described in *Point Two*) for monitoring Johne's disease and control efforts:

1. herd test results; prevalence, distributions, comparisons
2. suspect and diagnosed clinical cases; data outlined in *Point Two*
3. cull cows; condition, salvage price, value, reason, Johne's disease-related.

The team should review that the plan is working at useful intervals, i.e. every six months, seasonally etc. and modify as developments and new information suggests. Changes in prevalence or clinical disease requires months or years to become apparent, however once established as part of the routine, control efforts become easier to sustain.

The control of Johne's disease is complicated by uncertainties in the epidemiology, diagnostic tests, costs of disease, effective control strategies, and in how to integrate Johne's disease control as a beneficial process on the farm. However, existing knowledge and tools are adequate to control Johne's disease cost-effectively. This *eight point process* outlines a practical but thorough approach that reviews the farm operation and Johne's disease situation, educates the producer and veterinarian, and leads to development of a control plan that fits the individual farm. The hope is that by offering this approach (which could apply to other health management issues as well) veterinarians will be encouraged to assess Johne's disease and its potential impact in their herds with their clients sooner, and help them establish good preventive management practices and practical control plans to prevent its insidious spread.

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