United States
Department
of Agriculture

Animal and
Plant Health
Inspection
Service

**Veterinary
Services**

Johne's disease
on U.S. Dairy Operations

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NAHMS Dairy '96

October 1997

Study Collaborators

- USDA:Animal and Plant Health Inspection Service (APHIS):Veterinary Services (VS)
  - Centers for Epidemiology and Animal Health (CEAH)
  - Veterinary Medical Officers and Animal Health Technicians in Dairy ‘96 Study states
  - National Veterinary Services Laboratories
- USDA:National Agricultural Statistics Service (NASS)
- State Veterinary Medical Officers in Dairy ‘96 Study states
- National Johne’s Working Group
- Dairy ‘96 Study participating producers

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Abstract

Objective (as part of the NAHMS Dairy '96 study)**:** Assess dairy producer awareness of Johne's disease, estimate national and regional herd-level prevalence of *Mycobacterium paratuberculosis* infection, estimate economic losses due to Johne's disease on dairy operations, and describe use of recommended preventive measures on U.S. dairy operations.

Design: Population-based cross-sectional study.

Sample population: U.S. dairy operations with at least 30 milk cows in 20 states representing 79.4 percent of U.S. dairy cows.

Procedure: Questionnaires were administered to dairy managers and blood samples collected from milk cows by veterinary medical officers and animal health technicians at herd visits. Sera were tested for antibodies to *M. paratuberculosis* using a commercially available ELISA.

Results: Results showed lack of widespread recognition, testing, and use of herd certification programs for Johne's disease by U.S. dairy producers. From serologic testing and use of herd historical information, the best estimate of herd infection prevalence of *M. paratuberculosis* on U.S. dairy operations was 21.6 percent. Herd size differences were apparent, however, with higher infection prevalence in larger herds. Economic analyses showed the annual adjusted value of production was over $200 per cow for positive herds with at least 10 percent of their cull cows showing clinical signs consistent with Johne's disease.

Implications: Johne's disease is endemic in U.S. dairy operations, although there appears to be many herds at low risk or free of *M. paratuberculosis* infection. Cost of Johne's disease to individual affected herds can be large, and the national average cost across all herds is $22 per cow. With implementation of preventive strategies, progress to reduce prevalence of Johne's disease is possible. However, a broad educational effort is first needed to increase disease awareness among dairy producers which would help encourage implementation of such practices.

Introduction

What is Johne's disease?

Johne's disease, or paratuberculosis, is a chronic infectious disease of domestic and exotic ruminants, including dairy and beef cattle, sheep, goats, cervids, and camelids. The disease, caused by *Mycobacterium paratuberculosis*, occurs worldwide. *M. paratuberculosis* is a slow-growing bacteria that causes thickening of the intestinal wall of cattle which reduces absorptive capability. Johne's disease in cattle and other species is characterized by chronic, granulomatous degenerative enteritis that causes intermittant but persistent diarrhea, progressive weight loss, and eventually, death. The disease is untreatable and slowly progressive.

A U.S. national study in 1983-84 showed a 2.9 percent prevalence of infection in cull dairy cows, based on culture of ileocecal lymph nodes collected from culled dairy cows at slaughter (Merkal et al, 1987). Other studies have shown cow-level prevalences of 17.1 percent (Braun et al, 1990), 7.2 percent (Whitlock et al, 1985) and 4.8 percent (Collins et al, 1994), using either culture or serologic methods. Prevalence estimates from only one of these studies (Collins et al, 1994) was adjusted for test sensitivity and specificity, creating further difficulty in comparison across studies. Only one of these studies evaluated herd infection prevalence, estimated to be 34 percent of Wisconsin dairy herds (Collins et al, 1994).

Johne's disease is found in almost all countries around the world. Exceptions may include certain regions of Australia and Sweden (Collins and Manning, 1995). The Australian states of Queensland and Western Australia and the Northern Territory have been considered lower risk regions for Johne's disease, although these regions contain less than 15 percent of the dairy cattle in Australia (written communication, Australian Bureau of Statistics, 1995-96). Sweden has employed Johne's disease test and cull control policies to maintain lower risk status.

Why is Johne's disease important?

On dairy operations, economic losses occur through premature culling, reduced milk production, and body weight losses in slaughtered cattle, among others. In a recent summary of production studies (Nordlund, 1996), milk production losses alone ranged from 2 to 19 percent reduction in milk yield in Johne's-positive dairy cows compared to herdmates.

Although Johne's disease has been reported from virtually all countries around the world, to date no major restrictions in international trade have been created due to the disease (Collins and Manning, 1995). Expanded efforts to control this disease, including regulatory programs in some states, may lead to future market restrictions.

How is Johne's disease spread?

M. paratuberculosis is usually introduced to dairy herds through the purchase of infected though clinically normal cattle (Sweeney, 1996). Other methods of herd-to-herd spread such as introduction of contaminated feces to the operation by vehicles or equipment are possible, though less likely in practice to be the initial source of infection.

Once *M. paratuberculosis* is present on a dairy operation, calves under 6 months of age are the most susceptible animals and most infections are assumed to occur at this time. Transmission of infection occurs mainly through the fecal-oral route, but may also occur via colostrum, milk, and through the placenta in utero. A primary method of transmission of infection is through fecal contamination of the calf's environment, including contamination of milk and feed, resulting in oral ingestion of the agent by the calf. In addition, both clinically affected and normal appearing infected cows may shed *M. paratuberculosis* in their colostrum and milk, especially in the later stages of infection (Sweeney et al, 1992; Streeter et al, 1995). This route can be a source of infection for replacement calves when pooled milk or colostrum is fed. In addition, calves born to clinically ill, infected cows and normal-appearing, infected cows may have been infected in utero (Seitz et al, 1989; Sweeney et al, 1992).

How can Johne's disease be controlled?

For herds free of Johne's disease, the best method of prevention is to avoid introduction of infected cattle, either through maintaining a completely closed herd or to carefully screen introduced cattle. Purchasing cattle only from certified, Johne's disease-free herds is preferable to testing cattle to be introduced before entry due to the low sensitivity of available tests on an individual animal basis.

For herds with existing Johne's disease, within herd transmission can be limited through changes in calf and heifer management (Goodger et al, 1996) and by culling infected cows prior to parturition to prevent in utero transmission. A Johne's control program requires a herd plan specific to the operation (Rossiter and Burhans, 1996) and is a long-term strategy, since current detected cattle were likely infected at least 2 to 3 years previously. Additional information about Johne's disease control begins on page 43 (adapted from "Johne's disease: paratuberculosis in cattle", a flyer by the Animal Health Commission, Pennsylvania Department of Agriculture.

Johne's disease herd certification is an option for producers, especially for those selling breeding stock. In 1993, a Task Force of representatives from the cattle industry, universities, and regulatory veterinary medicine developed the National Paratuberculosis Certification Program as a recommended uniform model for certifying herds as low risk for Johne's disease. This program involves repeated testing of all cattle over 24 months of age to assure marketing low risk cattle to other dairy producers.

Industry concern about Johne's disease has increased in recent years due to a desire to expand and protect international markets for U.S. dairy and beef cattle and to mitigate the economic impact of Johne's disease on U.S. producers. A few other countries are already addressing the problem of Johne's disease in their cattle and sheep through implementation of market assurance, control, or eradication programs.

Due to industry interest and concern regarding the perceived economic impacts of Johne's disease, several states have implemented Johne's disease programs, usually with an educational focus and sometimes involving movement controls on test-positive cattle. In addition, the U.S. Animal Health Association created a National Johne's Working Group to assess available information and enhance development of a strategy for a national preventive program. Successful employment of such a program, however, requires improved information in the following areas:

- Level of producer interest and knowledge of this disease,
- Current prevalence of Johne's disease infection nationally and regionally to serve as a baseline for future control efforts,

- Economic impact of Johne's disease on dairy operations, and
- Demonstrated preventive and control strategies on dairy operations.

NAHMS Dairy '96 Study

The National Animal Health Monitoring System (NAHMS), conducted by the U.S. Department of Agriculture:Animal and Plant Health Inspection Service:Veterinary Services (USDA:APHIS:VS), in collaboration with many others within the livestock and poultry industries, provides information on animal health and related issues. NAHMS activities include implementation of periodic national studies to address issues of concern.

NAHMS received broad industry support to utilize the Dairy '96 Study, conducted during 1996, to collect information regarding Johne's disease on U.S. dairy operations. This health problem was identified as a priority by focus groups representing dairy producer groups, veterinary and dairy scientist groups, USDA:APHIS, and the National Johne's Working Group to support the development of herd preventive programs directed towards *M. paratuberculosis.*

Objectives of this study were to:

- Assess producer awareness of Johne's disease.
- Estimate national and regional herd-level prevalence of *M. paratuberculosis* infection.
- Estimate economic losses due to Johne's disease in dairy cattle.
- Evaluate associations between specific management practices and herd-level *M. paratuberculosis* prevalence (analysis ongoing) and prevalences of use of these management practices.

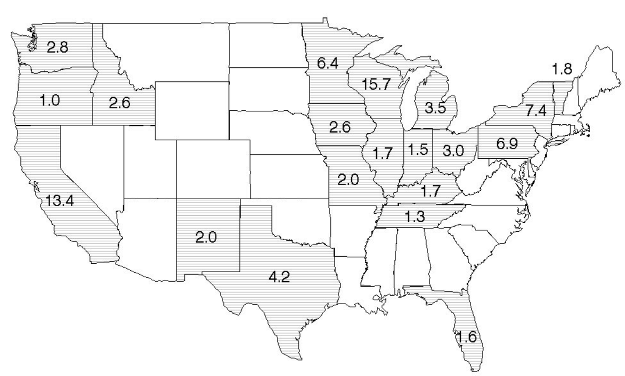
Methods

These objectives were met using the following study framework:

Baseline management questionnaire phase

USDA:National Agricultural Statistics Service (NASS) enumerators visited a stratified random sample of dairy operations in January 1996 in each of 20 selected states that represented 83.1 percent of U.S. dairy cows (see map). A NAHMS Dairy '96 baseline questionnaire was administered at each operation to collect dairy health and management information (USDA, APHIS, 1996a) and changes in health management since 1991 (USDA, APHIS, 1996b). Participation by dairy producers was voluntary and individual producer results remained confidential. A total of 2,542 dairy producers participated. At the conclusion of the interview, producers with at least 30 milk cows were asked to participate in the second phase of the study. If producers were willing, the names were turned over to USDA:APHIS.

Percent of U.S. Milk Cow Inventory, January 1, 1996, for States Participating in the NAHMS Dairy '96 Study



Total = 83.1 percent of the U.S. milk cow inventory.

Health management questionnaire and biological sampling phase

From February through May of 1996, each participating dairy producer was visited by a USDA:APHIS or state veterinary medical officer or animal health technician. At the herd visit, the producer completed a questionnaire assessing producer familiarity with and recognition of Johne's disease and use of management practices associated with the disease, such as aspects of maternity management, heifer management, and introduction of cattle to the operation. Other study objectives from this visit have been reported previously (USDA, APHIS, 1996c). Again, participation by dairy producers was voluntary and individual producer results were confidential. A total of 1,219 dairy producers participated in this study phase.

Additionally, blood samples were collected from a random sample of milk cows on participant operations during the visit and sent to the USDA:APHIS:VS, National Veterinary Services Laboratories for *M. paratuberculosis* testing using a commercially available enzyme-linked immunosorbant assay (ELISA, IDEXX Laboratories, Westbrook, ME). This test has a reported test sensitivity of 45-50 percent and test specificity of 99.0-99.7 percent (Collins and Sockett, 1993; Sweeney et al, 1995). In this study, single well per sample testing was used, using the test protocol provided by the manufacturer.

To detect at least one positive sample within the herd with 90 percent confidence, if the herd had at least a 10 percent actual prevalence of infection (5.3 percent measured prevalence), the following sampling strategy was used:

Herd Size (Number Cows)	Number Samples/Herd
30-49	25
50-99	30
100-299	35
300 or more	40

A total of 1,004 dairy producers voluntarily responded to the administered NAHMS Dairy '96 Study questionnaire and blood sampling. The data were weighted to represent dairy producers with at least 30 milk cows in the 20 sampled states, representing 79.4 percent of the U.S. dairy cow population.

Nonresponse analysis showed that producer response from the first phase of the study to this one was related to herd size (slightly higher in larger herds), region (lower in the southeast), Dairy Herd Improvement Association (DHIA) participation (higher for DHIA herds), and rolling herd average milk production (higher for higher-producing herds). Analysis weights were adjusted to account for differences in response by herd size, region, and DHIA participation levels. Differences in response rates by rolling herd average milk production were not significant after adjusting for these other variables.

Terms used in this report

Cow level: estimates provided as percent of cows across all dairy operations.

Herd level: estimates provided as percent of dairy operations.

Herd sensitivity: percent of infected herds that test positive by test procedures.

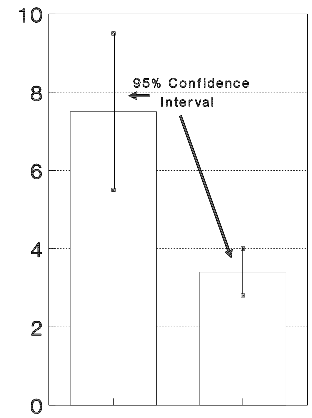
Herd specificity: percent of uninfected herds that test negative by test procedures.

Operation Average: the average value for all operations; a single value for each operation is summed over all operations reporting divided by the number of operations reporting.

Optical density: measure of antibody level in tested sera provided by an ELISA test for *M. paratuberculosis*.

Population estimates: averages and proportions weighted to represent the population of all dairy operations with 30 or more milk cows in the 20 participating states. Most of the estimates in this report are provided with a measure of variability called the standard error and denoted by (±). Chances are 95 out of 100 that the interval created by the estimate plus or minus two standard errors will contain the true population value. In the example at right, an estimate of 7.5 with a standard error of ±1.0 results in a range of 5.5 to 9.5 (two times the standard error above and below the estimate). The second estimate of 3.4 shows a standard error of ±0.3 results with a range of 2.8 and 4.0.

Examples of 95% Confidence Intervals



(± 1.0) (± 0.3)
Standard Errors
#9991[1]

P-value: probability of obtaining a difference at least as large as the observed difference by chance alone given that the null hypothesis is true.

Prevalence:
- Apparent prevalence: percent of cows or herds that test positive and assumes test used is always correct (100 percent sensitivity and 100 percent specificity.)
- Adjusted prevalence: prevalence estimated by adjusting for test sensitivity and specificity.

Regions (see map):
- Midwest: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.
- Northeast: New York, Pennsylvania, and Vermont.
- Southeast: Florida, Kentucky, and Tennessee.
- West: California, Idaho, New Mexico, Oregon, Texas, and Washington.

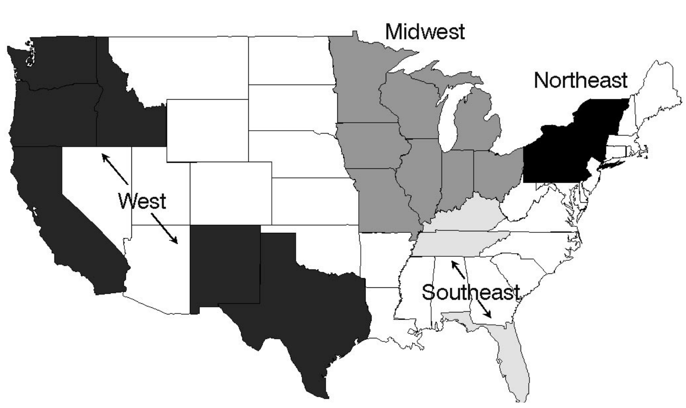
Sample profile: information that describes characteristics of the reporting operations from which Dairy '96 data were collected.

Standard error: see population estimates.

Test sensitivity: percent of infected cows that test positive by test procedure.

Test specificity: percent of uninfected cows that test negative by test procedure.

Within-herd prevalence: percent of cows infected within infected herd.



1 Identification numbers are assigned to each graph in this report for public reference.

Sample profile for Dairy '96 reporting operations

1. Cattle Inventory on January 1, 1996

Size Group	Number Operations Completing Health & Management Questionnaire	Number Operations Participating in Blood Collection
a. Total cattle and calves on hand:		
Less than 50	11	10
50-99	204	167
100-399	733	601
400 or more	271	230
Total	1,219	1,008
b. Total dairy cows, dry or milked:		
Less than 50	196	164
50-99	434	358
100-299	412	329
300 or more	177	157
Total	1,219	1,008
c. Total number of dairy heifers:		
Less than 10	34	21
10-29	161	121
30-49	258	217
50-99	366	308
100 or more	400	341
Total	1,219	1,008

Note: Data from the above sampled operations were weighted in further analyses to represent all dairy operations with at least 30 milk cows in the 20 states participating in the study.

Part I: Johne's Disease Recognition

A. Producer-reported population estimates of Johne's disease

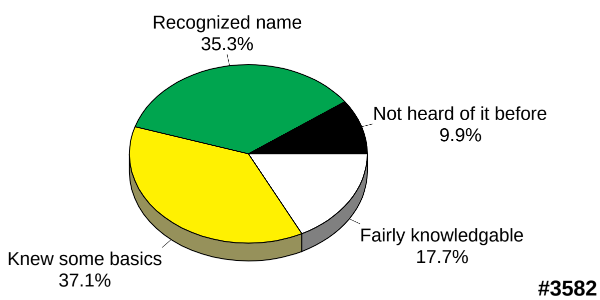
Fifty-five percent of U.S. dairy producers reported being fairly knowledgeable about Johne's disease or knowing at least some basics. About 35 percent of dairy producers did not consider themselves knowledgeable of Johne's disease beyond name recognition, and another 10 percent of producers had not heard of the disease before. Lack of knowledge of the disease by almost half of U.S. dairy producers indicates that additional educational efforts will be needed before broad preventive approaches can be implemented.

1. Johne's disease: Familiarity

a. Percent of operations by familiarity with Johne's disease and herd size:

	Percent Operations									
	Number Dairy Cows									
Familiarity	Less than 50	Standard Error	50-99	Standard Error	100-299	Standard Error	300 or More	Standard Error	Study Total	Standard Error
Unaware: had not heard of it before	11.0	(± 2.3)	8.5	(± 1.5)	9.1	(± 1.7)	16.4	(± 3.3)	9.9	(± 1.1)
Aware: recognized the name, but not much else	40.3	(± 3.6)	34.3	(± 2.6)	30.2	(± 2.9)	24.5	(± 3.8)	35.3	(± 1.8)
Knew some basics	32.2	(± 3.5)	40.9	(± 2.6)	39.2	(± 3.1)	32.2	(± 3.9)	37.1	(± 1.7)
Fairly knowledgeable	16.5	(± 2.6)	16.3	(± 2.0)	21.5	(± 2.8)	26.9	(± 4.0)	17.7	(± 1.3)
Total	100.0		100.0		100.0		100.0		100.0	

Dairy Producer Familiarity with Johne's Disease



Percent Operations

b. Percent of operations by familiarity with Johne's disease by region:

	Percent Operations							
Familiarity	West	Standard Error	Midwest	Standard Error	Northeast	Standard Error	Southeast	Standard Error
Unaware: had not heard of it before	21.9	(± 2.6)	5.3	(± 1.3)	15.6	(± 2.4)	15.5	(± 6.1)
Aware: recognized the name, but not much else	35.6	(± 3.1)	32.3	(± 2.4)	41.7	(± 3.5)	38.0	(± 7.6)
Knew some basics	31.5	(± 2.9)	41.6	(± 2.5)	30.2	(± 3.0)	27.2	(± 6.2)
Fairly knowledgable	11.0	(± 1.8)	20.8	(± 1.9)	12.5	(± 2.3)	19.3	(± 5.2)
Total	100.0		100.0		100.0		100.0	

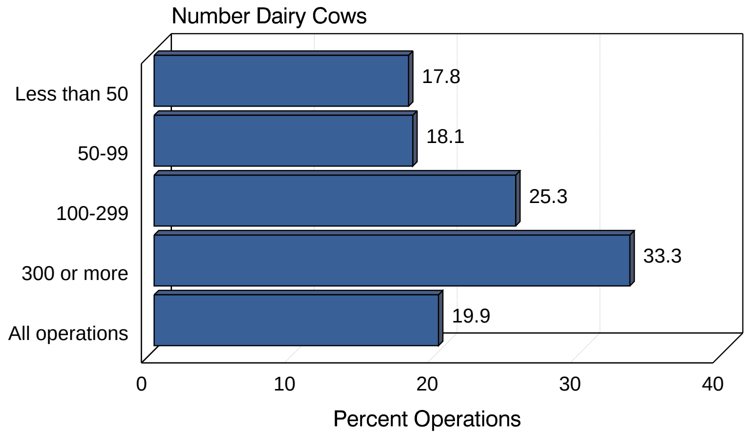
For operations aware of Johne's disease, reported diagnosis of Johne's disease in the past 10 years varied by herd size, from 18 percent of herds with fewer than 100 milk cows to 33 percent of herds with at least 300 milk cows. Method of diagnosis varied and included a proportion by veterinary clinical diagnoses.

2. Johne's disease: Method of diagnosis

a. Percent of operations by method of diagnosis in the last 10 years and herd size:

	Percent Operations Number Dairy Cows									
Method	Less than 50	Standard Error	50-99	Standard Error	100-299	Standard Error	300 or More	Standard Error	Study Total	Standard Error
Positive fecal test	5.5	(± 1.6)	8.0	(± 1.5)	8.9	(± 1.7)	14.3	(± 3.1)	7.6	(± 0.9)
Positive blood test	11.6	(± 2.5)	9.5	(± 1.6)	16.6	(± 2.6)	20.7	(± 3.8)	12.0	(± 1.2)
Clinical diagnosis by a veterinarian	14.7	(± 2.7)	13.6	(± 1.8)	20.2	(± 2.7)	31.5	(± 3.9)	15.9	(± 1.3)
Any of the above	17.8	(± 2.9)	18.1	(± 2.0)	25.3	(± 2.9)	33.3	(± 3.9)	19.9	(± 1.5)

Percent Operations That Reported a Diagnosis of Johne's Disease*
by Herd Size



*By positive fecal or blood test or veterinary clinical diagnosis in the 10 years prior to Dairy '96 study.

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b. Percent of operations by method of diagnosis in the last 10 years by region:

	Percent Operations							
Method	West	Standard Error	Midwest	Standard Error	Northeast	Standard Error	Southeast	Standard Error
Positive fecal test	5.5	(± 1.3)	7.3	(± 1.2)	8.5	(± 2.0)	9.6	(± 3.5)
Positive blood test	7.1	(± 1.5)	14.0	(± 1.8)	8.8	(± 2.1)	12.1	(± 4.1)
Clinical diagnosis by a veterinarian	13.2	(± 1.9)	17.9	(± 1.9)	11.1	(± 2.1)	22.1	(± 5.5)
Any of the above	14.6	(± 2.0)	22.6	(± 2.1)	14.9	(± 2.5)	22.7	(± 5.5)

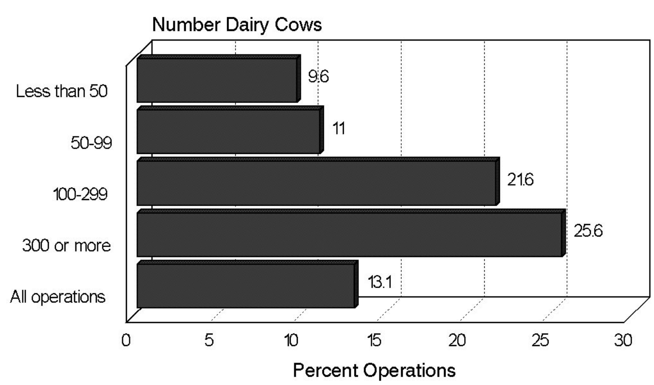
Within the past 2 years, only 13 percent of dairy operations reportedly had any cows tested for Johne's disease by blood or fecal testing. These results varied by herd size, with 10 percent of operations with fewer than 50 milk cows and 22 percent in herds with 100-299 milk cows. Within herds with at least 300 milk cows, 26 percent had cows tested for Johne's disease in the previous 24 months.

3. Johne's disease: Method of testing

a. Percent of operations where any cattle had been tested for Johne's disease by blood or fecal testing in the 24 months prior to the Dairy '96 interview by herd size:

Number Dairy Cows	Percent Operations	Standard Error
Less than 50	9.6	(± 2.1)
50-99	11.0	(± 1.6)
100-299	21.6	(± 2.7)
300 or more	25.6	(± 4.0)
All operations	13.1	(± 1.1)

Percent Operations Testing for Johne's Disease* by Herd Size



* By blood or fecal testing in 24 months prior to Dairy '96 study.

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b. Percent of operations where any cattle had been tested for Johne's disease by blood or fecal testing in the 24 months prior to the Dairy '96 interview by region:

Region	Percent Operations	Standard Error
West	10.9	(± 1.9)
Midwest	14.8	(± 1.6)
Northeast	10.1	(± 1.9)
Southeast	10.7	(± 3.7)

Only 1 percent of dairy operations reported participating in a Johne's disease certification program.

4. Johne's disease: Certification program

a. Percent of operations currently on a Johne's certification program by herd size:

Number Dairy Cows	Percent Operations	Standard Error
Less than 50	1.2	(± 0.8)
50-99	0.8	(± 0.4)
100-299	0.5	(± 0.4)
300 or more	0.2	(± 0.2)
All operations	0.9	(± 0.3)

b. Percent of operations currently on a Johne's certification program by region:

Region	Percent Operations	Standard Error
West	0.0	(± 0.0)
Midwest	0.8	(± 0.4)
Northeast	1.4	(± 0.8)
Southeast	0.2	(± 0.2)

Clinical signs of Johne's disease in cattle include chronic diarrhea and weight loss that do not respond to treatment despite a normal appetite. These signs can mimic other diseases including intestinal parasitism, malnutrition, salmonellosis, hardware disease, and winter dysentery.

In the NAHMS Dairy '96 Study, U.S. dairy producers reported a very low percentage (2 percent) of culled dairy cows with clinical signs consistent with Johne's disease in the previous 12 months. However, 16 percent of the herds had at least 5 percent of their cull cows with these signs. Even in the unlikely event that all of these cull cows had Johne's disease, estimates of Johne's disease based on clinically diseased cattle still only represent the "tip of the iceberg" of infection, and on a herd level, may represent only 5 percent of the total number of infected cattle (Whitlock, 1992). This hidden nature of Johne's disease is one reason for its lack of recognition as an important bovine pathogen by many dairy producers.

5. Johne's disease: Clinical signs

a. Percent of operations by percent of cull cows showing clinical signs consistent with Johne's disease (as defined previously) in the 12 months prior to the Dairy '96 interview by herd size:

	Percent Operations									
	Number Dairy Cows									
Percent Culled Cows	Less than 50	Standard Error	50-99	Standard Error	100-299	Standard Error	300 or More	Standard Error	Study Total	Standard Error
0	81.4	(± 3.0)	86.0	(± 1.8)	70.1	(± 3.0)	48.5	(± 4.1)	80.0	(± 1.4)
0.1-4.9	0.1	(± 0.1)	1.2	(± 0.6)	10.6	(± 1.9)	30.7	(± 4.1)	3.7	(± 0.5)
5.0-9.9	2.2	(± 0.9)	4.8	(± 1.1)	9.8	(± 1.9)	13.6	(± 3.5)	5.1	(± 0.7)
10.0-19.9	9.7	(± 2.5)	5.8	(± 1.3)	4.8	(± 1.4)	3.6	(± 1.2)	6.9	(± 1.1)
20.0 or more	6.6	(± 1.8)	2.2	(± 0.7)	4.7	(± 0.7)	3.6	(± 1.5)	4.3	(± 0.8)
Total	100.0		100.0		100.0		100.0		100.0	

b. Percent of operations by percent of cull cows showing clinical signs consistent with Johne's disease in the 12 months prior to the Dairy '96 interview by region:

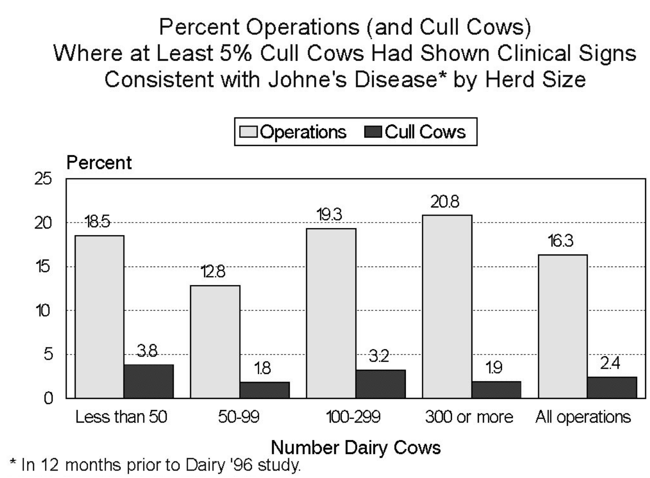
	Percent Operations							
Percent Culled Cows	West	Standard Error	Midwest	Standard Error	Northeast	Standard Error	Southeast	Standard Error
0	76.4	(± 2.5)	76.9	(± 2.1)	88.1	(± 2.1)	80.7	(± 5.0)
0.1-4.9	11.3	(± 1.8)	2.9	(± 0.6)	2.9	(± 0.8)	6.3	(± 2.6)
5.0-9.9	6.9	(± 1.7)	5.5	(± 0.9)	2.9	(± 0.9)	9.4	(± 4.3)
10.0-19.9	2.7	(± 0.9)	9.7	(± 1.7)	2.6	(± 1.0)	1.4	(± 0.7)
20.0 or more	2.7	(± 1.0)	5.0	(± 1.1)	3.5	(± 1.5)	2.2	(± 1.9)
Total	100.0		100.0		100.0		100.0	

c. Percent of *operations* where at least 5 percent of cull cows had shown clinical signs consistent with Johne's disease in the 12 months prior to the Dairy '96 interview by herd size:

Number Dairy Cows	Percent Operations	Standard Error
Less than 50	18.5	(± 3.0)
50-99	12.8	(± 1.8)
100-299	19.3	(± 2.7)
300 or more	20.8	(± 3.7)
All operations	16.3	(± 1.4)

d. Percent of *operations* where at least 5 percent of cull cows had shown clinical signs consistent with Johne's disease in the 12 months prior to the Dairy '96 interview by region:

Region	Percent Operations	Standard Error
West	12.3	(± 2.0)
Midwest	20.2	(± 2.1)
Northeast	9.0	(± 2.0)
Southeast	13.0	(± 4.6)



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e. Percent of *cull cows* reported by all herds that had shown clinical signs consistent with Johne's disease in the 12 months prior to the Dairy '96 interview by herd size:

Number Dairy Cows	Percent Culled Cows	Standard Error
Less than 50	3.8	(± 1.1)
50-99	1.8	(± 0.3)
100-299	3.2	(± 0.6)
300 or more	1.9	(± 0.3)
All operations	2.4	(± 0.3)

f. Percent of *cull cows* that had shown clinical signs consistent with Johne's disease in the 12 months prior to the Dairy '96 interview by region:

Region	Percent Culled Cows	Standard Error
West	1.4	(± 0.3)
Midwest	3.2	(± 0.4)
Northeast	2.3	(± 0.7)
Southeast	3.0	(± 0.8)

B. Summary

Results from this study indicate U.S. dairy producers lack widespread awareness of Johne's disease. In addition, only about 13 percent of dairy producers tested for this disease in the previous 2 years. Adoption of herd certification programs to date has been low. Despite this low participation, about 16 percent of herds reported at least 5 percent of their cull cows in previous years with clinical signs consistent with Johne's disease. Education efforts are needed before large-scale Johne's disease control programs can be successfully initiated.

Part II: *M. paratuberculosis* Test Results

A. Cow-level *M. paratuberculosis* test results

A total of 32,622 cows from 1,004 operations were tested serologically for *M. paratuberculosis* during the NAHMS Dairy '96 Study. A total of 31,745 cows were tested from 967 herds that did not vaccinate against Johne's disease.

Sera were tested for antibody to *M. paratuberculosis* with a commercially available ELISA[1] using single well per sample testing and procedures provided by the manufacturer. Results from ELISA testing are provided as optical density (OD) values, as measures of the antibody level in tested sera. The mean positive control OD value was 1.19 and the mean negative control value was 0.08. As shown below, the mean sample OD value was 0.09 and the median (50th percentile) was 0.07, with 95 percent of OD values less than or equal to 0.14.

1. Distribution of *M. paratuberculosis* test results (nonvaccinated cows)

a. Control optical density (OD) values:

Values	Mean	Standard Deviation	Minimum	Maximum
Positive	1.19	0.30	0.60	2.18
Negative	0.08	0.02	0.003	0.13

b. Sample optical density values:

Mean	Standard Deviation	Minimum	Maximum
0.09	0.07	0.004	4.17

c. Sample optical density percentiles:

Percentiles				
50	75	90	95	99
0.07	0.09	0.11	0.14	0.29

1 *M. paratuberculosis* antibody test kit, IDEXX Laboratories, Westbrook, ME.

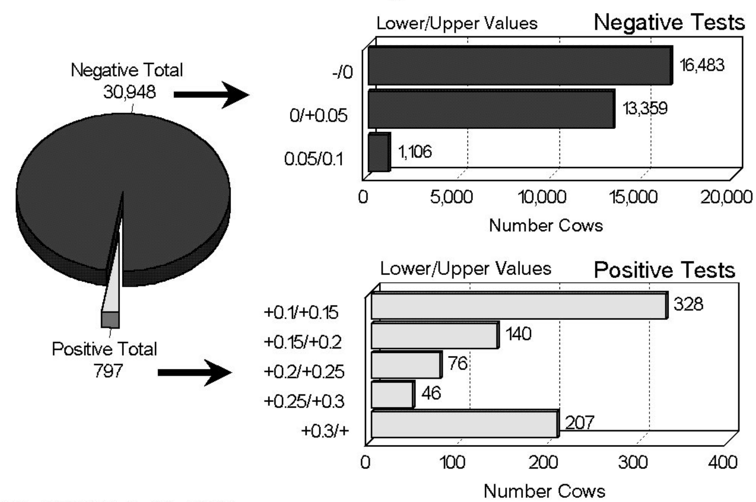
For each ELISA plate, the positive test cut-off value was set, according to manufacturer recommendations, as the mean negative control OD value plus 0.1. Sample OD values greater than the positive cut-off value for the plate (OD value plus 0.1) were considered test positive. Despite this method of defining positive and negative test results, many diagnosticians agree that, due to the nature of ELISA tests, test results near the cut-off value are sometimes considered indeterminate and retesting using another type of test for *M. paratuberculosis* is recommended for verification on an individual animal basis. Retesting was not done in the Dairy '96 Study as the study objective was herd prevalence estimation.

d. Sample OD value in relation to distance from mean negative control OD value on each plate (nonvaccinated cows):

Distance from mean negative control OD value:

Lower Value	Upper Value	Test Status	Number Cows	Percent Cows
Less than mean negative control OD value		Negative	16,483	51.9
0	+0.049	Negative	13,359	42.1
+0.05	+0.099	Negative	1,106	3.5
+0.1	+0.149	Positive	328	1.0
+0.15	+0.199	Positive	140	0.4
+0.2	+0.249	Positive	76	0.2
+0.25	+0.299	Positive	46	0.2
+0.3		Positive	207	0.7
			31,745	100.0

Optical Density Distribution of *M. paratuberculosis* Test Results in Relation to the Mean Negative Control OD Value



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Herds vaccinating against Johne's disease, in most states, have had cows previously diagnosed as Johne's positive, and should therefore be considered as *M. paratuberculosis* positive. These herds were not included in seroprevalence estimates since test status may be confused by vaccination.

From a 1997 survey (S. Wells, unpublished) of USDA:APHIS:Veterinary Services Area Offices or State Veterinarians in the 20 states involved in the NAHMS Dairy '96 Study, only 0.6 percent of dairy operations were vaccinating dairy animals against Johne's disease. The commercially available killed vaccine is available for use in the U.S. only with approval from the State Veterinarian and only for use in calves from 1 through 35 days of age.

2. Johne's disease vaccination

a. Percent of dairy operations[1] vaccinating against Johne's disease by region:

Region	Percent Operations
West	0.1
Midwest	0.8
Northeast	0.2
Southeast	0.0
All operations	0.6

NAHMS Dairy '96 results showed that 27.3 percent of vaccinated cows tested positive for antibodies to *M. paratuberculosis* compared to 2.6 percent of nonvaccinated cows.

In a previous study from one vaccinated herd tested negative by culture and DNA test kit, 59 percent of vaccinated cattle were ELISA-positive (Anderson et al, 1991).

b. Percent of cows that tested positive by vaccination status:

Status	Percent Cows	Standard Error	p-value[2]
Vaccinated against Johne's disease	27.3	(± 5.2)	<0.001
Not vaccinated	2.6	(± 0.2)	

1 Denominator = dairy herds with permits to ship milk (Hoard's Dairyman, October 25, 1996) in the 20 states involved in the NAHMS Dairy '96 Study.

2 P-value from chi-square test of independence.

Apparent prevalence is defined as the percent of cows that tested positive. In this study, apparent prevalences have been weighted to adjust for the sample design, to represent 79 percent of U.S. dairy cows, as described previously. The IDEXX ELISA has a reported test sensitivity of 45 percent and test specificity of 99 percent with single well per sample testing (Sweeney et al, 1995). Assuming these values, 45 percent of the truly infected cows were detected by the test, while 99 percent of uninfected cows were test negative. To adjust the apparent cow prevalence for test sensitivity and specificity, the following formula (Schwabe et al, 1977) was used:
Adjusted prevalence = (apparent prevalence + test specificity - 100)/(test sensitivity + test specificity - 100).

Using this method, the adjusted prevalence of *M. paratuberculosis* infection at the cow level was 3.4 percent. However, there are some indications that the true test sensitivity of the ELISA may be somewhat lower than 45 percent. Fecal culture methods have been used to determine infection status for most positive sera used to estimate the ELISA sensitivity, and the sensitivity of conventional fecal culture on Herrold's egg yolk agar has been estimated at 45 percent (Sockett, et al, 1992). Therefore, use of fecal culture as a gold standard (which implies 100 percent test sensitivity and specificity) to evaluate other tests should be carefully interpreted. If the true test sensitivity of the ELISA is less than 45 percent, the adjusted prevalence would be greater than 3.4 percent. (For example, if the test sensitivity is 20 percent, the adjusted cow-level prevalence estimate would be 7.9 percent.)

There were no significant differences in apparent prevalence among herd size groups or regions. There was a strong association between percent of cull cows with clinical signs consistent with Johne's disease (as reported by dairy producers) and cow-level apparent prevalence of *M. paratuberculosis*. In cow-level analyses, factors associated with *M. paratuberculosis* seropositivity included cow type, fecal score, body condition score, and lactation number.

3. Cow-level seroprevalence of *M. paratuberculosis* from nonvaccinated herds[1]

a. Percent of cows positive for *M. paratuberculosis* by herd size:

Number Cows	Apparent Prevalence	Standard Error	p-value[2]	Adjusted Prevalence[3]
Less than 50 cows	2.4	(± 0.4)	0.45	3.0
50-99 cows	2.3	(± 0.2)		3.0
100-299 cows	2.3	(± 0.3)		3.0
300 or more cows	3.0	(± 0.4)		4.5
All operations	2.5	(± 0.2)		3.4

1 Vaccinated cows excluded.

2 P-value from univariable logistic regression using STATA to account for study design.

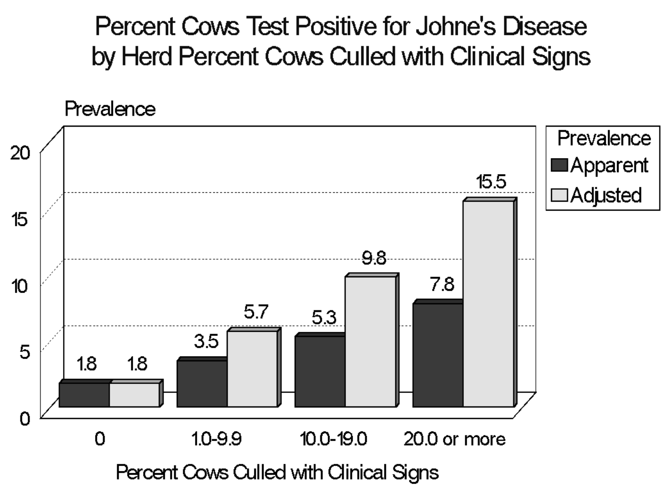
3 Assuming test sensititivity = 45 percent and test specificity = 99 percent.

b. Percent of cows positive for *M. paratuberculosis* by region:

Region	Apparent Prevalence	Standard Error	p-value	Adjusted Prevalence
West	2.5	(± 0.4)	0.53	3.4
Midwest	2.8	(± 0.2)		4.1
Northeast	2.3	(± 0.3)		3.0
Southeast	2.1	(± 0.6)		2.5

c. Percent of cows positive for *M. paratuberculosis* by percent of culled cows with clinical signs consistent with Johne's disease in the herd:

Percent Cows Culled with Signs	Apparent Prevalence	Standard Error	p-value	Adjusted Prevalence
0	1.8	(± 0.1)	<0.001	1.8
0.1-9.9	3.5	(± 0.5)		5.7
10.0-19.9	5.3	(± 0.8)		9.8
20.0 or more	7.8	(± 1.5)		15.5



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d. Percent of cows positive for *M. paratuberculosis* by type of cow:

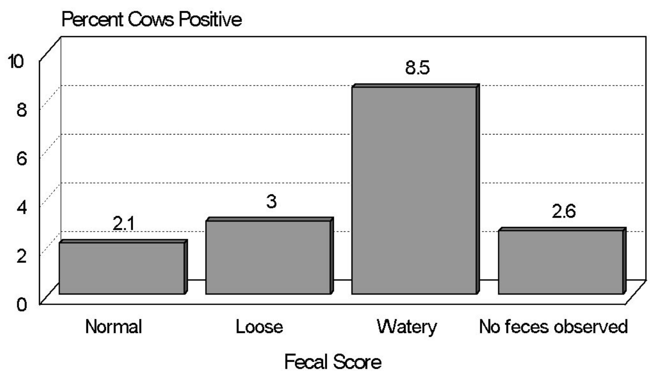
Cow Type	Apparent Prevalence	Standard Error	p-value	Adjusted Prevalence
Milk cow	2.4	(± 0.1)	<0.001	3.2
Dry cow	3.3	(± 0.5)		5.2
Sick cow	4.0	(± 1.8)		6.8
Cull cow (to be culled within next 7 days)	4.1	(± 1.6)		7.5
Reproduction problem	1.8	(± 0.9)		1.8
Mastitis/udder problems	2.5	(± 1.5)		3.4
Lameness or injury	4.1	(± 2.2)		7.0
Disease	45.8	(± 12.3)		Not estimable[1]
Low production	0.7	(± 0.6)		Not estimable[1]
Other	5.2	(± 3.6)		9.5

1 Not estimable using adjusted prevalence formula from Schwabe et al, 1977.

e. Percent of cows positive for *M. paratuberculosis* by fecal score:

Fecal Score	Apparent Prevalence	Standard Error	p-value	Adjusted Prevalence
Normal	2.1	(± 0.2)	0.001	2.5
Loose	3.0	(± 0.4)		4.5
Watery	8.5	(± 3.2)		17.0
No feces observed	2.6	(± 0.3)		3.6

Percent Cows Test Positive for Johne's Disease by Fecal Score



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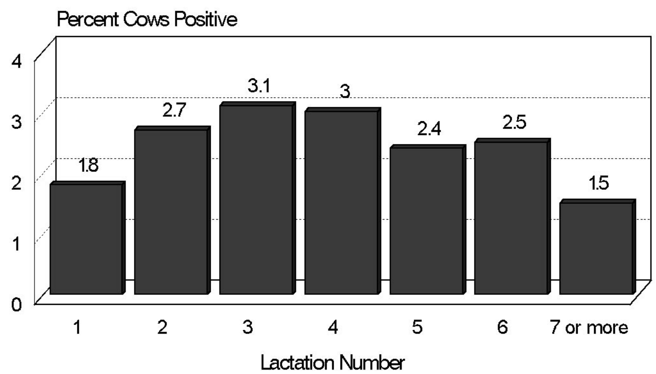
f. Percent of cows positive for *M. paratuberculosis* by body condition score:

Body Condition Score	Apparent Prevalence	Standard Error	p-value	Adjusted Prevalence
1 Extremely emaciated	5.7	(± 1.0)	0.001	10.7
2	2.4	(± 0.3)		3.2
3	2.4	(± 0.2)		3.2
4	1.9	(± 0.3)		2.0
5 Extremely fat	4.0	(± 1.5)		6.8

g. Percent of cows positive for *M. paratuberculosis* by lactation number:

Lactation Number	Apparent Prevalence	Standard Error	p-value	Adjusted Prevalence
1	1.8	(± 0.2)	0.005	1.8
2	2.7	(± 0.3)		3.9
3	3.1	(± 0.3)		4.8
4	3.0	(± 0.4)		4.5
5	2.4	(± 0.4)		3.2
6	2.5	(± 0.6)		3.4
7 or more	1.5	(± 0.5)		1.1

Percent Cows Test Positive for Johne's Disease by Lactation Number



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h. Percent of cows positive for *M. paratuburculosis* by aborted calves at 3 or more months gestation in last 12 months:

Status	Apparent Prevalence	Standard Error	p-value	Adjusted Prevalence
Aborted calves at 3 or more months gestation	4.0	(± 0.9)	0.06	6.8
Did not abort calves at 3 or more months gestation	2.5	(± 0.2)		3.4

B. Herd-level *M. paratuberculosis* test results

Sampling of cows from participating herds for serologic testing was designed to have 90 percent confidence of detecting at least one positive cow in herds with a true infection prevalence of at least 10 percent. Therefore, some herds with a true infection prevalence of less than 10 percent were likely to have been missed by this sampling scheme, and would be falsely reported as negative herds. On the other hand, the probability of a test being false positive is 1 percent (assuming an ELISA test specificity of 99 percent, Sweeney, et al, 1995). When multiple cows are tested from the same herd, the probability of getting at least one false positive test result multiplies. For example, if 30 cows from a truly negative herd are tested, the probability of at least one false positive test is 26.0 percent (probability of one false positive test is 22.4 percent and probability of two or more false positives is 3.6 percent). The probability of false positives created problems in the NAHMS Dairy '96 Study in definitively classifying herds, especially those with only a single positive test result, as being truly positive herds. The classification problem was particularly important in this study because 55 percent of herds testing positive (224/408) had only a single positive test result.

1. Distribution of herd test results (nonvaccinated herds)

a. Number of cows tested for *M. paratuberculosis* per herd:

Number Cows Sampled	Number Herds	Percent Herds Sampled
25 or fewer	30	3.1
26-30	528	54.6
31-35	268	27.7
36-40	141	14.6
Total	967	100.0

b. Number of *M. paratuberculosis*-positive cows per herd:

Number Cows Test Positive	Number Herds	Percent Herds Sampled
0	559	57.8
1	224	23.2
2	101	10.4
3	37	3.8
4	18	1.9
5 or more	28	2.9
Total	967	100.0

c. Distribution of percent cows positive in *M. paratuberculosis*-positive herds[1]:

	Percent Herds by Percent Samples Positive					
Percent herds	25%	50% (median)	75%	90%	95%	99%
Percent positive cows within herd	2.9	3.3	6.7	11.4	15.0	23.3

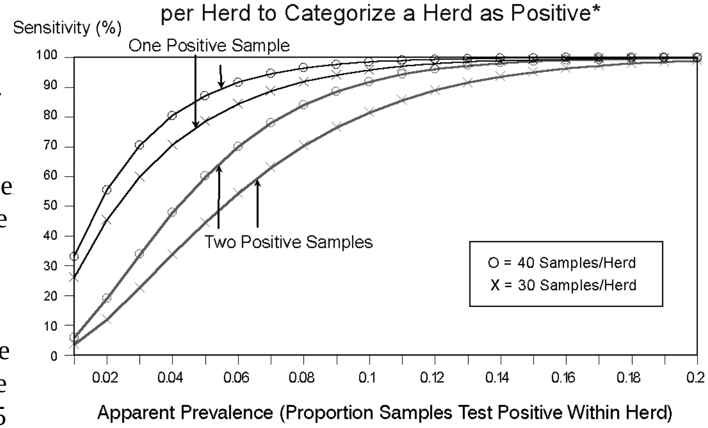
1 Percent of positive herds with percent of samples positive less than or equal to value. The minimum positive percent was 2.5 percent, due to maximum 40 samples per herd (1/40 = 2.5).

Estimation of the true herd prevalence of *M. paratuberculosis* infection should incorporate factors, such as sensitivity, specificity, sample size, and within-herd prevalence, that lead to uncertainty in the observed herd prevalence of 40.6 perent in this study (Martin et al, 1992). For example, if the test sensitivity and specificity are assumed to be 45 percent (45 percent of the infected cows are detected by the test) and 99 percent, respectively, then the probability that a herd has disease given it has exactly one positive test result is only about 25 percent. We used two approaches to increase the chance of identifying a herd as negative when it is truly negative, i.e. increase the herd specificity, which should lead to a conservative revision of the herd prevalence of *M. paratuberculosis* infection. The first approach, described by Jordan (1996), was to increase the cut-off number of positive cows required to call a herd truly positive. The second approach was to raise the cut-off number of positive cows required and include herds with one positive test result if at least 5 percent of the cows culled in the previous year had clinical signs of Johne's disease.

Herd level specificity, which is unaffected by within-herd prevalence, increases when the cut-off number of positive cows required to categorize a herd as positive is changed from one to two regardless of sample size (see table). However, as the specificity increases, the sensitivity will decrease and some of the truly positive herds which had only one positive test result will be classified as negative herds. The decreased sensitivity is more important at low within-herd prevalences but sensitivity can be increased with highe sample sizes (see graph below). Using the cut-off of two positive test results, the percent of test positive herds is 16.8 percent. However, this herd prevalence estimate may be overly conservative since it is likely that some of the herds with one positive test are truly positive (roughly 25 percent from previous paragraph).

Cut-off Number of Positive Tests To Categorize a Herd as Positive	Herd Level Specificity Sample Size 30	40
1	74.0%	66.9%
2	96.4%	93.9%

Herd Level Sensitivity for Cutoff of One and Two Positive Samples per Herd to Categorize a Herd as Positive*



*Assuming sampling from large herd.

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The second approach, changing the cut-off to two test positives and including herds with one test positive and clinical signs of Johne's disease in at least 5 percent of cull cows, is an attempt to use available information from the herds to correctly identify herds that have one positive test as truly positive herds. Of the 224 herds that had one test positive, 48 also had more than 5 percent of their cull cows with clinical signs of Johne's disease. This percentage (48/224=21.4 percent) of one-test positive herds that are categorized as truly positive compares favorably with the predicted percent of truly positive one-test positive herds (25 percent). This approach results in a herd prevalence of *M. paratuberculosis* infection of 21.6 percent. Although it is not possible to calculate the herd sensitivity and specificity after inclusion of a portion of the one-test positive herds, the true values will lie

Classification of Dairy Herds into Johne's Disease Negative and Positive Herds

Percent of Cull Cows with Reported Clinical Signs of Johne's Disease	Number of *M. paratuberculosis* Test Positive Cows per Herd: 0	1	≥2
	Johne's Disease Classification		
<5%	Negative	Negative	Positive
≥5%	Negative	Positive	Positive

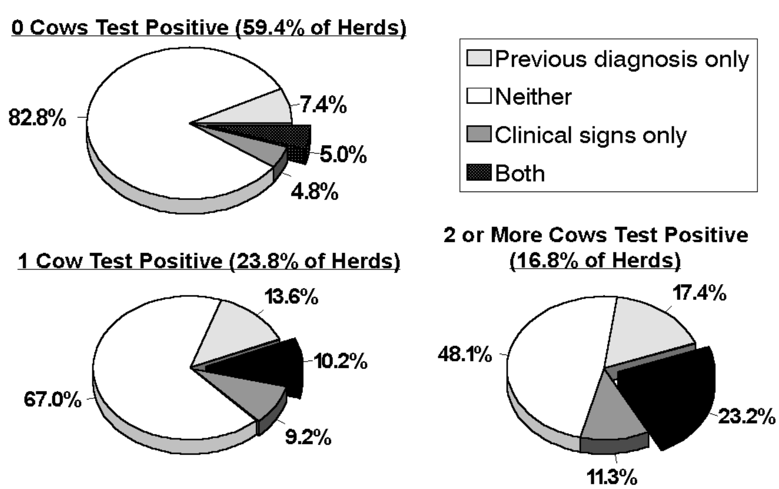
between those described for the cut-offs of one and two positives. This is our best estimate of the herd prevalence of *M. paratuberculosis* infection, but it is likely to still be an underestimate of the true prevalence since the study was not designed to detect most low-prevalence herds.

To further evaluate our categorization of *M. paratuberculosis* infection based on both ELISA results and clinical signs, we also evaluated reported diagnoses of Johne's disease in the past 10 years. Only 5.0 percent of herds with no cows test positive had both a diagnosis of Johne's disease in the past 10 years and at least 5 percent of culled cows with clinical signs consistent with Johne's disease, compared to 10.2 percent of herds with one cow test positive and 23.2 percent of herds with two or more cows test positive (see graph below). Looked at another way, 17.2 percent of herds with no cows test positive had historical evidence of Johne's disease (previous diagnosis and/or clinical signs in 5 percent or more of culled cows) compared to 33.0 of herds with one cow test positive and 51.9 percent of herds with two or more cows test positive.

These trends in overlap of the herd-level characteristics provide supportive evidence for classifying herds with two or more cows test positive or one cow test positive and at least 5 percent of culled cows with clinical signs consistent with Johne's disease as *M. paratuberculosis*-positive herds. Not all test-positive herds would be expected to have had previous diagnoses of Johne's disease, depending on levels of previous familiarity and testing. In addition, not all test-positive herds were expected to have reported at least 5 percent of culled cows with clinical signs consistent with Johne's disease, because manifestation of disease is dependent on herd management and prevention (i.e., strict culling of cows with lower milk production may result in fewer cows developing weight loss and diarrhea).

A limitation of this study was the single sample collection visit for each participating dairy herd. For determination of herd status of *M. paratuberculosis* infection on individual operations for herd disease control purposes, additional tests may be used along with ELISA testing, as well as information related to history of known Johne's disease in the herd and the number of cows culled with clinical signs of Johne's disease.

Percent of Herds with Clinical Signs and Previous Diagnosis of Johne's Disease by Number of Test-Positive Cows per Herd



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2. Percent of nonvaccinated herds that tested positive for *M. paratuberculosis*[1]

a. Percent of operations positive for *M. paratuberculosis* by herd size:

Percent Herds Positive for *M. paratuberculosis*

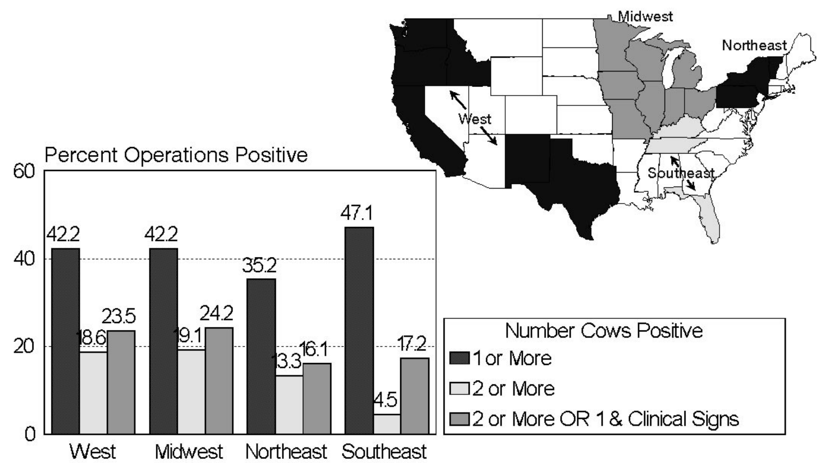
	One or More Cows Tested Positive		Two or More Cows Tested Positive		Two or More Positives OR 1 Positive with At Least 5% with Clinical Signs	
Number Cows	Percent	Standard Error	Percent	Standard Error	Percent	Standard Error
Less than 50	36.6	(± 4.0)	13.3	(± 2.8)	18.6	(± 3.3)
50-99	39.9	(± 3.0)	17.2	(± 2.3)	20.5	(± 2.5)
100-299	45.2	(± 3.7)	18.7	(± 2.8)	25.7	(± 3.4)
300 or more	59.4	(± 4.5)	32.8	(± 4.4)	39.7	(± 4.5)
Total	40.6	(± 2.0)	16.8	(± 1.5)	21.6	(± 1.7)
p-value[2]	0.001		0.001		<0.001	

b. Percent of operations positive for *M. paratuberculosis* by region:

Percent Herds Positive for *M. paratuberculosis*

	One or More Cows Tested Positive		Two or More Cows Tested Positive		Two or More Positives OR 1 Positive with At Least 5.0% with Clinical Signs	
Region	Percent	Standard Error	Percent	Standard Error	Percent	Standard Error
West	42.2	(± 3.5)	18.6	(± 2.7)	23.5	(± 3.0)
Midwest	42.2	(± 2.8)	19.1	(± 2.2)	24.2	(± 2.4)
Northeast	35.2	(± 3.6)	13.3	(± 2.5)	16.1	(± 2.6)
Southeast	47.1	(± 12.6)	4.5	(± 2.4)	17.2	(± 9.0)
p-value[2]	0.39		0.02		0.15	

Percent Operations Positive for *M. paratuberculosis* by Region



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1 Sampling to detect at least one positive cow within each herd (with 90 percent confidence if true prevalence greater than or equal to 10 percent).

2 P-value from univariable logistic regression using STATA to adjust for study design.

Positive herds were more likely to have had reported cows with chronic diarrhea, and have reported deaths due to diarrhea or other digestive problems. Culling rate was not associated with *M. paratuberculosis* positivity.

3. Relationship with clinical disease and culling in nonvaccinated herds

a. Percent of operations positive for *M. paratuberculosis*[1] by percent of dairy cows that had diarrhea for more than 48 hours in 1995:

Percent Dairy Cows	Percent Operations Within Group That Were Positive[1]	Standard Error	p-value[2]
0	14.0	(± 1.9)	<0.001
Greater than 0	33.9	(± 3.0)	

b. Percent of operations positive for *M. paratuberculosis*[1] by percent of dairy cow deaths that were due to diarrhea or other digestive problems:

Percent Dairy Cow Deaths	Percent Operations Within Group That Were Positive[1]	Standard Error	p-value[2]
0	20.5	(± 1.8)	0.01
Greater than 0	33.5	(± 5.6)	

c. Percent operations positive for *M. paratuberculosis*[1] by percent of dairy cows culled for slaughter:

Percent Dairy Cows Culled	Percent Operations Within Group That Were Positive[1]	Standard Error	p-value[2]
Less than 20	20.4	(± 2.6)	0.66
20-29.9	21.4	(± 2.7)	
30.0 or more	24.4	(± 3.6)	

1 Classified as positive by two or more positives per herd or one positive with at least 5 percent of culled cows in the previous year with clinical signs consistent with Johne's disease.

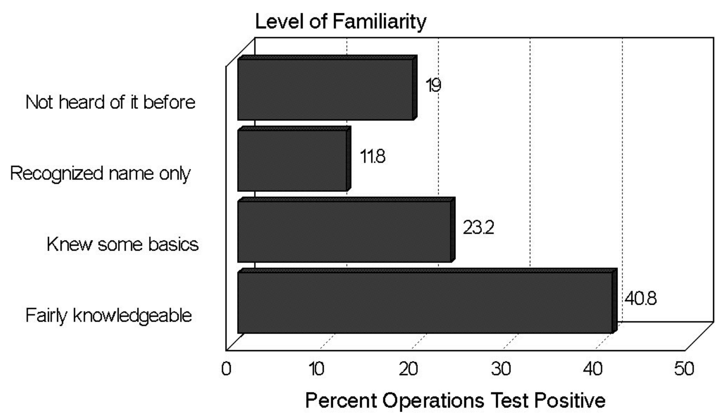
2 P-value from univariable logistic regression using STATA to account for study design.

4. Relationship with producer awareness in nonvaccinated herds

a. Percent of operations positive for *M. paratuberculosis* by level of producer familiarity with Johne’s disease in cattle:

Level of Familiarity	Percent Operations within Group that Were Positive[1]	Standard Error	p-value[2]
Hadn’t heard of it before	19.0	(± 5.8)	<0.001
Recognized the name, not much else	11.8	(± 2.2)	
Knew some basics	23.2	(± 2.9)	
Fairly knowledgeable	40.8	(± 4.8)	

Percent Operations Test Positive for *M. paratuberculosis* by Producer Familiarity with Johne's Disease*



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b. Percent of operations positive for *M. paratuberculosis* by whether a positive fecal or blood test or clinical diagnosis of Johne’s disease by a veterinarian had been made in the last 10 years:

Previous Diagnosis	Percent Operations within Group that Were Positive[1]	Standard Error	p-value
Yes	46.5	(± 4.8)	<0.001
No	14.7	(± 1.6)	
Hadn’t heard of Johne’s disease before	19.0	(± 5.8)	

1 Classified as positive by two or more positives per herd or one positive with at least 5 percent of culled cows in the previous year with clinical signs consistent with Johne’s disease.

2 P-value from univariable logistic regression using STATA to adjust for study design.

c. Percent of operations positive for *M. paratuberculosis* by whether any cattle on the operation had been tested for Johne's disease by blood or fecal testing in the last 24 months:

Tested in Previous 24 Months	Percent Operations within Group that Were Positive[1]	Standard Error	p-value[2]
Yes	42.3	(± 5.2)	<0.001
No	18.3	(± 1.8)	
Hadn't heard of it before	19.0	(± 5.8)	

d. Percent of operations positive for *M. paratuberculosis* by participation in a Johne's herd certification program:

Certification Program	Percent Operations within Group that Were Positive[1]	Standard Error	p-value[2]
Yes	5.1	(± 4.2)	0.15
No	21.9	(± 1.8)	
Hadn't heard of it before	19.0	(± 5.8)	

C. Summary

Results suggest there are many dairy herds in the U.S. with *M. paratuberculosis* infection, with a best estimate of 21.6 percent. This estimate does not include the 0.6 percent of U.S. dairy herds vaccinated against Johne's disease that may remain infected. Herd prevalence was strongly related to herd size, but only minor regional differences were noted. In addition, this study indicated a large percentage of U.S. dairy herds free or at low risk of *M. paratuberculosis* infection. Industry identification and recognition of test-negative (low risk) herds, to serve as low risk sources of replacement cattle for other herds, would be extremely beneficial. This information will be useful to support Johne's disease control programs, education, and research. It will also serve as a baseline from which to evaluate the success of control programs.

Future surveys to more precisely estimate herd prevalence using diagnostic tests currently available may not be beneficial. However, further research in other areas would be helpful to improve our understanding of this disease. These areas include an evaluation of within-herd prevalence, especially in low prevalence herds that were beyond the detection limits of this study. An opportunity exists to resample certain volunteer ELISA-positive herds to evaluate fecal shedding status as well as the possibility of DNA markers for cow shedding and immunologic response. Further evaluation of volunteer test-negative herds would also be valuable. Finally, improved diagnostic tests to assist evaluation of this complex disease would be extremely beneficial.

1 Classified as positive by two or more positives per herd or one positive with at least 5 percent of culled cows in the previous year with clinical signs consistent with Johne's disease.

2 P-value from univariable logistic regression using STATA to adjust for study design.

Part III: Economic Impact of Johne's Disease on U.S. Dairy Operations

A. Economic loss measures used in analysis

Economic losses from Johne's disease include obvious losses such as reduced milk production and decreased weight and salvage value for clinically affected cattle at cull markets. Other costs include increased culling and greater mortality.

Economic loss: a reduction in adjusted annual value of dairy production for the dairy operation on a per milk cow basis. **Adjusted annual value of dairy production** equals:

+ annual value milk production
+ annual value of calves at birth
+ annual value of milking cows sold (cows sold to other producers)
+ annual value of cull cows (cows sold for slaughter)
- annual value of replacement cows (cows and heifers added to the herd).

Milk production value: annual value of milk production was estimated as the reported annual rolling herd average milk production per cow multiplied by a milk price of $13/cwt (prices averaged $13.29/cwt for the January 1995-July 1996 time period of the study [USDA:NASS]).

Calf value: annual value of calves on a per cow basis was estimated as the total number of calves born alive in 1995 divided by January 1, 1996, cow inventory multiplied by $50/head calf price. (Average of $75 for day-old heifer calf and $25 for day-old bull calf, based on prices reported in The Western Dairyman, June 1996.) It is assumed that Johne's disease does not impact preweaned calves or heifers and thus their rearing was considered a separate enterprise and excluded from this analysis.

Value of milking cows sold: annual value of cows sold for dairy purposes was estimated as the total number of cows sold to other producers divided by January 1, 1996, cow inventory multiplied by a cow price of $1,100/head (based on average prices received for replacement cows, January 1995- July 1996 [USDA:NASS]).

Cull cow value: value of cull cows has two components: culls in normal body condition and culls in poor body condition. Producers were asked how many cull cows in the previous 90 days were in normal body condition and in poor body condition (low cutter or canner grade) and the per head price received for each category. The proportion of cows in each category was then determined by dividing the number of head in each category by the total number of cows culled during the previous 90 days. Proportions for normal and poor culls were then multiplied by the number of cows culled during the previous year to obtain an estimate of annual number of normal and poor cull cows. Total value then was determined by multiplying the number of cows in each category by the price received per head for each category. Annual value of cull cows on a per cow inventory basis was determined by dividing total cull cow value by January 1, 1996, cow inventory.

Some producers did not report any culls during the previous 90 days. Since most (89 of 101) of the producers who had no culls during the previous 90 days milked less than 100 cows and we did not want to delete them from the analysis, we assumed their proportion of poor conditioned cull cows was the same as other producers in the same herd size group and region. Producers who had no culls did not report a cull cow price. For these producers and an additional 55 who had cull cows but did not report cull cow prices, median prices from each herd size-region combination were substituted for the missing data. Nationally, producers reported median prices for a normal condition cull cow of $400 per head and $250 per head for a poor-conditioned cull cow.

Replacement cost: annual value of replacement cows was estimated as the total number of cows added to the herd multiplied by a cow price of $1,100 per head and divided by the January 1, 1996, cow inventory. Data were collected on number of bred heifers, milking cows, and dry cows that were brought onto the operation during the year. The number of raised heifers added to the milking string during the year was not collected. It was assumed that the number of raised heifers that entered the milking string equaled the number of first calf heifers at time of inventory minus bred heifers brought onto the dairy operation during the previous year.

B. Modeling economic impact of Johne's disease on U.S. dairy operations

To estimate the economic impact of Johne's disease on U.S. dairy operations, a linear regression model was used. The SUDAAN™ algorithm was used to incorporate study design into the analysis, i.e., parameter estimates were weighted estimates with the weights being a function of study design. Of the 1,219 herds (described on page 7), 974 herds had complete data related to the economic variables used in this analysis. Economic analysis included those herds that had been vaccinated for *M. paratuberculosis*.

Johne's disease economic categories:
To gain better insight into the economic impact of Johne's disease, negative and positive herds (see page 22 for definitions of negative and positive herds) were subdivided by percent of cull cows showing clinical signs consistent with Johne's disease. Even herds classified as being Johne's negative could have cull cows showing clinical signs consistent wtih Johne's disease as other agents can cause similar clinical signs. The three subcategories for negative herds were:

1) no reported cull cows with clinical signs

2) less than 10 percent of cull cows reported showing clinical signs

3) at least 10 percent of cull cows reported showing clinical signs

The two subcategories for positive herds were:

1) less than 10 percent cull cows reported showing clinical signs

2) at least 10 percent of the cull cows with clinical signs

For analysis purposes, negative herds with no reported cull cows with clinical signs consistent with Johne's disease were the base category, i.e., herds in all other categories were compared to the base herds. (For national percentage of herds in each category see table 1 on the next page.)

1. Herd characteristics of Johne’s disease and variables used in Johne’s disease regression model[1]:

Number of Herds:	
Actual	974
Represented	75,522
Number of cows represented[2]	7,876,258
Johne’s Disease Economic Analysis Categories	**Percent Operations**
Negative herds:	
0% cull cows with clinical signs	51.8%
<10% cull cows with clinical signs	22.0%
≥10% cull cows with clinical signs	4.0%
Positive herds:	
<10% cull cows with clinical signs	15.0%
≥10% cull cows with clinical signs	7.2%
Herd Size:	
Less than 50 cows	32.9%
50 - 99 cows	44.4%
100 - 149 cows	10.4%
150 - 249 cows	6.5%
250 - 499 cows	3.2%
500 or more cows	2.6%
Region:	
Midwest	60.7%
West	8.3%
Southeast	4.5%
Northeast	26.5%
Use DHIA Records (yes)	51.9%
Graze Pastures (yes)	53.6%
Of those that pasture, pastures supply 90% or more of roughages (yes)	36.3%
bST (yes)	13.6%
bST (% of cows in herds that use bST)	49.3%
First Calf Heifers:	
25% or less	36.1%
26% - 33%	24.5%
34% or more	39.4%
Bulk Tank Somatic Cell Count:	
199,999 or less	28.9%
200,000 - 399,999	54.0%
400,000 or more	17.1%
Percent of Cows Holstein Breed:	
0 - 49	6.6%
50 - 89	6.5%
90 - 99	13.2%
100	73.7%
90% or more cows registered (yes)	12.5%
Changes in herd inventory:	
Expansion (>5% increase in cow numbers)	54.4%
Contraction (>5% decrease in cow numbers)	18.5%
Same (cow number change within +/- 5%)	27.1%

1 Percentages based on represented herds.
2 Weighted number of herds based on sampling procedures.

Herd size and region were included in the analysis as covariates. Herd size was split into six categories: fewer than 50 cows, 50-99 cows, 100-149 cows, 150-249 cows, 250-499 cows, and 500 or more cows. The smallest herd size was the base group. (For percentages of herds in each size group and percentages of other covariates, see table 1 on page 30.) Herds were grouped into four regions (west, midwest, southeast, and northeast) with the midwest being the base level for analysis.

Other variables were added to the model because of their expected influence on one or more of the components of adjusted production value. Use of Dairy Herd Improvement Association (DHIA) records was included as a proxy variable to measure management level of the producer. It was expected that operations using DHIA records would produce more milk per cow and have higher adjusted values of production.

Rotational pasture grazing has gained in popularity as a method for controlling per hundred weight production cost even though milk production per cow may drop. Producers were asked if they pastured their cows during the summer months and if so, whether the pasture during this time period provided 90 percent or more of the cows’ roughage requirement. Milk production and adjusted production value were expected to be less for those herds that were pastured, especially if the pasture provided 90 percent or more of the cows’ roughage requirement. No use of pasture was the base category.

Bovine somatotropin (bST) is used to increase milk production per cow. The greater the percentage of cows receiving bST, the greater the expected increase in average milk production per cow. Initial analysis focusing on milk yield and bST use showed that the relationship between milk production per cow and percent bST use was curvilinear. This curvilinear relationship was modeled by transforming percent bST use into the square root of percent bST use.

A percentage of cows in their first lactation can have both positive and negative impacts on average herd milk production. Cows in their first lactation generally produce less milk than in later lactations. As the percentage of first calf heifers increases, average milk production per cow would be expected to decline. On the other hand, aggressive culling that replaces low producing cows with heifers of high milk potential can increase average milk production. Three levels of first calf heifers were used: 25 percent or less, 26 to 33 percent, and greater than 33 percent. The 25 percent or less first calf heifers level was the base category.

High somatic cell count is associated with a decrease in milk production. Bulk tank somatic cell count was divided into three levels: less than 200,000 cells/ml, 200,000 to 399,999 cells/ml and 400,000 or more cells/ml. The less than 200,000 cells/ml was the base level for this analysis.

Holsteins generally produce more milk than other breeds of dairy cows. Four levels of percent Holsteins in the herd were included: 100 percent, 90 to 99 percent, 50 to 89 percent, and 0 to 49 percent. One hundred percent Holstein was the base level.

The last two covariates, percent registered cows and percent change in cow inventory, dealt with cows being sold or added to the herd. Herds with 90 percent or more registered cows were expected to sell more cows to other producers than herds with less than 90 percent registered cows. Percent change in cow inventory accounted for changes in herd inventory as changes in herd inventory impact cow sales revenue and replacement costs.

C. Model results: Economic impact of Johne's disease on U.S. dairy operations

Johne's disease can greatly reduce production value in dairy herds, especially when the proportion of cull cows showing clinical signs consistent with Johne's disease is 10 percent or more. For such herds the cost of Johne's disease is over $200 per cow inventory. Most of this cost is due to a greater than 1,500 pounds per cow reduction in milk production.

1. Impact of Johne's disease on adjusted value of dairy production and by component[1]:

	Johne's Negative Herds		Johne's Positive Herds	
	Percent Cull Cows with Clinical Signs			
Parameter	0.1-10%	≥10%	<10%	≥10%
	Dollars per Cow			
+ Milk value	-10.00	-142.69	-29.68	-202.61
p-value[2]	(.783)	(.022)	(.406)	(<.001)
+ Calves born	-0.02	-0.95	1.08	1.82
p-value	(.986)	(.560)	(.423)	(.226)
+ Cows sold as replacements	-2.24	2.82	4.65	11.76
p-value	(.561)	(.758)	(.471)	(.381)
+ Cull cow revenue	3.59	-9.05	-1.82	-7.12
p-value	(.298)	(.162)	(.609)	(.152)
- Replacement cows	14.05	13.04	14.33	30.72
p-value	(.103)	(.527)	(.097)	(.081)
= Annual adjusted value[3]	-22.72	-162.91	-40.10	-226.88
p-value	(.538)	(.012)	(.272)	(<.001)

Results show that Johne's disease is indeed costly to dairy producers. For positive Johne's disease herds with less than 10 percent of cull cows reported showing clinical signs consistent with Johne's disease (hereafter referred to Johne's low clinical herds), adjusted annual value of production was $40 per cow lower than Johne's negative herds with no reported cull cows with clinical signs (hereafter referred to as Johne's base negative herds) (see the table above). For positive Johne's herds with 10 percent or more cull cows reported showing clinical signs (hereafter referred to Johne's high clinical herds), the economic impact was $227 per cow.

1 Value (dollars per cow) for herds in the listed categories are compared to negative Johne's disease herds that had no reported cull cows showing clinical signs consistent with Johne's disease.

2 P-value test that coefficient differs from 0 from linear regression model.

3 Some columns may not total due to rounding.

2. Impact of Johne's disease on dairy production parameters[1]:

Parameter	Johne's Negative Herds: 0.1-10%	Johne's Negative Herds: ≥10%	Johne's Positive Herds: <10%	Johne's Positive Herds: ≥10%
	Percent Cull Cows with Clinical Signs			
Milk production				
(lbs. per cow)	-76.91	-1,097.59	-228.30	-1,558.56
p-value[2]	(.783)	(.022)	(.406)	(<.001)
Calves born				
(number per 100 cows)	-0.03	-1.89	2.16	3.63
p-value	(.986)	(.560)	(.423)	(.226)
Pregnant culls (number per 100 cull cows)	6.93	4.11	0.91	14.64
p-value	(.014)	(.444)	(.775)	(.012)
Cows sold as replacements (number per 100 cows)	-0.20	0.26	0.42	1.07
p-value	(.561)	(.758)	(.472)	(.381)
Replacement cows (number per 100 cows)	1.28	1.19	1.30	2.79
p-value	(.103)	(.527)	(.097)	(.081)
Cows slaughtered (number per 100 cows)	1.24	-0.40	0.65	1.09
p-value	(.105)	(.819)	(.398)	(.446)
Cows died (number per 100 cows)	0.04	1.59	0.65	1.71
p-value	(.906)	(.052)	(.122)	(.013)
Poor conditioned culls (number per 100 culls)	2.40	19.24	4.77	14.48
p-value	(.289)	(.015)	(.090)	(.006)

Reduced milk production was the main factor causing Johne's positive herds to have reduced annual adjusted value of production. Johne's low clinical herds produced 228 pounds per cow less than Johne's base negative herds and the reduction for Johne's high clinical herds was 1,559 pounds per cow (see table 2 above).

1 Value for herds in the listed categories are compared to negative Johne's disease herds that had no reported cull cows showing clinical signs consistent with Johne's disease.

2 P-value from test that coefficient differs from 0 from linear regression model.

The second most important economic impact was increased replacement needs. Johne's low clinical herds required an additional 1.30 replacement animals per 100 cows which reduced annual adjusted value by $14 per cow (see tables 1 and 2 on pages 32 and 33). The impact was even greater for the Johne's high clinical herds. These herds needed almost three additional replacements per 100 cows at an annual cost of almost $31 per cow.

Even though Johne's positive herds culled more cows, their revenue from cull cow sales was less than Johne's base negative herds ($1.82 per cow for Johne's low clinical herds and $7.12 per cow for Johne's high clinical herds) (see table 2 on page 33). This decline in cull cow revenue can be explained in part by increased proportion of cull cows from Johne's positive herds that were in poor body condition (see table 2 on page 33) and thus were discounted in the market place.

D. Discussion

Cost of Johne's disease reported in other studies varies widely. To reduce this variance and compare study results, costs from these studies were standardized to a common milk price and, when possible, to common cull cow prices for clinical cases (see table 1 on page 35). Estimated economic impact of Johne's disease using a $13/cwt milk price ranged from $389 to $959 per infected cow with clinical signs of Johne's disease and $123 to $696 per infected cow not showing any clinical signs. Two studies did not separate costs between clinical and subclinical infected cows. Overall, cost per identified Johne's cow, combining both clinical and subclinical infected cows, ranged from $145 to $1,094 per cow with Johne's disease. Some of the variance between studies can be attributed to replacement cost, as some studies included this cost while others did not.

1. Summary of studies estimating annual economic impact of paratuberculosis in dairy cows, standardized to a common milk price ($13/cwt):

	Percent	Dollars per Cow			
Study	Cow Prevalence[1]	Infected, Clinically Positive	Infected, Clinically Negative	Infected, Clinically Positive & Negative	Total Study Population
Bendictus et al, 1987[2,3]	-	887	696	-	-
Meyer and Hall, 1994[4,3]	6.2[5]				
Method I[6]	-	-	-	365	23
Method II[7]	-		-	387	24
Whitlock et al, 1985[4,3]	1.8[5]	-	-	1,094	20
Buergelt and Duncan, 1978[2,8]	17.5[9] 27.5[10]	959	517	689	310
Abbas et al, 1983[4,8]	0.9[9] 7.2[10]	389	239	256	21
Chiodini and Van Kruiningen, 1986[4,3]	1.4[9] 16.6[10]	401	123	145	26

1 Percent based on total cow numbers in study.

2 Economic impact includes lost milk production, reduced cull value, and extra replacement.

3 Data collected from multiple herds.

4 Economic impact includes lost milk production and reduced cull value.

5 Both clinical and subclinical infected cows.

6 Net present value method over cow's lifetime.

7 Reduced annual revenue flows.

8 Data collected from a single herd.

9 Clinical disease only.

10 Subclinical infected cows only.

Even though these studies showed a wide variance in cost per infected cow, they have a much narrower range of cost per all cows (i.e., per all cows in the study population), from $20 to $26 for all but one study. NAHMS Dairy '96 Study findings can be compared to these studies by adjusting for percent of herds in each Johne's disease category. Johne's low clinical sign herds were 15.0 percent of total herds in this economic analysis, and an additional 7.2 percent were Johne's high clinical sign herds. Cost of Johne's disease across all herds equalled $22 ($40.10 x 15.0% + $226.88 x 7.2%) per cow. Thus, on a national basis, the Dairy '96 Study is consistent with previous Johne's disease cost estimates.

The $40 per cow per year for Johne's low clinical herds and $227 per cow per year for Johne's high clinical herds is significant when compared to net earnings a cow generates. For example, USDA's Economic Research Service (1996) estimated that the middle 50 percent of dairy producers based on cost of production earned $243 per cow over cash expenses in 1993. Thus, for average cost producers, Johne's disease has the potential for eliminating much of the cash returns from milking cows.

Other diseases that can result in clinical signs similar to that of Johne's disease include intestinal parasitism, malnutrition, salmonellosis, hardware disease, and winter dysentery. These diseases generate economic losses as well and such losses were estimated in this analysis by the negative herd categories. The difference between Johne's negative herds with no cull cows with clinical signs consistent with Johne's disease and those negative herds with at least 10 percent of the cull cows showing clinical signs was $163 per cow. However, for a given level of cull cows with clinical signs, Johne's positive herds had a greater economic loss than Johne's negative herds.

One limitation to this study was that costs, except for cow replacements, were not included. Feed costs, the greatest expense on a dairy operation, are related to milk production level. With Johne's disease positive herds producing less milk, one might expect their feed cost per cow to be lower. The definition of clinical signs of Johne's disease, however, was chronic diarrhea and weight loss that does not respond to treatment despite a normal appetite; the mechanism for this includes intestinal malabsorption. Thus, the suggested reduction in feed intake may not be significant for herds with clinical signs of Johne's disease. Other costs, such as labor and capital charges, are largely a function of the number of cows within the herd. Therefore, while the inclusion of costs would have been preferred, they were not included since the quality of these data by producer reporting via questionnaires was expected to be low, and their impact on the study results would not be expected to be great.

Some may conclude that the $40 per cow cost associated with Johne's low clinical herds is not as important since its statistical significance is greater than 0.1. However from a decision maker's point of view using a safety first criteria (Katooka's method) as a method for making decisions that involve risk (Robison, et al, 1984), 88 percent of the time Johne's low clinical herds will have less adjusted value of production than Johne's base negative herds. In addition there is a 79 percent chance that the annual economic impact will be at least $10 per cow inventory.

A disturbing result of this study in terms of disease control was that Johne's high clinical herds were at least as likely to sell replacement cows to other producers than Johne's base negative herds. Even though the association was not statistically significant, the occurrence of sales from high risk herds serve as a warning to producers to be careful about purchasing cattle and to select cows only from herds free of Johne's disease.

The economic impact presented in this analysis is an annual cost, i.e., it is a recurring cost that will continue year after year until Johne's disease is eliminated from the herd. Such recurring costs offer incentive to producers of positive herds to initiate a Johne's disease control program. Producers of negative herds have strong incentive to implement a biosecurity program to keep Johne's disease from entering their herds.

E. Complete regression model and related information

Table 1 on page 38 lists the variables used in estimating annual value of production and milk production per cow. The parameter estimates represent the impact each variable has on annual value of production. For example, herds in which the manager reported using DHIA records had an average milk production of 1,545.63 pounds per cow greater than non-DHIA herds. Annual value of production was $199.88 per cow higher.

1. Impact of Johne's on annual adjusted value of production per cow[1] and milk production per cow:

Variable	Adjusted value ($/cow) Parameter estimate	Adjusted value ($/cow) Prob > |t|[2]	Milk production (lb/cow) Parameter estimate	Milk production (lb/cow) Prob > |t|
Johne's disease economic analysis categories				
Negative herds:				
0% cull cows with clinical signs	Base	N/A	Base	N/A
<10% cull cows with clinical signs	-22.72	.538	-76.91	.783
≥10 cull cows with clinical signs	-162.91	.012	-1,097.59	.022
Positive herds:				
<10% cull cows with clinical signs	-40.10	.272	-228.30	.406
≥10 cull cows with clinical signs	-226.88	<.001	-1,558.56	<.001
Herd size:				
Less than 50 cows	Base	N/A	Base	N/A
50 - 99 cows	82.33	.019	645.33	.013
100 - 149 cows	95.82	.017	845.62	.005
150 - 249 cows	137.07	.002	1,164.44	<.001
250 - 499 cows	143.92	.005	1,136.01	.003
500 or more cows	241.49	<.001	2,016.72	<.001
Region:				
Midwest	Base	N/A	Base	N/A
West	9.23	.844	-20.05	.955
Southeast	-209.68	.006	-1,642.76	.004
Northeast	-32.78	.334	-266.74	.293
Use DHIA records	199.88	<.001	1,545.63	<.001
Pasture grazing (<90% roughage)	-18.91	.527	-168.84	.448
Pasture grazing (≥90% roughage)	-127.96	.005	-1,076.63	.001
Square root - % cows BST	38.09	<.001	317.06	<.001
First calf heifers:				
25% or less	Base	N/A	Base	N/A
26 % - 33%	78.42	.027	1,020.50	.001
34% or more	40.62	.264	1,164.18	<.001
Bulk tank somatic cell count				
199,999	Base	N/A	Base	N/A
200,000 - 399,999	-78.97	.009	-565.08	.011
400,000 or more	-295.48	<.001	-1,956.03	<.001
Percent of cows Holstein breed				
0% - 49%	-668.29	<.001	-5,086.23	<.001
50% - 89%	-255.33	<.001	-1,900.54	<.001
90% - 99%	-107.57	.002	-759.16	.003
100%	Base	N/A	Base	N/A

1 Prices: milk $13/cwt; calves $50/head; replacement cows purchased or sold $1100/head; cull cows (medium value): good condition $400/head, poor condition $250/head.

2 P-value from test that coefficient differs from 0 from linear regression model.

1. Continued.

Variable	Adjusted value ($/cow) Parameter estimate	Adjusted value ($/cow) Prob > |t|[1]	Milk production (lb/cow) Parameter estimate	Milk production (lb/cow) Prob > |t|
90% or more cows registered	51.15	.252	97.58	.761
Cow inventory change (percent)	-7.71	<.001	-4.43	.494
Intercept	2,103.88	<.001	16,976.97	<.001
Dependent variable mean value	2,038.85		17,464.44	
R-square	.4895		.5170	
Number of observations	974		974	

The reference population for the following population estimates (see table 2 below) is dairy herds with 30 or more cows in the 20 Dairy '96 Study states, representing 79 percent of U.S. dairy cows. These estimates are provided as reference for economic cost estimates for Johne's disease on U.S. dairy operations.

2. Culling and milk production (population estimates[2]):

a. Culling

i. For operations that culled cows in the 90 days prior to the Dairy '96 interview, percent of cows culled by lactation:

Lactation	Operation Average Percent	Standard Error	Percent Culled Cows	Standard Error
First	16.5	(± 0.9)	17.6	(± 0.7)
Second	16.1	(± 0.9)	20.4	(± 0.6)
Third or more	67.4	(± 1.2)	62.0	(± 1.0)
Total	100.0		100.0	

ii. Culling: pregnant cows

(a). For operations that culled cows in the 90 days prior to the Dairy '96 interview, percent of culled cows known or assumed to be pregnant by herd size:

Number Dairy Cows	Operation Average Percent	Standard Error	Percent Culled Cows	Standard Error
Less than 100	19.3	(± 1.5)	20.8	(± 1.7)
100-199	17.8	(± 1.6)	19.6	(± 1.7)
200 or more	17.3	(± 1.3)	17.8	(± 1.3)
All operations	18.9	(± 1.1)	19.5	(± 0.9)

1 Test that coefficient differs from 0 from linear regression model.

2 See sample profile on page 7.

(b). For operations that culled cows in the 90 days prior to the Dairy '96 interview, percent of culled cows known or assumed to be pregnant by region:

Region	Operation Average Percent	Standard Error	Percent Culled Cows	Standard Error
West	20.0	(± 1.5)	19.5	(± 1.6)
Midwest	18.2	(± 1.5)	19.5	(± 1.6)
Northeast	17.0	(± 2.2)	16.3	(± 1.4)
Southeast	38.8	(± 6.7)	31.2	(± 4.6)

iii. Body condition of culled cows:

(a). Percent of cows culled in the 90 days prior to the Dairy '96 interview by body condition and herd size:

Body Condition	Percent Cows Culled	Standard Error
Normal	78.1	(± 0.9)
Poor	21.9	(± 0.9)
Total	100.0	

iv. Average price received

(a). Normal body condition cows culled

- Average price received per cow by herd size:

Cow Average Price (Dollars)

Number Dairy Cows							
Less than 100	Standard Error	100-199	Standard Error	200 or More	Standard Error	Total	Standard Error
$379	(± $4)	$380	(± $6)	$398	(± $6)	$386	(± $3)

- Average price received per cow by region:

Cow Average Price (Dollars)

West	Standard Error	Midwest	Standard Error	Northeast	Standard Error	Southeast	Standard Error
$401	(± $7)	$386	(± $4)	$371	(± $6)	$347	(± $14)

(b). Poor body condition cows culled

- Average price received per cow by herd size:

Cow Average Price (Dollars)

Number Dairy Cows							
Less than 100	Standard Error	100-199	Standard Error	200 or More	Standard Error	Total	Standard Error
$233	(± $7)	$242	(± $6)	$235	(± $6)	$236	(± $4)

- Average price received per cow by region:

Cow Average Price (Dollars)

West	Standard Error	Midwest	Standard Error	Northeast	Standard Error	Southeast	Standard Error
$239	(± $6)	$243	(± $6)	$224	(± $8)	$197	(± $9)

(c). For operations that culled cows of both normal and poor body condition, operation average price difference by herd size:

Operation Average Price Difference (Dollars)							
Number Dairy Cows							
Less than 100	Standard Error	100-199	Standard Error	200 or More	Standard Error	Total	Standard Error
$154	(± $9)	$138	(± $6)	$158	(± $7)	$151	(± $6)

(d). For operations that culled cows of both normal and poor body condition, operation average price difference by region:

Cow Average Price (Dollars)							
West	Standard Error	Midwest	Standard Error	Northeast	Standard Error	Southeast	Standard Error
$154	(± $6)	$147	(± $9)	$153	(± $9)	177	(± $47)

b. Rolling herd average milk production

i. All herds

- Operation average (and cow average) rolling herd milk production (pounds per cow) by herd size and Dairy Herd Improvement Association (DHIA) participation:

	Pounds per Cow			
Number of Dairy Cows	Operation Average	Standard Error	Cow Average	Standard Error
Less than 100	16,152	(± 117)	16,809	(± 92)
100-199	18,302	(± 166)	18,350	(±159)
200 or more	19,215	(± 151)	19,768	(± 165)
All operations	16,587	(± 100)	18,198	(± 79)
DHIA or other computer records	18,470	(± 111)	19,463	(± 104)
No DHIA or other computer records	14,903	(± 152)	16,083	(± 120)

- Percent of operations by rolling herd average milk production:

Average Pounds	Percent Operations	Standard Error
Less than 14,000	21.4	(± 1.2)
14,000 - 15,999	17.5	(± 1.1)
16,000 - 19,999	42.3	(± 1.3)
20,000 - 21,999	10.8	(± 0.7)
22,000 or more	8.0	(± 0.6)
Total	100.0	

- Percent of operations reporting rolling herd average milk production from the Dairy Herd Improvement Association (DHIA) or other computerized records:

Percent Operations	Standard Error
46.8	(± 1.2)

ii. Holstein herds[1]

- Operation average (and cow average) rolling herd milk production for Holstein operations by herd size and Dairy Herd Improvement Association (DHIA) participation:

	Pounds per Cow			
Number of Dairy Cows	Operation Average	Standard Error	Cow Average	Standard Error
Less than 100	16,505	(± 116)	17,093	(± 92)
100-199	18,497	(± 155)	18,528	(±152)
200 or more	19,375	(± 151)	19,938	(± 159)
All operations	16,925	(± 99)	18,442	(± 78)
DHIA or other computer records	18,694	(± 111)	19,633	(± 102)
No DHIA or other computer records	15,282	(± 148)	16,352	(± 116)

- Percent of Holstein operations by rolling herd average milk production:

Average Pounds	Percent Operations	Standard Error
Less than 14,000	17.9	(± 1.2)
14,000 - 15,999	17.5	(± 1.2)
16,000 - 19,999	44.5	(± 1.3)
20,000 - 21,999	11.6	(± 0.7)
22,000 or more	8.5	(± 0.6)
Total	100.0	

F. Summary

Economic losses associated with *M. paratuberculosis* in U.S. dairies can be substantial. Lost milk production, higher cow replacement costs, and lower cull cow revenue all contribute to decreased value of production per cow inventory in Johne's disease infected herds. Reduced revenue as measured by this study is dependent on percentage of cull cows showing signs consistent with Johne's disease. If the percent of cull cows with clinical signs is less than 10 percent, the annual cost of Johne's disease is $40 per cow inventory. Infected herds that had more than 10 percent of their cull cows showing clinical signs consistent with Johne's disease suffered severe economic losses of $227 per cow inventory per year.

In analyzing the economic impact of Johne's disease, a disturbing fact was discovered: producers from infected herds were at least as likely to sell replacement cows to other producers than producers of noninfected herds. Given the high cost associated with Johne's disease, producers need to be careful about purchasing cattle and consider only selecting animals from noninfected herds.

1 Operations where Holstein cows accounted for 50 percent or more of the January 1, 1996, cow inventory.

Part IV: Johne's Disease Prevention and Control

A. Johne's disease control on the farm

Text in Part A has been excerpted with permission from "Johne's disease: paratuberculosis in cattle," a flyer produced by the Animal Health Commission, Pennsylvania Department of Agriculture (November 1995).

There is no treatment for Johne's disease. The key to preventing, controlling and eliminating Johne's disease in a herd is MANAGEMENT. Testing is a valuable tool to evaluate the extent of the infection in the herd, to identify infected animals, determine the necessary intensity of a control program, and to monitor progress of control efforts. The general strategy for controlling infection is to identify and adopt appropriate management and sanitation procedures for the individual farm that will best accomplish three main goals:

1. Prevent **highly susceptible** newborn calves and young animals from ingesting manure from infected adults, whether from the dam, from the environment, or from the feed or water.

2. Prevent **all other susceptible** animals from ingesting low levels of infected manure, especially by preventing contamination of feed and water.

3. Reduce the **total farm exposure** level to *M. paratuberculosis* by removing the bacteria from the environment and reducing the number of infected animals that are shedding the bacteria.

Goals one and two are achieved by sanitation and accepted good management practices, which benefit the farm as a whole. Goal three is accomplished by more rigorous sanitation and by testing and culling specifically for Johne's disease. For a given level of infection, detecting and culling infected animals in the earlier stages of the disease will speed the rate at which Johne's disease is reduced or eliminated from a herd.

Specific recommendations: The specifics and intensity of a Johne's disease control strategy for cattle will vary with the individual farm situation. To be relevant and effective, the program must be designed to fit the immediate and future goals of the farm, and available resources.

Many specific methods can be used to accomplish the three main management goals. The most effective and practical measures to break the cycle of infection and disease in the herd are outlined:

1. Management of newborn calves and young animals is critical and is the most effective area to focus the control effort

Calves should be born in an area that is dry, clean of manure, and well bedded. Calving areas should be used only by one or a few animals at a time and for maternity ONLY. Clean teats and udders are essential.

The most effective control measure is to remove newborn calves from the dam and maternity area immediately, thus ELIMINATING attempts to find the udder and nurse and the chance to ingest manure.

Feed newborns colostrum, ideally within one to two hours. Use only colostrum from healthy appearing dams, who are least likely to pass *M. paratuberculosis* into the udder and milk.

Milk replacer eliminates the risk of possible infection from feeding whole or pooled milk to calves. Use of replacer should be seriously considered, especially in herds with significant infection.

Young calves and heifers should be housed separately from adults and should have no direct contact with manure from adult cattle. Separate facilities are ideal, but sections protected by partitions, dry alleyways or buffer zones, or low traffic zones are effective.

Do NOT contaminate feed or feed mangers with manure from equipment or feet of farm personnel.

2. Management to prevent low levels of exposure in all older animals is important

Prevent manure contamination of feed and waterers. DO NOT use the same loader or equipment to clean up manure and to load feed. DO NOT walk in the feed bunks. Eliminate or fence animals out of natural drinking water sources, that are slow moving or stagnant, that collect run-off containing manure and or that animals stand in.

3. Identifying and removing infected animals and their manure is necessary to reduce the risk of continued exposure for all animals

Test the herd to identify infected animals that are, or probably will be, shedding the disease-causing bacteria. Based on evaluation of test results, infected animals determined to be infected should be culled as heavily as economic considerations permit. The most severely infected should be culled first.

An initial test of the whole herd followed by aggressive culling is very effective in initially reducing the prevalence in the herd. Appropriate management should be started at the same time. Testing and culling, combined with management, will control Johne's disease more effectively, and in less time, than partial culling and management or either measure alone. Frequency of testing and culling will depend on what is practical for the farm. The simplest and most effective approach to take in any infected herd is to manage all animals as if they are infected and assume all manure is guilty. This management attitude works all the time, and is especially important if testing and early culling is not practical.

Attempt to recognize and cull animals with suspicious clinical signs earlier, before they further contaminate facilities and lose salvage value. These animals are shedding billions of organisms each day. If you are uncertain, ISOLATE or cull anyway, and test to confirm for your knowledge.

SANITATION has no substitute. Remove manure as thoroughly and as often as possible. Always strive for more often. Spread manure on cropland not on pasture to be harvested or grazed the same season.

4. Reduce the risk of introducing infected animals into the herd, especially when elimination of infection is the goal

Be cautious and investigate animals to be purchased. Purchase animals from test negative herds, herds with no history of Johne's disease, and/or farms that look clean. Reduce risk by testing prior to purchase with serology or by fecal culture when animals arrive at the farm.

What are the goals of a Johne’s disease control program?

In herds with low to moderate infection (one percent or fewer clinical cases per year), wise use of a combination of testing, culling and management can be expected to reduce the number of clinical cases to zero within 1 to 3 years and to eliminate most infection in 5 to 7 years. As the herd turns over, each succeeding generation will have fewer infected animals, all of which will eventually be non-shedders. Complete elimination of infected cattle is likely to take many years after Johne’s disease becomes invisible in the herd, but it can happen. Preventive management should remain in place; otherwise, Johne’s disease is likely to recur.

With repeated negative herd tests, herds can qualify for paratuberculosis test negative certification status in certain states. These state programs are consistent with the National Paratuberculosis Certification Program Guidelines adopted by the U.S. Animal Health Association, November 1993.

Herds with severe, widespread infection will require aggressive control programs and many years to eliminate Johne’s disease. However, a practical control program and sound herd management can be expected to eliminate clinical disease in these herds and reduce the economic impact of Johne’s disease in the herd to a minimum.

For further information on control of Johne’s disease, see:

- “Johne’s disease: paratuberculosis in cattle,” a flyer by the Animal Health Commission, Pennsylvania Department of Agriculture (November 1995).
- Paratuberculosis (Johne’s disease). July 1996. Veterinary Clinics of North America: Food Animal Practice. W.B. Saunders Company, 12(2). Ed: R.W. Sweeney. Philadelphia, PA.
- Johne’s Information Center on the World Wide Web at http://www.vetmed.wisc.edu/pbs/johnes/

B. Use of specific Johne's disease preventive management strategies in 1995

The following population estimates refer to management practices considered as Johne's disease control measures. The reference population is U.S. dairy operations with at least 30 milk cows from the 20 participating Dairy '96 Study states, representing 79 percent of U.S. dairy cows.

1. Percent of operations by how soon newborn dairy calves were usually separated from their dams:

Hours	Percent Operations	Standard Error
Less than 1	13.1	(± 1.3)
1-6	38.3	(± 1.8)
7-12	23.0	(± 1.5)
13-24	12.1	(± 1.2)
More than 24	13.5	(± 1.3)
Total	100.0	

a. Operation average percent of heifer calves born on the operation that stayed with their dams more than 24 hours:

Operation Average Percent	Standard Error
15.1	(± 1.3)

b. Percent of operations by percent of heifer calves born on the operation that remained with their dams more than 24 hours:

Percent Heifers	Percent Operations	Standard Error
0	64.8	(± 1.8)
0-4.9	7.6	(± 1.0)
5.0-24.9	12.1	(± 1.2)
25.0-49.9	1.1	(± 0.4)
50.0 - 99.9	2.3	(± 0.6)
100	12.1	(± 1.2)
Total	100.0	

2. Percent of operations where teats and udders were usually washed before colostrum was collected (or before nursing):

Percent Operations	Standard Error
68.2	(± 1.7)

3. Percent of operations by frequency of using calving area as a hospital area for sick cows:

Frequency	Percent Operations	Standard Error
Frequently	16.0	(± 1.3)
Occasionally	38.9	(± 1.8)
Never	45.1	(± 1.8)
Total	100.0	

4. Percent of operations by bedding routines used for calving areas:

Routines	Percent Operations	Standard Error
Bedding material added between each calving	70.4	(± 1.5)
Bedding material added every 2-5 calvings	12.6	(± 1.1)
Bedding material added after 5 or more calvings	3.5	(± 0.5)
Bedding not used	13.5	(± 1.1)
Total	100.0	

5. Percent of operations by how often equipment used for manure handling was also used to handle feed fed to heifers less than 12 months of age:

Frequency	Percent Operations	Standard Error
Regularly (at least weekly)	12.4	(± 1.2)
Occasionally (less than weekly)	10.5	(± 1.1)
Not a practice	77.1	(± 1.5)
Total	100.0	

6. Percent of operations where heifers less than 12 months of age shared common feed or water sources with adult cattle:

Percent Operations	Standard Error
25.9	(± 1.7)

7. Direct contact between heifers and adult cows

a. Percent of operations by operation average age (in months) at which heifers first had direct contact with adult cows in the herd:

Age (Months)	Percent Operations	Standard Error
Less than 6	11.7	(± 1.3)
6-11 months	7.0	(± 1.0)
12 months or more	81.3	(± 1.5)
Total	100.0	

8. Percent of operations that brought the following classes of cattle onto the operation during 1995:

Cattle Introduced	Percent Operations	Standard Error
Unweaned heifers	5.0	(± 0.7)
Dairy heifers weaned but not bred	7.3	(± 0.7)
Bred dairy heifers	18.5	(± 0.9)
Lactating dairy cows	19.9	(± 1.0)
Dry dairy cows	7.1	(± 0.8)
Other heifers and cows (including beef)	1.9	(± 0.4)
Bulls (weaned)	8.7	(± 0.7)
Steers (weaned)	2.0	(± 0.3)
Any beef or dairy cattle	43.9	(± 1.3)

i. Percent of operations by percent of milk cows born off the operation:

Percent Milk Cows	Percent Operations	Standard Error
0	35.6	(± 1.7)
1-24	38.3	(± 1.8)
25 or more	26.1	(± 1.6)

ii. For operations that brought beef or dairy cattle onto the operation during 1995, percent of operations normally requiring Johne's disease (*M. paratuberculosis*) tests before bringing animals on farm:

Percent Operations	Standard Error
9.1	(± 1.1)

9. Percent of operations by maternity housing facilities or outside areas used during 1995:

Facility/Area Used	Percent Operations	Standard Error
Freestall	5.6	(± 0.5)
Individual animal area	38.3	(± 1.2)
Multiple animal area	26.3	(± 1.1)
Tie stall or stanchion	26.3	(± 1.1)
Drylot	28.9	(± 1.1)
Pasture	41.9	(± 1.3)
Freestall, multiple animal area, or drylot	47.4	(± 1.3)

10. Percent of operations in which maternity housing was separate from housing used for lactating dairy cows:

Percent Operations	Standard Error
45.4	(± 1.2)

C. Summary

This study identified several opportunities for improving Johne's disease herd management:

- Although 63 percent of dairy operations reported no heifer calves remaining with their dams more than 24 hours, at least 25 percent of heifer calves remained with their dams more than 24 hours on 15.5 percent of operations.
- 31.8 percent of operations did not routinely wash udders before collecting colostrum or before nursing.
- Many U.S. dairy operations used calving areas as hospital pens frequently (16 percent of operations) or occasionally (39 percent).
- On 12 percent of operations, equipment for manure handling was also used to handle heifer feed on a regular basis (at least weekly). Eleven percent of operations used equipment for manure handling to handle heifer feed less frequently.
- Heifers shared feed and water sources with adult cattle on 26 percent of operations.
- Forty-four percent of operations introduced new cattle in the previous year.
- Calving cows were housed with lactating cows on 55 percent of operations.

Analyses are ongoing to identify specific associations between herd management and prevalence of Johne's disease infection.

Johne's disease can be controlled on dairy operations through careful use of certain biosecurity and preventive measures. However, diagnostic test limitations and a long incubation period require Johne's disease control to be a long-term strategy.

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PRODUCTS*

and Related Study Objective(s)

1. Describe baseline dairy health and management practices.
   - Part I: Reference of 1996 Dairy Management Practices, May 1996
   - Biosecurity Practices of U.S. Dairy Herds, May 1996
   - Economic Opportunities for Dairy Cow Culling Management Options, May 1996
   - Part II: Changes in the U.S. Dairy Industry, 1991-1996, September 1996
   - Management Practices Associated with High-Producing Dairy Herds, February 1997

2. Describe management practices related to production of quality dairy products.
   - Part III: Reference of 1996 Dairy Health and Health Management, November 1996
   - Antibiotic Injection Practices on U.S. Dairy Operations, February 1997

3. Profile manure management systems.
   - Part III: Reference of 1996 Dairy Health and Health Management, November 1996
   - Waste Handling Facilities and Manure Management on U.S. Dairy Operations, February 1997

4. Describe the incidence of digital dermatitis (hairy heel warts).
   - Digital Dermatitis on U.S. Dairy Operations, March 1997

5. **Estimate national and regional prevalances of *M. paratuberculosis* (Johne's disease), bovine leukosis virus, and Neospora in adult dairy cows.**
   - High Prevalence of BLV in U.S. Dairy Herds, February 1997
   - Johne's disease on U.S. Dairy Operations, October 1997

6. Evaluate factors related to shedding of *Salmonella* and *Escherichia coli* 0157 in adult dairy cows.

* Released as of October 1, 1997. Additional products are planned.

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