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Evaluation of Factors that Would Initiate or Propagate Epidemic Coxiellosis in the U.S. Domesticated Goat Population

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Abstract

Coxiellosis is a zoonosis caused by *Coxiella burnetii*, an intracellular Gram-negative bacterium that is prevalent globally. Many animal species are susceptible to infection by *C. burnetii*, including ruminants, domestic carnivores, wildlife mammals, birds, and arthropods. The clinical presentation of coxiellosis is non-specific in most animals, with the exception of ruminants where coxiellosis is responsible for reduced fertility, abortions, and stillbirths during late gestation, as well as low birth weight. In humans, two clinical patterns of Q fever are observed. The acute disease resembles a flu-like syndrome, and is usually a self-limiting febrile illness during which pneumonia or hepatitis can occur. The chronic disease is a severe and possibly fatal illness. Q fever can lead to abortions, stillbirth, or premature deliveries in pregnant women. In fewer than 5 percent of the cases it causes chronic illness which includes endocarditis and chronic fatigue syndrome.

In 2005, coxiellosis was diagnosed for the first time in ruminants in the Netherlands as a cause of abortion on a dairy goat farm. In 2006, 2007, 2008, and 2009, six, seven, seven, and six new cases, respectively, were confirmed on other dairy goat farms. During the same period, two cases of abortion caused by *C. burnetii* were found on dairy sheep farms. In 1978, human Q fever became a notifiable disease in the Netherlands. The number of notifications per year between 1978 and 2006 was one to 32. In 2007, 168 confirmed human cases were reported. In 2008, 1,000 human cases were reported, making this the largest community outbreak of Q fever ever recorded. In 2009, 2,357 human cases of Q fever were reported. The human Q fever cases were linked to abortion epidemics on large dairy goat farms and dairy sheep farms.

In the United States, on April 22, 2011 the coxiellosis bacterium *C. burnetii* was detected in a goat placenta collected from a farm in Washington where does had aborted during January to April 2011. An epidemiological investigation concluded that goats from the index premises had been dispersed to 21 farms in 3 States. Seventeen farms participated in the outbreak investigation; *C. burnetii* infection was detected in 16 of 17 goat herds and in 161 of 667 (24 percent) goats tested. Q fever in at least six people was linked to the index farm and/or associated premises.

Coxiella burnetii infection in domesticated goats in the United States is endemic, and outbreaks of coxiellosis in goats are sporadic. Continual expansion of the goat industry in the United States, along with the explosive and concurrent epidemic of Q fever in the European Union (EU) Member States, has increased concerns among animal and human health officials of the likelihood of a similar epidemic in goats in the United States. To alleviate the concerns, we identified and evaluated factors that could potentially initiate and/or propagate an epidemic of coxiellosis in the U.S. goat population.

We concluded the likelihood is low that three factors would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States. These three factors are: (1) goat industry structure, (2) laboratory capacity to diagnose coxiellosis, and (3) reporting and monitoring coxiellosis. We concluded that the likelihood is medium that four additional factors would initiate and/or propagate an epidemic of coxiellosis. These four factors are: (1) goat health and general management, (2) accessibility to caprine health professionals, (3) responses to coxiellosis diagnosis, and (4) accessibility to coxiellosis vaccines. Finally, we concluded that the likelihood is low to medium that all seven factors, when considered together, would initiate and/or propagate an epidemic of coxiellosis in the U.S. domesticated goat population.

Keywords: Q fever, *Coxiella burnetii*, coxiellosis, epidemic, goat disease

Audience: Health professionals whose primary responsibilities are to develop risk-reduction strategies for transmissible infectious diseases of animals and humans.

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Evaluation of Factors that Would Initiate or Propagate Epidemic Coxiellosis in the U.S. Domesticated Goat Population

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Contents

List of Tables

List of Figures

Acronyms

AASRP	American Association of Small Ruminant Practitioners
AEO	Area Epidemiology Officer
AFSSA	French Food Safety Agency
AHS	Animal Health Service of Dutch Government
ANICAP	National Association of French Goat Milk Producers
CAHIA	Center for Animal Health Information and Analysis
CBS	Central Bureau voor de Statistiek, Netherlands
CDC	Center for Disease Control and Prevention
CEVA	CEVA Sante Animale pharmaceutical and vaccines
CFT	complement fixation test
CVI	Central Veterinary Institute, the Netherlands
EFSA	European Food Safety Authority
ELISA	enzyme linked immunosorbent assay
EU	European Union
IFA	immunofluorescence assay
LSI	Laboratory Services International, France
MLVA	multiple locus variable number tandem repeat analysis
MS	Member State in the EU
NAHLN	National Animal Health Laboratory Network
NAHMS	National Animal Health Monitoring System
NAHRS	National Animal Health Reporting System
NASPHV	National Association of State and Public Health Veterinarians
NASS	National Agriculture Statistics Service
NRL	National Reference Laboratory
NVSL	National Veterinary Services Laboratories, United States
OIE	World Organization for Animal Health
PCR	polymerase chain reaction
Q fever	query fever

Glossary

Coxiellosis – disease in any animal species due to infection with the bacterium *Coxiella burnetii*.

Q fever – disease in humans due to infection with the bacterium *Coxiella burnetii*.

1. Executive Summary

Coxiellosis is a zoonosis caused by *Coxiella burnetii*, an intracellular Gram negative bacterium that is prevalent globally, with the exception of New Zealand. Many animal species are susceptible to infection by *C. burnetii*, including ruminants, domestic carnivores, wildlife mammals, birds, and arthropods. The clinical presentation of coxiellosis is non-specific in most animals, with the exception of ruminants where coxiellosis is responsible for reduced fertility, abortions, and stillbirths during late gestation, as well as low birth weight.

Q fever was first recognized as a disease transmissible from animals to humans in abbatoir workers in 1935 in Australia. In today's society, the source of human infection is often unknown, although goats and sheep are linked to outbreaks more than other animal species. Domestic ruminants are considered the main source of human infection, given that ruminants shed *C. burnetii* in urine, feces, milk, and birth by-products. One billion bacteria may be excreted during abortion. In humans, two clinical patterns of Q fever are observed. The acute disease, which is most often asymptomatic and resembles a flu-like syndrome, is usually a self-limiting febrile illness during which pneumonia or hepatitis can occur. The chronic disease occurs in fewer than five percent of cases and is a severe and possibly fatal illness, usually culminating in endocarditis and occasionally vascular infection, osteomyelitis, and/or chronic hepatitis. Some human patients may develop a chronic fatigue syndrome. Q fever can also lead to abortions, stillbirth, or premature deliveries in pregnant women.

Coxiellosis in Europe has been described in nearly every country. In 2005, coxiellosis was diagnosed for the first time in the Netherlands as a cause of abortion on a dairy goat farm. Diagnosis was confirmed by immunohistochemistry on sections of placenta. A second case was diagnosed later in 2005. In 2006, 2007, 2008, and 2009, six, seven, seven, and six new cases, respectively, were confirmed on other dairy goat farms—mainly in the southern part of the country. During the same period, two cases of abortion caused by *C. burnetii* were found on dairy sheep farms, one in the southern and one in the northern part of the country.

In 1956, Q fever in humans in the Netherlands was first diagnosed. In 1978, Q fever became a notifiable disease in the Netherlands. The number of notifications per year between 1978 and 2006 was between 1 and 32, most of which involved patients that worked in high-risk occupations. In 2007, 168 confirmed human cases were reported, representing a significant increase and a hospitalization rate of 50 percent. In 2008, 1,000 human cases were reported, making this the largest community outbreak of Q fever ever recorded in the world. In 2009, 2,357 human cases of Q fever were reported. The hospitalization rates in 2008 and 2009 were approximately 20 percent each year. The human Q fever cases were linked to abortion waves on large dairy goat farms and – to a much lesser extent – abortion waves on dairy sheep farms.

In the United States, on April 22, 2011 the coxiellosis bacterium *C. burnetii* was detected in a goat placenta collected from a farm in Washington where 14 of 50 (28 percent) pregnant does had aborted during January to April 2011. An epidemiological investigation concluded that goats from the index premises had been dispersed to 21 farms in three States. Seventeen farms participated in the outbreak investigation. *C. burnetii* infection was detected in 16 of 17 goat herds, including polymerase chain reaction (PCR) confirmation of bacterial shedding in feces, vaginal mucous, or milk in 161 of 667 goats tested (24 percent). Q fever in at least six people was linked to the index farm and/or associated premises.

The goat industry in the United States was the only livestock industry to experience an increase in the number of animals and number of farms during the 20-year period from 1987 to 2007. In epidemiological language, *Coxiella burnetii* infection in domesticated goats in the United States is endemic and outbreaks of coxiellosis in goats are sporadic. Continual expansion of the goat industry in the United States—along with the explosive and concurrent epidemic of coxiellosis in the EU Member States, increased concerns among animal and human health officials. These concerns posed the following question: “Is it possible that the United States could experience a coxiellosis epidemic similar to that of the Netherlands and other EU Member States?” To answer this question, we identified and evaluated factors that could potentially initiate and/or propagate an epidemic of coxiellosis in the goat population. The seven factors evaluated were:

1. Goat industry structure in the United States
2. Goat health and general management practices
3. Laboratory capacity to diagnose coxiellosis in goats
4. Reporting and monitoring coxiellosis in animals
5. Accessibility to caprine health professionals
6. Responses to coxiellosis diagnosis in ruminants
7. Accessibility to coxiellosis vaccines in the United States

The goal of this assessment was to estimate the likelihood of an epidemic of coxiellosis in the domesticated goat population in the United States. The working hypothesis for this assessment was “The likelihood is non-negligible that one or more of the evaluated factors could initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.”

We completed an extensive search of peer-reviewed literature on coxiellosis in domesticated ruminants. We also conducted a series of interviews with the small ruminant commodity specialist for the National Animal Health Monitoring System (NAHMS), which is part of the USDA Animal and Plant Health Inspection Service (APHIS) Veterinary Services (VS) Centers for Epidemiology and Animal Health (CEAH) unit to reach consensus on the list of relevant factors that were considered in this assessment. Commodity specialists acquire extensive knowledge of numerous aspects of health and management practices as part of periodic national studies of each livestock sector in the United States. We conducted extensive and intensive searches of web pages of public and private animal health organizations, and we used electronic mail to distribute abbreviated questionnaires to gather information about some factors, if other sources of data were not available. Guidelines developed by the World Organization of Animal Health (OIE) were used to complete a qualitative assessment of the likelihood that each factor could contribute to an epidemic. The scope of this assessment is restricted to coxiellosis in domesticated ruminants, and is further restricted specifically to goats, wherever possible. The scope does not include evaluation of the role that any of these seven factors may play in transmission of *Coxiella burnetii* from domesticated ruminants to humans (i.e., spillover to humans), leading to an epidemic of Q fever in humans.

The total number of goats in the Netherlands increased 53.9 fold between 1984 and 2010. The average number of goats per farm in the severely affected region was 600. The average number of goats per infected farm in the Netherlands was 900. The herd size in the severely affected province in the Netherlands was 300 to 7,000 goats. The goat population in the Netherlands is geographically concentrated. The dairy goat is the predominant production-type in the Netherlands. The total number of goats in the United States increased only 1.4 fold between 1987 and 2011.The average number of goats per farm in the United States in 2007 was 21.7. Only 1.98 percent of all goat farms in the United States have more than 100 goats in the herd. Less than

1/4th of 1 percent of all goat farms in the United States have more than 500 goats in the herd (N = 356 herds). The goat population in the United States is more geographically dispersed.

Goat producers' knowledge of infectious disease, including Q fever, is inadequate. Q fever was the least recognizable of five important zoonoses of goats. Goat producers solicit the services of a veterinarian less frequently than producers in nearly all other livestock sectors. Public visitors to goat operations are permitted to enter the production areas frequently, increasing the risk of direct contact with environmental pathogens. Less than half of operations isolate new herd additions from their established herds. Veterinarians are not a key source of goat health information for 70.3 percent of producers; other goat producers are the most important source of goat health information for 33.3 percent of producers.

Diagnostic services for coxiellosis in goats in the United States are available at as much as 92.16 percent of 51 member-laboratories in the National Animal Health Laboratory Network (NAHLN). Many NAHLN laboratories that do not offer diagnostic services on-site do offer referral services to other laboratories. Direct detection of *C. burnetii* and serology are offered by most laboratories. Direct detection methodologies include PCR, RT-PCR, and IHC. Although the European Food Safety Authority (EFSA) recommends the ELISA as the preferred serological test for coxiellosis, serological tests used in United States vary among laboratories and include ELISA, CF, and IFA.

Coxiellosis was not reportable in the Netherlands in 2008, and monitoring and reporting coxiellosis in the EU in general was not harmonized as of 2008. However, evidence of coxiellosis was present in ruminant populations in all 18 Member States that reported findings during 2007 to 2008. Monitoring and reporting coxiellosis in the United States varies among States. Coxiellosis is reportable to many of the leading animal health agencies in the States and to nearly all of the leading human health agencies in the States. There are a few States in which coxiellosis appears to be un-reportable. Animal health agencies within a State also may report diagnosis of coxiellosis to the National Animal Health Reporting System (NAHRS), but reporting to NAHRS is not a requirement. Although there is no central repository for reporting diagnosis of coxiellosis in animals in the United States, legal requirements for reporting generally are widespread among the States.

The American Association of Small Ruminant Practitioners (AASRP) as a veterinary specialty embraces the concept of serving as a key provider of health services for small ruminants, including goats. The median number of AASRP members per State is 12, and the interval is 0 to 49 members. AASRP members (51.2% percent) reported that their professional interest in domestic goats is less than 10 percent. The paucity of animal health professionals with an interest in goats should elevate concerns that transmissible infectious diseases (e.g., coxiellosis) of this livestock sector are more likely to undergo delayed diagnosis, or remain undiagnosed for a protracted period.

A list of 16 potential control options was developed by the EFSA, after the epidemic of coxiellosis in the Netherlands. The Netherlands implemented numerous control options in response to the epidemic. Many of the control options were the result of a series of legislative mandates issued during June 12, 2008 to December 18, 2009. Vaccination of dairy goats and dairy sheep on farms with more than 50 animals was required by law. By contrast, there is no singular response to coxiellosis diagnosis in domesticated ruminants in the United States. A national survey of actions taken in the United States, in response to diagnosis of coxiellosis in ruminants, was administered and education of livestock producers about coxiellosis was one of the most frequently cited actions taken in the United States. Goat producers in the United States must play a pivotal role in control of coxiellosis on their operations because most potential control options are not mandated by individual States.

Coxiellosis vaccine was prohibited in the Netherlands prior to the epidemic and through 2008. The coxiellosis epidemic in the Netherlands led to licensing of vaccine and eventually to mandatory vaccination in 2009 to control the epidemic. Coxiellosis vaccine has been granted full approval in the European Union (EU). Clinical trials provide evidence that phase I vaccine has superior efficacy to phase II vaccine, and that preventive vaccination is far superior to outbreak vaccination. Vaccination protects against abortion, colonization, and contamination of a variety of caprine tissues. Vaccination decreases contamination of the environment, which may decrease transmission of infection to animals and humans. Coxiellosis vaccines are not licensed for use in the United States.

We concluded the likelihood is low that three factors would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States. These three factors are: (1) goat industry structure; (2) laboratory capacity to diagnose coxiellosis; and (3) reporting and monitoring coxiellosis. We concluded further that the likelihood is medium that four additional factors would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States. These four factors are: (1) goat health and general management; (2) accessibility to caprine health professionals; (3) responses to coxiellosis diagnosis; and (4) accessibility to coxiellosis vaccines. Finally, we concluded that the likelihood is low to medium that all seven factors, when considered together, would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.

None of the factors in this assessment was assigned a high likelihood that they would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States, although there is opportunity to improve the coordinated response to coxiellosis in the livestock population. Similarly, none of the factors in this assessment was assigned a negligible likelihood that they would initiate and/or propagate an epidemic of coxiellosis.

2. Introduction and Background

2.1 Coxiellosis and Q fever in the Netherlands, 2005 to 2010

In 2005, coxiellosis was diagnosed for the first time in the Netherlands, as a cause of abortion on a dairy goat farm. Diagnosis was confirmed by using immunohistochemistry on sections of placenta (Wouda and Dercksen, 2007). A second case was diagnosed later in 2005. In 2006, 2007, 2008, and 2009, six, seven, seven, and six new cases, respectively, were confirmed on dairy goat farms, mainly in the southern part of the country. During the same period, two cases of abortion caused by *C. burnetii* were found on other dairy sheep farms, one in the southern and one in the northern part of the country. The average number of goats per infected farm was 900, of which 20 percent of the pregnant goats on average (10 to 60 percent) had aborted. The average number of sheep for the two infected sheep farms was 400 and the abortion rate was 5 percent (van de Brom and Vellema, 2009).

In 2008, all 15,772 blood samples from small ruminants to be tested as part of the *Brucella melitensis* monitoring program were also tested for coxiellosis using an ELISA (Ruminants Serum Q fever LSI Kit, LSI, Lissieu, France). From those samples, 12,363 were of ovine and 3,409 of caprine origin. Based on these blood samples, seroprevalence for goats in the Netherlands was 7.8 percent with 95 percent confidence interval of 6.9 to 8.7, and for sheep 2.4 percent with 95 percent confidence interval of 2.1 to 2.7 (van den Brom and Vellema, 2009).

Dairy sheep and dairy goat farmers were also given the opportunity to test bulk milk samples using a PCR (TaqvetTM *Coxiella burnetii*, TaqMan Quantitative PCR, LSI, Lissieu, France). In total, 306 bulk milk samples were tested and 79 (26 percent) were positive (van den Brom and Vellema, 2009). By February 18, 2010, 73 dairy goat farms and 2 dairy sheep farms, out of the total of 360 dairy goat farms and 40 dairy sheep farms with more than 50 animals in the Netherlands, had been declared infected based on PCR-positive bulk milk testing.

In 1956, Q fever in humans in the Netherlands was first diagnosed. In 1978, Q fever became a notifiable disease in the Netherlands. The number of notifications per year between 1978 and 2006 was 1 to 32, most of which involved patients that worked in high-risk occupations. In 2007, 168 confirmed human cases were reported, and the hospitalization rate was 50 percent (Steenbergen et al., 2007). In 2008, 1,000 human cases were reported, making this the largest community outbreak of Q fever ever recorded in the world (Delsing and Kullberg, 2008; Schimmer et al., 2008; Schimmer et al., 2009). In 2009, 2,357 human cases of Q fever were reported. The hospitalization rates in 2008 and 2009 were approximately 20 percent each year (van der Hoek et al., 2010). The human Q fever cases were linked to abortion waves on large dairy goat farms, and to a much lesser extent abortion waves on dairy sheep farms.

2.2 Coxiellosis and Q fever Outbreak Associated with Goats

Washington and Montana, 2011

On April 22, 2011, the Q fever bacterium *Coxiella burnetii* was detected in a goat placenta collected from a farm in Washington, where 14 of 50 (28 percent) pregnant does had aborted during January to April 2011. A county health alert advised health-care providers to ask patients with symptoms compatible with Q fever (e.g., fever, headache, chills, and myalgia) about exposure to goats, and the owners of the farm informed purchasers of their goats that *C. burnetii* had been detected in their herd. On May 25, the county health department reported a symptomatic patient with antibodies to *C. burnetii* who had purchased goats from the farm in February 2011. On May 27, a report from Montana identified a child seropositive for *C. burnetii* whose family had purchased goats from the Washington farm in October 2010; one of the goats aborted triplets 2 weeks before the child's May 12, 2011 illness onset. On May 31, five more persons reported onset of symptoms compatible with Q fever from late March to mid-May, and following exposure at a Montana farm to goats that had been purchased from the Washington farm at various times during October 2010 to January 2011. On June 10, the Washington State Department of Health and Montana Department of Public Health and Human Services requested the Centers for Disease Control and Prevention (CDC) assistance to characterize the extent of the outbreak, distribute Q fever information, and identify others at risk of infection (Centers for Disease Control, 2011).

Goats sold after June 2010 by the Washington farm where *C. burnetii* initially was detected were traced to 21 farms in Washington (10 counties), Montana (3 counties), and Oregon (1 county). Seventeen farms participated in the outbreak investigation. *C. burnetii* infection was detected in 16 of 17 goat herds, including PCR confirmation of bacterial shedding in feces, vaginal mucous, or milk in 161 of 667 (24 percent) goats tested. An overall seroprevalence of 21 percent (131 of 615) was detected by enzyme-linked immunosorbent assay. As of October 14, 2011 19 percent (20 of 108; 11 in Washington and 9 in Montana) of serologically tested persons met the outbreak case definition of a person epidemiologically linked to at least 1 of the 17 farms of interest (i.e., as a goat owner, farm visitor, or neighbor) since January 2011 with a *C. burnetii* phase II immunoglobulin G titer ≥1:128 by immunofluorescence assay (Bamberg et al., 2007). No deaths were reported; 4 of the 20 persons were hospitalized, and 5 were asymptomatic.

Initially, movement restrictions were placed on the index premises, but that intervention was revised to a herd management plan. Eventually, both Washington and Montana implemented a herd management plan to promote continued communication between public health and agricultural authorities and to advise goat owners to disinfect birthing areas, avoid contact with birth products, limit visitor access to animal holding areas, maintain an animal registry, and report animal abortions and positive Q fever test results to State authorities. All homes within a 1-mile radius of the Washington farm where *C. burnetii* was initially detected, and a Montana farm that also had high goat seroprevalence linked to human illness, were visited once by CDC or by county public health officials and CDC in July or August 2011 to provide Q fever health education and offer human serologic testing. The States have received no additional reports of Q fever since July 2011. Prior to 2006, the number of cases-per-year of Q fever reported to CDC was approximately 5 in 1998 and 145 in 2005.

2.3 Summary

Netherlands:

- Q fever was diagnosed in humans in the Netherlands for the first time in 1956.
- Coxiellosis was diagnosed in dairy goats in the Netherlands for the first time in 2005.
- Prior to 2006, the number of reported cases per year of Q fever in humans was 32 or fewer.
- In 2009 alone, 2,357 human cases of Q fever were reported in the Netherlands.

United States:

- Prior to 2006, the number of cases-per-year of Q fever reported to CDC was approximately 5 in 1998 and 145 in 2005.
- Coxiellosis was diagnosed in a goat herd in Washington in 2011.

- An epidemiological investigation concluded that goats from the index premises had been dispersed to 21 farms in three States.
- *C. burnetii* was recovered from goats on many of the recipient farms.
- Q fever infection in at least six people was linked to the index farm and/or associated farms.
- A herd management plan for coxiellosis was implemented on the affected premises.

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3. Hazard Identification of Coxiellosis and Q fever

The gram-negative, obligate-intracellular bacterium *Coxiella burnetii* is the etiological agent of coxiellosis and Q fever. Q fever is a well-recognized but somewhat neglected zoonosis that has spread worldwide with the exception of New Zealand. The infection is habitually asymptomatic in both animals and humans (Maurin and Raoult, 1999; Norlander, 2000).

3.1 Clinical Signs

The number of *C. burnetii* reservoirs is large and includes mammals, birds and arthropods, mainly ticks. Generally, the clinical presentation of coxiellosis is non-specific in most animals, with the exception of ruminants where *C. burnetii* is responsible for reduced fertility, late term abortion, perinatal mortality, premature delivery, and low birth weight (Figure 1) (Moore et al., 1991; Bildfell et al., 2000).

Figure 1. Abortion during late gestation due to *C. burnetii* infection in a small ruminant (Bruschke, 2010).

In humans, two clinical patterns of Q fever can be observed. The acute disease, most often asymptomatic or resembling a flu-like syndrome, is usually a self-limiting febrile illness during which pneumonia or hepatitis can occur. The chronic disease in humans develops in about 5 percent of cases and is a severe and possibly fatal illness, usually resulting in endocarditis and occasionally in a vascular infection, osteomyelitis and/or chronic hepatitis. Q fever also may be a cause of chronic fatigue syndrome. The exact prevalence of chronic Q fever is unknown. Scientific reports from England and Wales, Spain, France, and the United States suggest that 11, 6, 5, and 1 percent, respectively, of human patients develop chronic Q fever (ECDC, 2010). The percent fatality in patients with chronic Q fever is 5 to 50 percent. Some patients may develop a chronic fatigue syndrome, and *C. burnetii* infection can lead to abortions, stillbirth, or premature deliveries in pregnant women (Maurin and Raoult, 1999).

3.2 Source, Transmission, and Maintenance

Numerous animal species are susceptible to infection by *C. burnetii* including ruminants, domestic carnivores, wildlife mammals, birds, and arthropods, such as ticks. Different species may play a role in the dissemination or maintenance of the disease, either as carriers or as vectors of *C. burnetii*, although the role of some of the species in the transmission of the disease has not been established with certainty. The source of human infection frequently cannot be established, but sheep and goats are linked more frequently to Q fever outbreaks in humans than are other animal species (McQuiston et al., 2002). For instance, most cases in humans follow a direct or indirect exposure to livestock and those cases have been attributed to a variety of livestock practices, such as spring lambing and shearing, which then lead to environmental contamination and spread of the microorganism. A diagram of a proposed model of transmission is presented in Figure 2 (Bruschke et al., 2010).

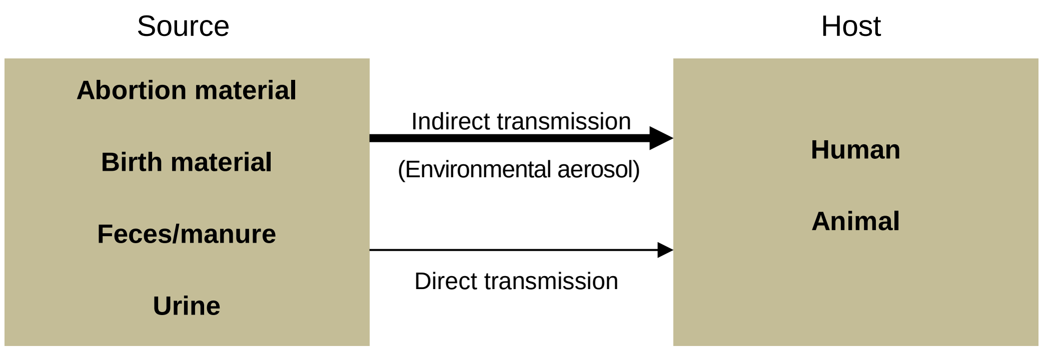

Figure 2. Proposed model of transmission of *Coxiella burnetii* infection in animals and humans (Bruschke et al., 2010; EFSA, 2010).

Shedding of *C. burnetii* into the environment mainly occurs during parturition, during which more than 10^9 bacteria are released at the time of delivery. Goats and cows mostly shed *C. burnetii* in vaginal mucus and milk, whereas sheep shed the bacteria mostly in feces (Rodolakis et al., 2007). The duration of shedding in milk from goats and cows is several months to years. The udder and retro-mammary lymph nodes may remain infected for more than 20 months. Goats can become chronically infected and may shed *C. burnetii* for two consecutive pregnancies. Goats can also shed *C. burnetii* in placenta and vaginal mucus during two or more subsequent kiddings. In contrast, ewes abort only one time, shed *C. burnetii* in vaginal mucus during the abortion, but do not shed in vaginal mucus at subsequent lambings (Berri, 2000). The duration of excretion of *C. burnetii* may play an important role in the persistence of infection. The EFSA working group on Q fever developed a simple conceptual model to highlight two aspects of the disease (Figure 3):

- Maintenance of the infection in animal populations, with particular emphasis on domestic ruminants, and
- Spillover of infection from animal populations to humans through amplification, transmission, and exposure

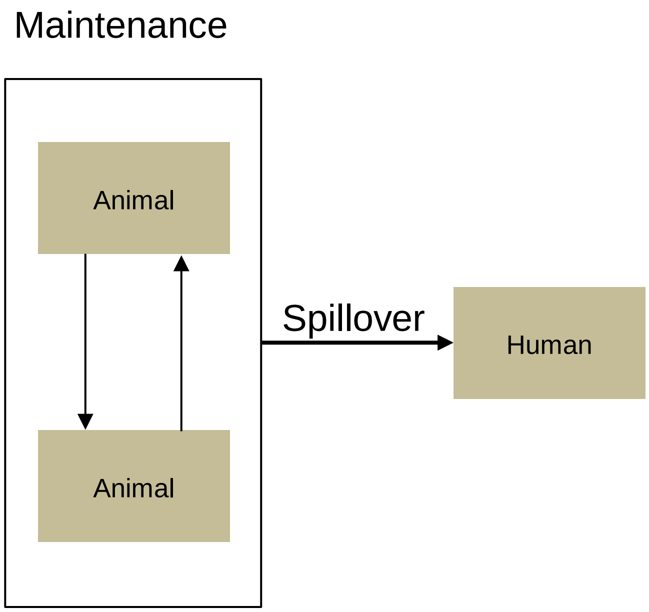

Figure 3. A conceptual model of maintenance of *Coxiella burnetii* infection in domestic ruminant populations, and spillover from animals to humans (EFSA, 2010).

Human incident cases or outbreaks are considered a good indicator of disease activity in a geographical area, leading to intensification of the investigation into likely sources of infection (Cutler et al., 2007, Lyytikäinen et al., 1998; Tissot-Dupont et al., 1999; Berri et al., 2003; van der Hoek et al., 2010). Nevertheless, domestic ruminants are considered the main source of human infection because ruminants may shed *C. burnetii* in urine, feces, milk, and birth products. High concentrations of *C. burnetii* are found in the placenta and vaginal secretions of infected animals (Arricau-Bouvery and Rodolakis, 2005a; Arricau-Bouvery et al., 2003; Berri et al., 2000; Berri et al., 2007). The contamination of humans occurs after inhalation of aerosol or dust contaminated with parturient fluids of infected livestock. In addition, survival of bacteria in an unfavorable environment and long-term persistence as a pseudo spore are likely to contribute to the prevalence of enzootic-epizootic foci of Q fever (EFSA, 2010).

3.3 Q fever in Humans in the European Union

In Europe, Q fever has been described in almost every country, but the epidemiological situation has not been clearly established because of a considerable variation in monitoring or the lack of specific Q fever surveillance systems across EU Member States. Moreover, the epidemiology of this disease is largely unstudied. Both human and animal *C. burnetii* infections are under-diagnosed and under-reported mostly because of the polymorphic nature of the disease, which may be characterized by the absence of apparent clinical symptoms and the lack of awareness of this disease in medical and veterinary communities. In addition, the definitive diagnosis of Q fever is a laboratory-based diagnosis and requires expensive and elaborate technological methods as well as highly trained personnel to establish an unequivocal Q fever diagnosis.

Although Q fever historically has not been perceived as an important public health threat in the medical or veterinary communities, *C. burnetii* can cause debilitating disease and may result in potentially fatal chronic infections among humans. It is also considered a potential agent of bioterrorism because of its accessibility, low infectious dose, resistance to environmental degradation, and aerosol route of transmission (CDC, 2012).

Human outbreaks in urban or residential areas have been recently reported in Member States of the EU (e.g., the Netherlands, Germany, and Bulgaria) and in Croatia, involving large numbers of cases and being linked to small ruminant flocks (Panaiotov et al., 2009; Medic et al., 2005; Porten, et al., 2006; Gilsdorf et al., 2008; Schimmer et al., 2008). Recently, it has become apparent that the Q fever situation in a country can escalate rather quickly, a very good example being the outbreak in the Netherlands. That outbreak began around 2007 and continued through 2010, with human deaths partly caused by Q fever, according to the National Institute for Public Health and the Environment, the Netherlands; http://www.rivm.nl. There were 194 cases in 2007, 982 cases in 2008, and 2,305 cases in 2009. The current situation is a significant contrast to the past situation where, between 1997 and 2006, relatively few cases of Q fever were reported in the country (i.e., 5 to 16 cases per year). Coxiellosis was not diagnosed as a clinical disease in ruminants in the Netherlands until a few years ago. The lack of efficient diagnostic methods could have hampered the diagnosis of coxiellosis at an earlier stage (Wouda and Dercksen, 2007). The situation in the Netherlands emphasizes the role of ruminants, in particular goats, as an important reservoir of infection. Therefore, surveillance of ruminant herds or flocks prone to abortions should be encouraged.

These recent and large outbreaks highlight how zoonoses such as Q fever may also represent a public health threat for urban populations and emphasize the need for strengthening surveillance regarding Q fever in affected countries. Therefore, the implementation, development, and standardization of monitoring and detection methods are crucial for supporting future preventive and control measures.

3.4 Summary of Hazard Identification

- *Coxiella burnetii* is the etiological agent of Q fever in animals and humans.
- The reservoir of *C. burnetii* includes mammals, birds, and arthropods.
- *C. burnetii* causes abortion in ruminants during late gestation.
- One billion organisms or more can be shed into the environment during parturition.
- *C. burnetii* also causes perinatal mortality and low birth weight in ruminants.
- Q fever in humans is an acute disease that can become a chronic disease.
- Sheep and goats are linked frequently to Q fever outbreaks in humans.
- Transmission of *C. burnetii* from ruminants to humans can be direct or indirect.
- Direct transmission to humans may result from contact with birth products or a fetus.
- Indirect transmission to humans is by aerosol.
- Recent outbreaks of coxiellosis highlight the impact of the disease at the herd level.
- Recent outbreaks also highlight the impact of Q fever on the human population.

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4. Problem Statement

Based on epidemiological terminology, *Coxiella burnetii* infection in domesticated goats in the United States is endemic and outbreaks of coxiellosis (i.e., the disease) in goats are sporadic. The epidemic of coxiellosis in goats, and the concurrent epidemic of Q fever in humans in the EU Member States, increased concerns among animal and human health professionals in the United States. These concerns posed the following question: “Is it possible that the United States could experience a coxiellosis epidemic (and subsequently a Q fever epidemic) similar to that of the Netherlands and other EU Member States?” To answer this question, we identified and evaluated factors that would potentially initiate and/or propagate an epidemic of coxiellosis in the goat population. The seven factors evaluated were:

1. Goat industry structure in the United States
2. Goat health and general management practices
3. Laboratory capacity to diagnose coxiellosis in goats
4. Reporting and monitoring coxiellosis in animals
5. Accessibility to caprine health professionals
6. Responses to coxiellosis diagnosis in ruminants
7. Accessibility to coxiellosis vaccines

5. Goal and Working Hypothesis

5.1 Goal

The goal of this assessment was to estimate the likelihood of an epidemic of coxiellosis in the domesticated goat population in the United States.

5.2 Working Hypothesis

The working hypothesis for this assessment was “The likelihood is non-negligible that one or more of the evaluated factors would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.”

6. Scope

The scope of this assessment is restricted to coxiellosis in domesticated ruminants and is restricted specifically to goats, wherever possible. The scope does not include evaluation of the role that any of these seven factors may play in transmission of *Coxiella burnetii* from domesticated ruminants to humans (i.e., spillover to humans), thus leading to an epidemic of Q fever in humans. An invaluable source of data for this assessment is the USDA NAHMS’s *National Study of the Domesticated Goat Population in 2009*. The geopolitical unit under consideration in the study “Goat 2009” was the entire United States. Thus, the geopolitical unit under consideration in this assessment also is the entire United States. Inferences about individual States in the United States were not attempted, with rare exceptions.

The results of this assessment may have implications for coxiellosis policies in the United States, but the assessment does not, nor was it ever intended to, directly address policies on coxiellosis. Any revision of current policies and formulation of new policies will remain at the discretion of each State. The National Association of State and Public Health Veterinarians (NASPHV) is preparing the document “Recommended Measures for Controlling *Coxiella burnetii* Infection

Among Humans (Q Fever) and Animals (Coxiellosis), 2012". As the title of that document suggests, the NASPHV publication focuses more specifically on coxiellosis policy. This assessment should serve as a complement to the NASPHV publication.

7. Materials and Methods

We completed an extensive search of published, peer-reviewed literature on coxiellosis in domesticated ruminants. We also conducted a series of interviews of the small ruminant commodity specialist for NAHMS (USDA–APHIS–Veterinary Services' Centers for Epidemiology and Animal Health) to reach consensus on the specific goal of the assessment and to define the list of factors that should be considered in this assessment. NAHMS's commodity specialists acquire extensive knowledge of numerous aspects of health and management practices as part of periodic national studies of each livestock sector. We conducted extensive and intensive searches of web pages of public and private animal health organizations, and we used electronic mail to distribute abbreviated questionnaires to gather information about some factors, if no other sources of data were available. When possible, we made direct comparisons of these factors between the Netherlands and the United States. In the context of a case-control epidemiological study design, the Netherlands was defined as the "case," or the affected country, and the United States was defined as the "control," or the unaffected country, in those comparisons. Guidelines developed by the OIE (World Organization of Animal Health) were used to conduct a qualitative assessment of the likelihood of an epidemic of coxiellosis in the domesticated goat population in the United States. First, the likelihood that an individual factor would initiate and/or propagate an epidemic of coxiellosis was estimated. Secondly, the individual estimates of likelihood were reconsidered to arrive at the likelihood that all factors in combination would initiate and/or propagate an epidemic of coxiellosis in goats in the United States. Risk estimates and descriptive definitions of the risk estimates that were utilized in this assessment are described in Table 1.

Table 1. Risk estimates and descriptive definitions of qualitative results of risk estimates.

Risk Estimate	Descriptive Definition of Qualitative Results
High	An epidemic due to a factor would be very likely to occur.
Medium	An epidemic due to a factor would be nearly as unlikely to occur as likely to occur.
Low	An epidemic due to a factor would be unlikely to occur.
Negligible	An epidemic due to a factor would almost certainly not occur.
Source: OIE (World Organisation for Animal Health. 2004. *Handbook on Import Risk Analysis for Animals and Animal Products.* Vol 1. Pg 27.	

8. Goat Industry Structure

8.1 Goat Industry Structure in the Netherlands

There were 6.4 million livestock units in the Netherlands in 2007, 0.4 percent more than in 2005. The total number of livestock holdings was 76,700. The average number of livestock units per holding increased from 78 to 84. Twenty-five percent (N =19,175) of the holdings specialized in goats, sheep, and other grazing livestock. There were 400,000 goats and 1.1 million sheep around January 1, 2011 (Table 2). The Netherlands does have specialized goat and sheep farms, but many goats and sheep are retained on cattle farms also. The total number of farms with goats (i.e., any number of goats) around January 1, 2011 was 3,170. Most goats (70 percent) are retained for milk production. The number of specialized goat farms was 367. The average number of goats on the specialized farms in 2009 was 895 and the average number on the non-specialized farms was only 16. Dairy goat farming as a specialty in the Netherlands began after the introduction of the European milk quotation system for dairy cattle in 1984 and it increased after the outbreaks of classical swine fever in 1997 and foot-and-mouth disease in 2001. Dairy goat farms produced 140,000 tons of milk, an increase from nearly 0 tons in 1984. There were 16 factories that process goat milk. The total number of goats increased from 7,415 in 1983 to 178,571 in 2000 and to 374,184 in 2009 (Table 3). The number of dairy goats more than 1 year old increased from 98,077 in 2000 to 231,090 in 2009 (Table 3) (Roest et al., 2011)

Table 2. Number of small ruminant premises and small ruminants in the Netherlands, 2009.

Production-type	Premises or Locations (Number)	Animals (Number)
Sheep	40,000	1,000,000
Goat	20,000	325,000
Dairy Sheep	Less than 50	Not reported
Dairy Goat	Less than 400	Not reported
Source: Vellema et al, 2010 Q fever conference presentation, image #09. Statistics Netherlands, Statistical Yearbook 2011, Agriculture, page 35. Note: The decrease from 374,184 in 2009 to 352,000 in early 2010 to 325,000 in later 2010 was due to depopulation of 50,000+ dairy goats.		

Table 3. Number of goats in the Netherlands during 4 years, 1983, 1995, 2000, 2009.

Year	Total Number of Goats	Total Number of Dairy Goats 1 Year of Age and Older
1983	7,415	Not reported
1995	76,063	Not reported
2000	178,571	98,077
2009	374,184	231,090
Sources: Statline Database Statistics Netherlands (CBS) cited in Roest et al 2011 ref #40, Statline Database Statistics Netherlands (CBS) cited in Roest et al 2011 #41.		

8.2 Goat Industry in the Epidemic Region

The dairy goat industry in the Netherlands is concentrated in the province of Noord-Brabant, located in the southeastern section of the country. The number of goats per farm in Noord-Brabant was 300 to 7,000 with an average of at least 600 goats in 2007. The number of farms populated with more than 200 dairy goats increased by 274 percent during the 9-year period between 1995 and 2003. There were 135 farms in 1995 and the number increased to a maximum of 370 farms in 2003. The number of farms with more than 200 dairy goats began to decline in

2004, but 315 of these farms still were operable as of 2008 (Figure 4). All dairy goats are housed throughout the year, except approximately 17,000 goats that are kept on organic farms. The goat farms in Noord-Brabant frequently were located close to villages and cities.

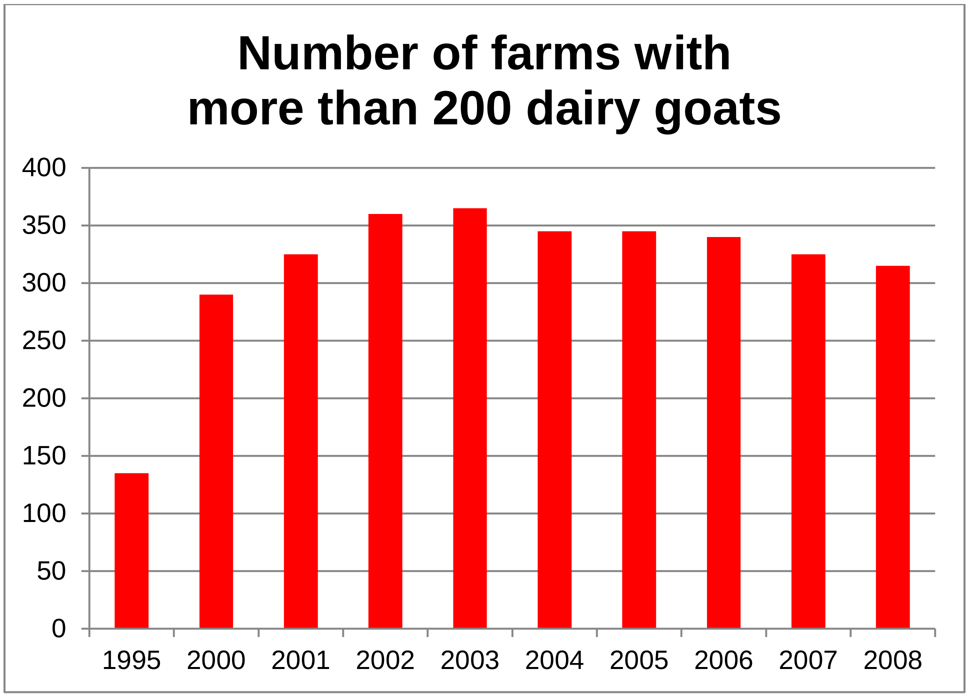

Figure 4. Number of dairy goat farms in the Netherlands with more than 200 goats per farm by year, 1995 and 2000 to 2008 (Vellema et al., 2010).

8.3 Goat Industry Structure in the United States

8.3.1 Trends in Goat Numbers, 1987 to 2007

The goat industry in the United States was the only livestock industry to experience an increase in number of animals and number of farms during the 20-year period from 1987 to 2007, the point at which the numbers began to stabilize (Figure 5). The number of meat goats increased by nearly 500 percent from 0.5 million to 2.5 million. Milk goats were virtually nonexistent in 1987 but the numbers increased to nearly 0.4 million by 2007. Angora goats were the predominant type in 1987, but the Angora sector of the goat industry began to abandon Angora goats in favor of meat goats in 1992. The sharpest decline in goat numbers was due to the decrease in the Angora production-type by 88 percent during years 1992 to 2007, but the decline in the number of Angora goats was offset by a sharp increase in the number of meat goats.

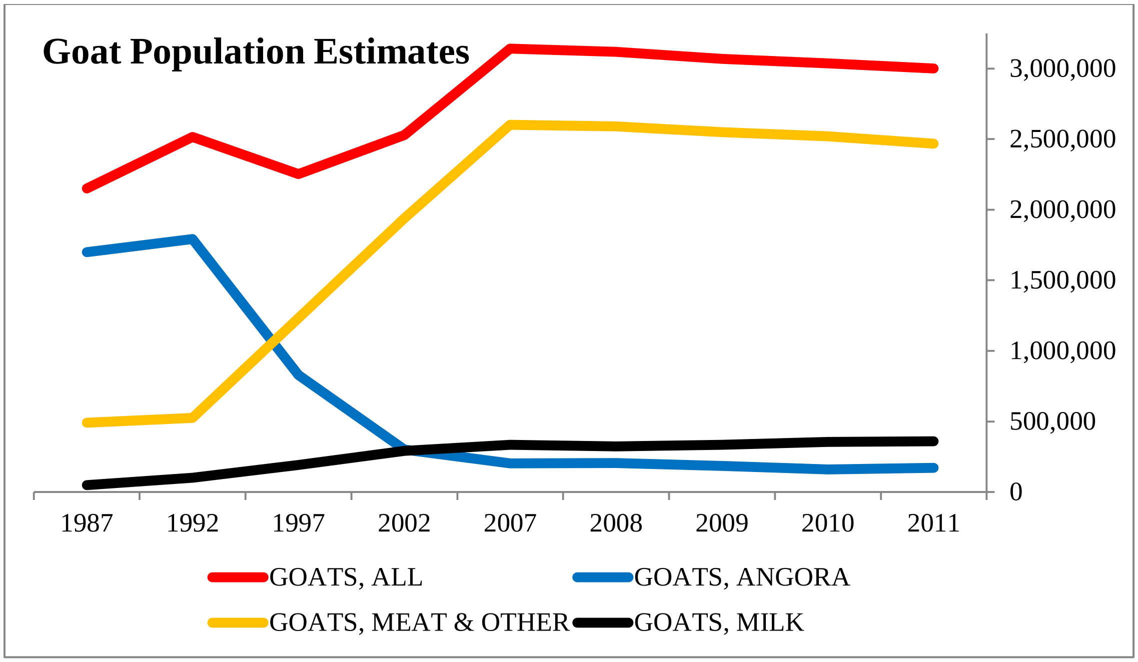

Figure 5. Trends in goat numbers in the United States, 1987 to 2011.

8.3.2 Goat Numbers, 2007

The U.S. goat population in 2007 was 3,140,529 (NASS, 2007). Slightly more than 82 percent (N=2,580,616) of all goats were located on premises in 21 States, each of which was assigned to one of three geographical regions (Table 4). There were 1,300,995 head in the West region, 827,711 in the Southeastern region, and 451,910 in the Northeast region. The State with the largest total number of goats was Texas with 998,833 head, and the State with the smallest total number was Michigan with 27,841 head.

Table 4. Number of goats on farms with 1 or more head of goats in the United States in 2007.

	Goat Production-type			
Geographical Region	**Meat**	**Milk**	**Angora**	**Total (21 States)**
West	1,084,115	78,116	138,764	1,300,995
Southeast	765,987	54,370	7,354	827,711
Northeast	320,013	124,023	7,874	451,910
Total (21 States)	2,170,115	256,509	153,992	2,580,616
Source: NASS 2007 Census of Agriculture.				

When categorized according to the National Agriculture Statistics Service (NASS) production-types, there were 2,601,669 “Meat and Other Goats,” 334,754 “Milk Goats,” and 204,106 “Angora Goats” in all 50 States. However, 83 percent (N=2,170,115) of these meat goats were located on premises in 21 States (Table 4). There were 1,084,115 meat goats in the West region, 765,987 in the Southeast region and 320,013 in the Northeast region. The State with the largest number of meat goats was Texas (west) with 855,653 head, and the State with the smallest number was Michigan with 16,900 head.

Seventy-six percent (N=256,509) of the milk goats were located on premises in 21 States (Table 4). There were 78,116 milk goats in the West region, 54,370 in the Southeast region, and 124,023 in the Northeast region. The State with the largest number of milk goats was California with 39,198 head, and the State with the smallest number was Oklahoma with 2,735 head.

Seventy-five percent (N=153,992) of the Angora goats were located on premises in 21 States (Table 4). There were 138,764 Angora goats in the West region, 7,354 in the Southeast region, and 7,874 in the Northeast region. The State with the largest number of Angora goats was Texas with 131,178 head, and the State with the smallest number was Oklahoma with 232 head (NASS, 2007).

8.3.3 Goat Farm Numbers, 2007

The number of goat farms in the United States in 2007 was 144,466 (NASS, 2007). There were 33,509 goat farms in the West region, 46,640 farms in the Southeastern region, and 28,967 farms in the Northeast region. The State with the largest total number of goat farms was Texas (west) with 17,369 farms, and the State with the smallest total number of farms was Oklahoma (west) with 2,165 farms. Nearly 73.0 percent of all U.S. goat farms, or 75,695, contained only 1 to 9 head of goats.

When categorized according to the NASS production-types, there were 123,278 “Meat and Other Goats” farms, 27,481“Milk Goats” farms, and 7,215 “Angora Goats” farms in the 50 States. Seventy-seven percent of the meat goat farms were located in only 21 States. There were 29,505 meat goat farms in the West region, 42,784 farms in the Southeast region, and 23,117 in the Northeast region (Table 5). The State with the largest number of meat goat farms was Texas (west) with 16,413 farms, and the State with the smallest number was Iowa with 1,793 farms.

Table 5. Number of goat farms with 1 or more head of goats in the United States in 2007.

	Goat Production-type			
Geographical Region	**Meat**	**Milk**	**Angora**	**Total (21 States)**
West	29,505	5,640	1,516	36,661
Southeast	42,784	5,906	976	49,666
Northeast	23,117	8,535	1,128	32,780
Total (21 States)	95,406	20,081	3,620	119,107
Source: NASS 2007 Census of Agriculture.				

Seventy-three percent of the milk goat farms were located in 21 States. There were 5,640 milk goat farms in the West region, 5,906 farms in the Southeast region, and 8,535 in the Northeast region. The State with the largest number of milk goat farms was California with 1,402 farms, and the State with the smallest number was Oklahoma (west) with 323 farms.

Fifty percent of the Angora goat farms were located in 21 States. There were 1,516 Angora goat farms in the West region, 976 farms in the Southeast region, and 1,128 in the Northeast region. The State with the largest number of Angora goat farms was Texas (west) with 600 farms, and the State with the smallest number was Oklahoma (west) with 27 farms.

8.3.4 Changes in Goat Numbers, 2007 to 2010

Data from the NASS Sheep and Goats report, January 28, 2010 were available to compare the 2007 and 2010 population (NASS, 2010). The United States total goat population on January 01, 2010 was 3,043,000, having decreased by 97,529 or 0.3 percent when compared to 2007 data. When the data were stratified according to NASS production-types, there were 2,538,000 "Meat and Other Goats," 355,000 "Milk Goats," and 150,000 "Angora Goats" in the United States. The geographical distribution of the various production types in 2010 remained the same as 2007, generally speaking. The State with the largest number of meat goats was Texas with 990,000 head, and the State with the smallest number was Michigan with 16,000 head (NASS, 2010). The State with the largest number of milk goats was Wisconsin with 46,000 head due to an increase of 10,000 head, and the State with the smallest number was Georgia with 3,000 head. The State with the largest number of Angora goats was Texas (West) with 95,000 head, and the State with the smallest reported number was Wisconsin with 1,000 head. Data on the Angora population in a number of States was not included in the 2010 NASS report; thus, the comparisons between 2007 and 2010 data were limited.

8.3.5 Changes in Goat Farm Numbers, 2007 to 2010

The NASS does not collect interim data on numbers of goat farms, so changes in goat farm numbers during the years 2007 to 2010 were not evaluated in this risk assessment.

8.3.6 Herd Size

The average number of goats per herd in the United States in 2007 was 21.7 (NASS, 2007). The NAHMS program categorizes goat herd sizes in the United States into 4 mutually exclusive categories: (1) fewer than 10 goats, (2) 10 to 19 goats, (3) 20 to 99 goats, and (4) 100 or more goats per herd. More than 55 percent of goat herds in the United States are populated with fewer than 10 goats. Only 3.5 percent of goat herds are populated with 100 goats or more. Operations with 10 to 19 goats represented 18.9 percent of the total, and operations with 20 to 99 goats represented 22.4 percent of the total (Table 6). Less than 1/4th of 1 percent of all goat farms in the United States have more than 500 goats in the herd (N = 356 herds).

Table 6. Percent of goat operations by herd size and by geographical region in the United States in 2007.

	Percent of Operations Herd Size (i.e., the number of goats and kids)				
	Fewer than 10	10 to 19	20 to 99	100-plus	All Sites
Region	Percent	Percent	Percent	Percent	Percent
West	13.7	5.1	7.5	2.0	28.3
Southeast	2.7	9.4	10.5	0.8	43.4
Northeast	18.9	4.4	4.3	0.7	28.3
Total	55.3	18.9	22.4	3.5	100
Source: NASS 2007 Census of Agriculture. Total operations = 109,116.					

8.3.7 Goat Density in the Netherlands and United States

The outbreak of coxiellosis in goats in the Netherlands was associated with a high goat population density (Roest et al., 2011). The density of goats in the Netherlands varies from 0 to 44 goats per square kilometer. The greatest density is in the southeastern section of the country, specifically in the province of Noord-Brabant and several surrounding provinces. Goat density in Noord-Brabant in 2007 was 38.1 goats per km^2 (Roest et al, 2011). More than 90 percent of 28 goat premises with a history of abortion due to Q fever were located in these provinces where the density is 10 to 44 goats per square kilometer. Provinces in which the density was less than 6 goats per square kilometer were rarely affected by epidemics of Q fever.

All States in the United States are populated with some goats. There are locations in the United States in which the density of the goat population approximates the density in provinces in the Netherlands where most of the incident case-premises were located (Figure 6). The northern plains and Rocky Mountains States appear to be the most sparsely populated (Figure 7). The locations in the United States with the highest densities of goats are central Texas, central Tennessee, and east central Ohio, where the densities are 6 to 40 goats per square kilometer (Figure 7). In addition to those three highly dense locations, there are moderately high densities of goats in eastern New York, eastern West Virginia, western North Carolina, central Kentucky, Georgia, Florida, northern Alabama, southwestern Wisconsin, eastern Iowa, eastern Kansas, eastern Oklahoma, and central California. The densities in these 12 locations were 2 to 4 goats per kilometer square.

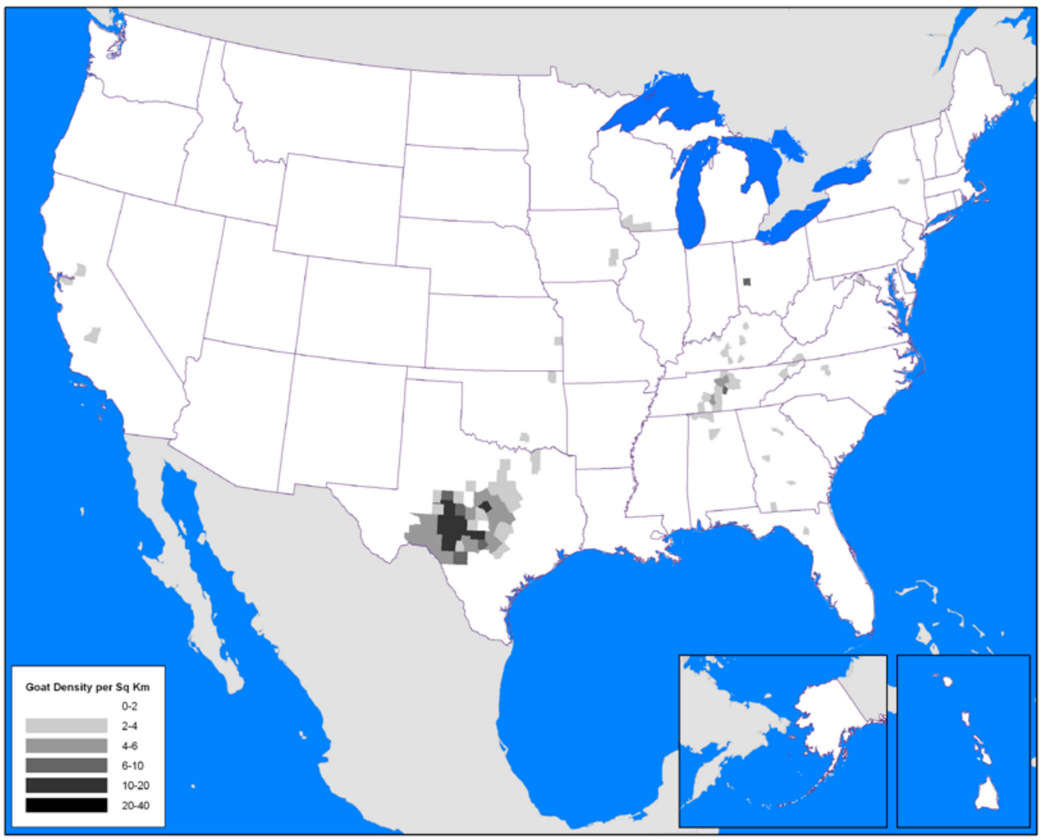

Figure 6. Geographical locations in the United States with goat densities that are equal to goat densities in the Q fever-infected regions in the Netherlands in 2009.

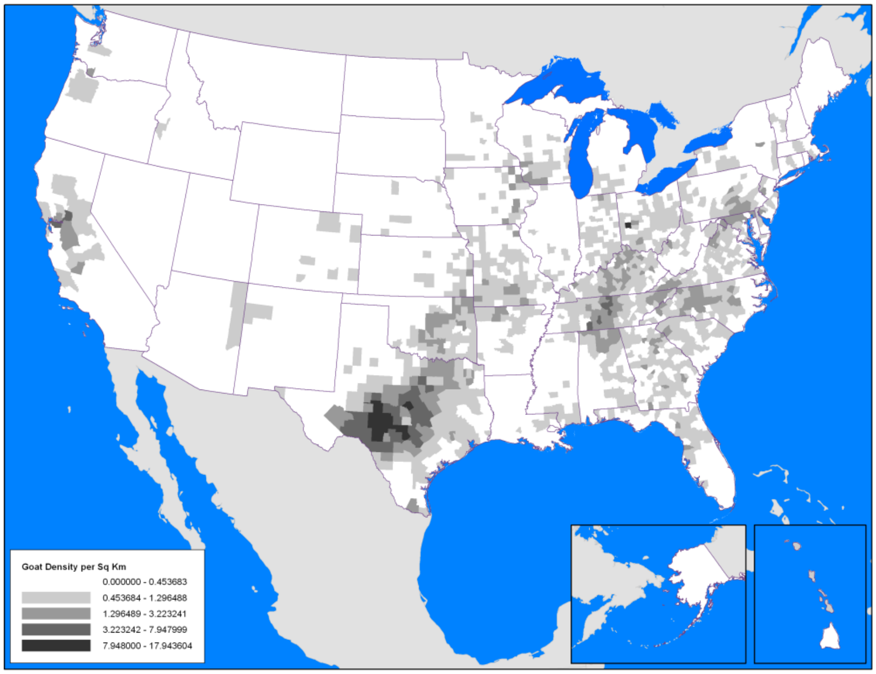

Figure 7. Geographical density of the goat population in the United States, 2007.

Although data on the density of goat farms in the Netherlands were not available for purposes of comparison, the density of goat farms in the United States was evaluated (Figure 8). The density of goat farms coincided with the density of goats in that the greatest densities of farms were in central Texas, central Tennessee, and Ohio. There are moderately high densities of goat farms in Pennsylvania, North Carolina, Georgia, Florida, Alabama, and Kentucky. In the extreme western United States, there are moderately high densities of goat farms in southwestern Washington and western Idaho.

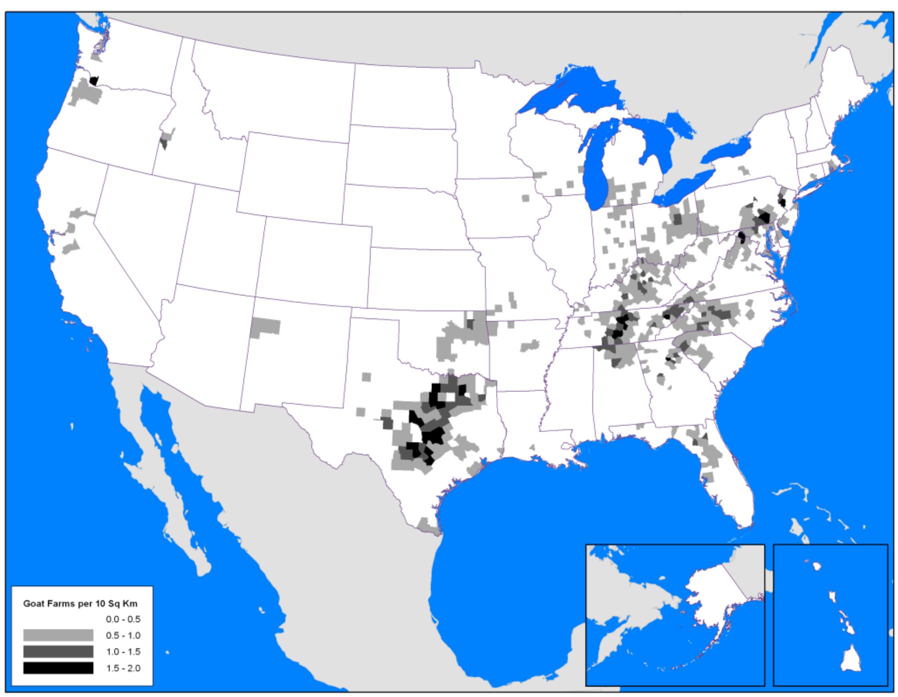

Figure 8. Geographical density of goat farms in the United States, 2007.

8.4 Summary of Goat Industry Structure

Netherlands

- The total number of goats in the Netherlands increased 53.9 fold between 1984 and 2010.
- The average number of goats per non-intensive farm in the Netherlands was 16.
- The average number of goats per farm in the severely affected region was 600.
- The average number of goats per infected farm in the Netherlands was 900.
- The herd size in the severely affected province in the Netherlands was 300 to 7,000 goats.
- The goat population in the Netherlands is geographically concentrated.
- The dairy goat is the predominant production-type in the Netherlands.

United States

- The total number of goats in the United States increased only 1.4 fold between 1987 and 2011.
- The average number of goats per farm in the United States in 2007 was 21.7.
- Only 1.98 percent of all goat farms in the United States have more than 100 goats in the herd.
- Less than 1/4th of 1 percent of all goat farms in the United States have more than 500 goats in the herd (N = 356 herds).
- The goat population in the United States is more geographically dispersed.
- There are three locations in the United States in which the density of goats is similar to the density in the Q fever-infected regions in the Netherlands.
- The meat goat is the predominant production-type in the United States.
- Texas is the location for 36 percent of all goats in the United States.
- The meat-goat industry in the United States is concentrated in Texas.
- The dairy goat industry in the United States is concentrated in CA, WI, and IA.

8.5 Conclusion in Regards to Goat Industry Structure

The likelihood is low that the factor “Goat Industry Structure” would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States. An epidemic due to “Goat Industry Structure” is unlikely to occur. Reasons for a low risk estimate due to this factor are the low density of the goat population, the small herd size, and the predominance of the meat goat in the United States, relative to the Netherlands. (However, there are several locations in the United States where the likelihood is medium that the factor “Goat Industry Structure,” (i.e., goat density, specifically) would initiate and/or propagate an epidemic.)

8.6 Bibliography

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9. Goat Health Management

9.1 The Goat 2009 Study

The Goat 2009 study is the first time that the USDA's National Animal Health Monitoring System has taken a detailed examination of the U.S. goat industry. The results of the Goat 2009 study provided the first nationally representative information on the health and management practices of the goat industry, one of the nation's most rapidly growing livestock industries.

9.2 Knowledge of Q fever

Goat producers were asked whether they were very familiar, somewhat familiar, or not familiar with several economically important diseases including coxiellosis/Q fever, brucellosis, caprine arthritis encephalitis, caseous lymphadenitis, Johne's disease, scrapie, and sore mouth (USDA, 2011). By far, producers were least familiar with Q fever of all diseases, with more than 75 percent of producers declaring unfamiliarity with coxiellosis/Q fever (Table 7). Only 6 percent of producers were very familiar with coxiellosis/Q fever, and the remaining 18 percent were somewhat familiar with the disease. Producers who managed large and medium herds were more familiar with coxiellosis/Q fever than producers who managed small and very small herds (Table 8). The level of familiarity with coxiellosis/Q fever did not differ based on production type. Only 28.2 to 29.9 percent of producers who owned meat, dairy, or fiber goat flocks were very familiar with coxiellosis/Q fever (Table 9).

Table 7. Percentage of operations by level of familiarity with various infectious diseases of goats.

	Percent of Operations Level of Familiarity							
	Very Familiar		Somewhat Familiar		Not Familiar		Total	
Disease	**Percent**	**(SE)**	**Percent**	**(SE)**	**Percent**	**(SE)**	**Percent**	**(SE)**
Brucellosis	14.6	(0.8)	36.1	(1.2)	49.3	(1.2)	100.0	
Caprine arthritis encephalitis	15.4	(0.8)	27.8	(1.1)	56.8	(1.2)	100.0	
Caseous lymphadenitis	19.2	(0.9)	29.7	(1.1)	51.1	(1.2)	100.0	
Johne's disease	11.3	(0.7)	26.0	(1.1)	62.7	(1.2)	100.0	
Q fever	6.0	(0.5)	18.0	(0.9)	76.0	(1.0)	100.0	
Scrapie	20.1	(0.9)	34.3	(1.2)	45.6	(1.2)	100.0	
Sore mouth	23.1	(0.9)	32.8	(1.2)	44.1	(1.2)	100.0	

SE = standard error.
Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 11.

Table 8. Percentage of operations that was somewhat familiar or very familiar with various infectious diseases of goats, by herd size.

	Percent of Operations									
	Herd Size (Number of Goats and Kids)									
	Very Small (Fewer than 10)		Small (10 to 19)		Medium (20 to 99)		Large (100 or more)		All Operations	
Disease	**Percent**	**(SE)**	**Percent**	**(SE)**	**Percent**	**(SE)**	**Percent**	**(SE)**	**Percent**	**(SE)**
Brucellosis	43.9	(2.2)	55.4	(2.3)	55.8	(1.9)	66.8	(2.3)	100.0	(1.2)
Caprine arthritis encephalitis	34.6	(2.1)	48.2	(2.2)	51.1	(1.9)	58.1	(2.5)	100.0	(1.2)
Caseous lymphadenitis	36.4	(2.1)	55.4	(2.3)	60.6	(1.9)	72.4	(2.3)	100.0	(1.2)
Johne's disease	28.1	(2.0)	44.1	(2.2)	44.2	(1.9)	56.1	(2.5)	100.0	(1.2)
Q fever	17.3	(1.7)	28.8	(2.1)	28.9	(1.8)	38.8	(2.5)	100.0	(1.0)
Scrapie	43.6	(2.2)	61.4	(2.2)	63.7	(1.9)	75.2	(2.1)	100.0	(1.2)
Sore mouth	39.4	(2.1)	64.8	(2.2)	70.9	(1.8)	88.0	(1.4)	100.0	(1.2)

SE = standard error.
Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 13.

Table 9. Percentage of operations that was somewhat familiar or very familiar with various infectious diseases of goats, by primary production type.

	Primary Production Type							
	Meat		Dairy		Fiber		Other	
Disease	**Percent**	**(SE)**	**Percent**	**(SE)**	**Percent**	**(SE)**	**Percent**	**(SE)**
Brucellosis	54.8	(1.7)	68.9	(3.0)	70.8	(6.0)	42.2	(2.1)
Caprine arthritis encephalitis	45.9	(1.7)	76.1	(3.0)	57.2	(6.4)	33.0	(1.9)
Caseous lymphadenitis	56.1	(1.7)	73.9	(3.0)	64.3	(6.3)	36.0	(2.0)
Johne's disease	41.5	(1.7)	61.5	(3.2)	53.2	(6.6)	27.5	(1.8)
Q fever	28.2	(1.5)	29.9	(2.9)	28.3	(6.3)	18.6	(1.6)
Scrapie	64.1	(1.7)	70.0	(3.2)	77.7	(5.8)	41.1	(2.1)
Sore mouth	69.2	(1.6)	72.8	(3.1)	69.8	(5.9)	39.1	(2.0)

SE = standard error.
Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 14.

9.3 Awareness of Zoonotic Diseases

Q fever, brucellosis, pinkeye (*Chlamydia*), sore mouth, and toxoplasmosis are diseases of goats that also are infectious to humans. If a producer believes that a disease in the flock is more likely to infect humans, including his/her family members, the belief may stimulate them to solicit the services of a veterinarian more consistently. Expertise from a veterinarian could lead to a more rapid diagnosis, decreased risk of further transmission of the disease within the herd, decreased risk of transmission to other herds, and decreased risk of transmission to humans. Unfortunately, Q fever was the least recognized of all diseases as a zoonotic pathogen. Only 11.2 percent of producers believed that Q fever was infectious to humans (Table 10).

Table 10. Percentage of operations by whether or not producers believed that the following infectious diseases of goats are also infectious to humans.

	Believed Infectious to Humans			
	Yes	No	Don't Know	Total
Disease	Percent (SE)	Percent (SE)	Percent (SE)	Percent (SE)
Brucellosis	28.2 (1.1)	36.4 (1.2)	35.4 (1.2)	100
Pinkeye (*Chlamydia*)	63.3 (1.2)	17.6 (0.9)	19.1 (1.0)	100
Q fever	11.2 (0.8)	41.5 (1.2)	47.3 (1.3)	100
Sore mouth	30.7 (1.1)	34.6 (1.2)	34.7 (1.2)	100
Toxoplasmosis	16.7 (0.9)	40.8 (1.2)	42.5 (1.3)	100

SE = standard error.
Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 15.

9.4 Use of a Veterinarian by U.S. Goat Operations

An excellent way to manage disease on goat operations is to improve biosecurity, which should be developed in concert with a veterinarian experienced in goat production. Good biosecurity reduces the likelihood of introducing disease into a herd and is beneficial in managing disease spread among animals within a herd. About one-third (34.8 percent) of operations had consulted a veterinarian during the 12 months preceding the Goat 2009 study. It is unclear why so few operations solicited the services of a veterinarian. One reason could be the difficulty in finding a veterinarian experienced in working with goats. The percentage of operations that used the services of a veterinarian was 28.7 percent of very small operations and 42.4 percent of large operations (Table 11).

Table 11. Percentage of operations that consulted a veterinarian for any reason related to goat health, productivity, or management during the previous 12 months, by herd size.

Percent of Operations				
Herd Size (Number of Goats and Kids)				
Very Small (Fewer than 10)	Small (10 to 19)	Medium (20 to 99)	Large (100 or more)	All Operations
Percent (SE)	Percent (SE)	Percent (SE)	Percent (SE)	Percent (SE)
28.7 (2.0)	36.8 (2.2)	42.2 (1.9)	42.4 (2.4)	34.8 (1.2)

SE = standard error.
Source: USDA.2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 22.

More than one-half (55.2 percent) of dairy goat operations consulted a veterinarian, compared with one-third of meat goat operations at 37.1 percent (Table 12). Because the source of the epidemic of Q fever in the Netherlands was dairy goats and dairy sheep operations, the use of a veterinarian by a higher percentage of dairy producers suggests that outbreaks of Q fever in dairy goats in the United States could be identified sooner than outbreaks in meat goats, fiber goats, and other goats. Producers in the Northeast region were more likely to consult a veterinarian than producers in the Southeast and West regions (Table 13).

Table 12. Percentage of operations that consulted a veterinarian for any reason related to goat health, productivity, or management during the previous 12 months, by primary production type.

Percent of Operations Primary Production Type							
Meat		Dairy		Fiber		Other	
Percent	(SE)	Percent	(SE)	Percent	(SE)	Percent	(SE)
37.1	(1.6)	55.2	(3.3)	44.9	(6.5)	27.8	(1.9)

SE = standard error.
Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 23.

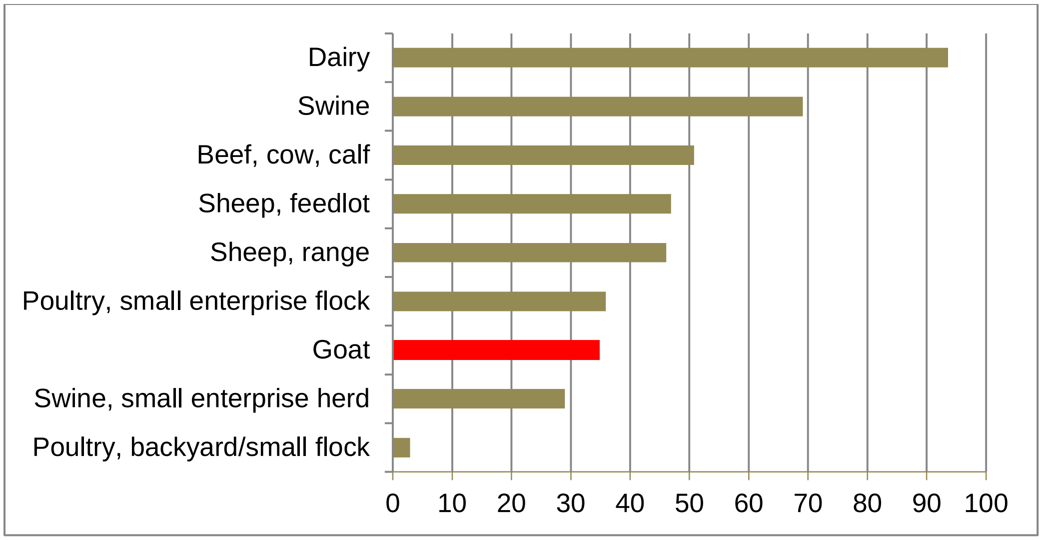
Table 13. Percentage of operations that consulted a veterinarian for any reason related to goat health, productivity, or management during the previous 12 months, by geographical region.

Percent of Operations Geographical Region					
West		Southeast		Northeast	
Percent	(SE)	Percent	(SE)	Percent	(SE)
34.1	(2.2)	30.8	(1.7)	41.6	(2.2)

SE = standard error.
Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 22.

9.5 Comparison of Veterinarian Use among Operations

Use of a veterinarian by producers can vary substantially among the different types of livestock sectors (e.g. beef versus swine) and for a variety of reasons. Use of a veterinarian by goat operations in comparison to other types of operations was relatively low. Dairy, swine, beef cow-calf, feedlot sheep, range sheep, and small-enterprise poultry producers used a veterinarian more than goat producers, if not substantially more (Figure 9). Only small-enterprise swine operations and backyard poultry operations used a veterinarian less than goat operations. Dairy cow operations were 1.7 times more likely to use a veterinarian than dairy goat operations (93.6 percent versus 55.2 percent), and beef cow-calf operations were nearly 1.4 times more likely to use a veterinarian than meat goat operations (50.8 percent versus 37.1 percent).



(*Source:* USDA, 2002; USDA, 2003a, b, c; USDA, 2003b; USDA, 2005; USDA, 2007; USDA, 2008 a,b; USDA, 2009 a,b; USDA, 2012.)

Figure 9. Percentage of operations that consulted a veterinarian for any reason related to livestock health, productivity, or management during the previous 12 months, by primary type of livestock enterprise on the operation.

9.6 Visitors to Goat Operations

Farm visitors who may or may not have contact with goats are potential sources of disease introduction and disease transmission within and among goat operations. Three categories and 8 types of visitors visited goat operations during the 12 months preceding the Goat 2009 study (USDA, 2011). More than 66 percent of goat operations received visitors of one type or another. A higher percentage of goat operations had been visited by members of the general public than by members of the remaining two categories, the health professional and non-health professional categories (Table 14). More than half of goat operations had been visited by members of the general public who were not customers, and 22.2 percent had been visited by customers. Health professionals visited 3.9 to 24.5 percent of operations, and non-health professionals visited 0.5 to 5.9 percent of the operations.

Table 14. Percentage of goat operations by visitor category and visitor type.

Visitor Category	Visitor Type	Percent
Health professionals	Extension agent or university veterinarian	3.9
	Federal/State veterinarian or animal health worker	4.1
	Private or company veterinarian	24.5
Non-health professionals	Renderer	0.5
	Nutritionist or feed company consultant	3.6
	Goat wholesaler, buyer, or dealer	5.9
General public	Customer (private individual) purchasing milk, fiber, goats, meat, cheese, or other goat product	22.2
	Other visitors (including other producers, neighbors, friends, school field trips, hunters, etc.	51.0
All Categories	All of the above types	66.7
Source: USDA, 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 24.		

In regards to the risk of disease transmission, visitors from the general public are least likely to be knowledgeable of appropriate farm biosecurity practices, are least likely to be in compliance with biosecurity, and they present a higher level of biosecurity risk to goat operations than health professionals and non-health professionals. Yet, the greatest number of visits to goat operations was by members of the general public, with an average of 15.2 to 40 visits per year. The number of visits by members of the health professional category was lowest at 3.5 to 6.4 per year, and the number of visits by members of the non-health professional category was 5.4 to 7.7 per year (Table 15).

Table 15. Average number of visits per year to goat operations by visitor category and visitor type.

Visitor Category	Visitor Type	Average Number
Health professionals	Extension agent or university veterinarian	3.5
	Private or company veterinarian	4.6
	Federal/State veterinarian or animal health worker	6.4
Non-health professionals	Nutritionist or feed company consultant	5.4
	Renderer	6.6
	Goat wholesaler, buyer, or dealer	7.7
General public	Customer (private individual) purchasing milk, fiber, goats, meat, cheese, or other goat product	15.2
	Other visitors (including other producers, neighbors, friends, school field trips, hunters, etc.	40.2
All Categories	All of the above types	No data

Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 26.

For the 66.7 percent of operations that had any visitors, more than one-half (59.5 percent) received visitors that entered the goat production area (Table 16). By extrapolation, 39.7 percent of all goat operations had visitors that entered the goat production area. The percent of operations that allowed visitors to enter production areas did not vary by herd size for small, medium, and large herds, but a lower percentage of very small herds accepted visitors into these areas than did medium and large herds. For operations on which any visitors entered the goat production area, a variety of biosecurity measures were taken to prevent introduction of disease. The biosecurity measure always used by the highest percentage of operations was to direct visitors to park away from the goat production area, although only 35.5 percent of operations always required this measure. Only 1.9 to 14.4 percent of operations always required adherence to either 1 or the other 6 biosecurity measures (Table 17). Conversely, 58.8 to 95.7 percent of operations never required adherence to either 1 or the other 6 biosecurity measures (Table 18).

Table 16. For operations that had any visitors during the previous 12 months, percentage of operations on which any visitors entered the goat production areas (barns, sheds, pasture, etc.), by herd size.

Percent of Operations Herd Size (Number of Goats and Kids)									
Very Small (Fewer than 10)		Small (10 to 19)		Medium (20 to 99)		Large (100 or more)		All Operations	
Percent	(SE)	Percent	(SE)	Percent	(SE)	Percent	(SE)	Percent	(SE)
53.4	(2.9)	61.3	(2.6)	65.6	(2.1)	64.7	(2.8)	59.5	(1.5)

SE = standard error.
Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 27.

Table 17. For operations on which any visitors entered the goat production area during the previous 12 months, percentage of operations that **always** required the following biosecurity measures.

Biosecurity Measure	Percent "Always"
Change into clean clothes coveralls	1.9
Use a footbath before entry	1.9
No contact with other livestock for at least 24 hours before visiting this operation	2.6
Scrub shoes before or immediately after entry	3.0
Change into clean boots, or use shoe covers	5.5
Wash hand before handling goats	14.4
Park away from the goat area	35.5
Any biosecurity measure (i.e., one or more)	40.8
Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 29.	

Table 18. For operations on which any visitors entered the goat production area during the previous 12 months, percentage of operations that **never** required the following biosecurity measures.

Biosecurity Measure	Percent "Never"
Park away from the goat area	58.8
Wash hand before handling goats	78.6
Change into clean boots, or use shoe covers	89.8
No contact with other livestock for at least 24 hours before visiting goats	91.8
Scrub shoes before or immediately after entry	93.2
Change into clean clothes coveralls	95.3
Use a footbath before entry	95.7
Any biosecurity measure	58.2
Source: USDA.2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 28.	

9.7 Visits Away from Goat Operations

In addition to visitors' coming onto goat operations and becoming a potential source of introduction of infectious disease, visits away from the operation by the producer, family members, and farm workers also may be a potential source of introduction of disease upon returning to the operation. Visits away from the operation were to seven different places and these seven places were further categorized as leading to maximal or some direct contact with live goats, versus minimal or no direct contact with live goats. Visits away from the operation that involved maximal or some direct contact with live goats were much higher than visits that involved minimal or no direct contact with live goats, with visits to feed mills being the one exception (Table 19). More than 50 percent of operations visited 3 places that would result in direct contact with live goats, but less than 7 percent of operations visited 3 other places that would not result in direct contact with live goats.

Table 19. Percentage of operations that had any workers, including the producer and family members, who had visited the following places during the previous 12 months.

Exposure Category	Place	Percent
Maximal or some direct contact with live goats	Goat sale, show, or fair	50.6
	Other farms where goats are raised	51.8
	Facility that sells goats (e.g. auction, flea market, swap meet, bird market)	56.1
Minimal or no direct contact with live goats	Rendering facility	1.7
	Milk, fiber, or other processing plant	5.5
	Goat slaughter facility	6.2
	Feed store or feed mill	87.4
Source: USDA. 2011. Goat 2009, Part II: Reference of Goat Health and Marketing Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.0411. Page 33.		

9.8 Herd Additions

About 20 percent of operations added goats or kids to the operation during the 12 months preceding the Goat 2009 study, and these additions accounted for nearly 20 percent of the total inventory on July 1, 2009. Herd additions by dairy goat operations were lowest at 11.3 percent, whereas herd additions by meat, fiber, and other goat operations were 20.9 to 25.1 percent of their total inventories. Most operations (72.8 percent) that added adult goats acquired them directly from another goat operation. The second most common source of adult goats was an auction market at 23.5 percent. Less than 5 percent of operations acquired their adult goats from dealers, feed stores, flea markets, fairs, shows, and other sources. The data were similar for kids in that most operations (69.1 percent) that added kids acquired them directly from other goat operations, and the second most common source of kids was auction markets at 21.2 percent. For all new goats and kids added to goat operations, more than 93 percent of adult goats and 80 percent of kids were from another premises, or from auction markets.

9.9 Isolating Herd Additions

Isolating new additions from the remainder of the herd is one way to decrease the risk of accidently introducing new pathogens to herd mates. Isolation is defined as actions taken to prevent nose-to-nose contact with other goats on the operation, and to prevent sharing of feed, water, and equipment. Ideally, new additions should be monitored for signs of disease during isolation. Should disease become apparent, the nature of the disease and its potential threat to the herd can undergo an evaluation. A total of 39.5 percent of operations that added new goats or kids never isolated the new arrivals, whereas 48.9 percent always isolated the new arrivals. New arrivals were isolated for an average of 21.2 days prior to introducing them to new herd mates. While quarantines with duration of 3 weeks are common, a minimum of 30 days has been recommended (Olcott, 2007). A relatively longer quarantine is more likely to minimize any transmission of unrecognizable infections. The ideal duration of quarantine is 60 days, which is 3 times longer than the reported operation average of 21.2 days. A doe that is naturally infected with *C. burnetii* can shed the pathogen in vaginal mucus for 14 days, in feces for 20 days, and in milk for 52 days (Table 20). Thus, the duration of quarantine that is being used by many operations is probably insufficient to prevent infected herd-additions from contaminating the premises with *C. burnetii*.

Table 20. Longest observed duration of excretion during the follow-up of naturally infected or experimentally infected domestic ruminants.

	Sources and Duration of Shedding by Source		
	Vaginal mucus	**Feces**	**Milk**
Doe	14 days	20 days	52 days
Ewe	71 days	08 days after lambing	08 days
Cow	Not determined	14 days	13 months
Source: Arricau-Bouvery, 2005b.			

9.10 Goat Movements

Goats were removed from the operation both temporarily and permanently. Goats that were removed temporarily were moved to another operation or were moved to an event such as a fair, show, sale, or rodeo. Temporary removals took place on 16.1 percent of operations, and there were nearly twice as many temporary removals from dairy goat operations (33.9 percent) than meat goat operations (18.0 percent). These goats may introduce and spread pathogens upon returning to the operation if not isolated for the recommended period of time. Most goat operations (61.8 percent) never isolated goats or kids before reintroduction to the herd after attending an event. Only 27.6 percent of operations always isolated goats or kids returning from an event of any kind, but the duration of isolation was only 19 days, substantially less than the recommended 30 to 60 days.

9.11 Sources of Information on Goat Health

Sources of goat health information were other goat producers, industry meetings, the internet, magazines, extension agents, veterinarians, feed salesperson, and books (Table 21). The three most important sources of goat health information were: (1) other goat producers at 33.3 percent, (2) veterinarian, nutritionist, or other paid consultant at 29.7 percent, and (3) the internet at 26.8 percent of operations. It should be of concern to both animal and human health professionals that a higher percentage of “other goat producers” were reported as a more important source of animal health information than animal health professionals. Two reasons for the concern are: (1) 76 percent of goat producers reported that they were not familiar with Q fever, and only 6.0 percent of producers reported that they were very familiar with Q fever, and (2) only 11.2 percent of producers believed that Q fever was infectious to humans.

Table 21. Percentage of operations by importance of the following sources of goat health information.

	Percent of Operations Importance							
	Very Important		Somewhat Important		Not Important		Total	
Health Information Source	Percent	(SE)	Percent	(SE)	Percent	(SE)	Percent	(SE)
Other goat producers	33.3	(1.2)	34.5	(1.2)	32.2	(1.2)	100.0	
Industry/association meetings	8.0	(0.7)	17.5	(0.9)	74.5	(1.0)	100.0	
Internet	26.8	(1.1)	26.0	(1.1)	47.2	(1.3)	100.0	
Magazines/newsletters	15.9	(0.9)	35.1	(1.2)	49.0	(1.3)	100.0	
Extension agent	16.3	(0.9)	24.3	(1.1)	59.4	(1.2)	100.0	
Veterinarian, nutritionist, paid consultant	29.7	(1.2)	34.3	(1.2)	36.0	(1.2)	100.0	
Feed or drug salespeople	12.4	(0.9)	34.3	(1.0)	36.0	(1.2)	100.0	
Production and management books	15.1	(0.9)	29.1	(1.1)	55.8	(1.2)	100.0	

SE = standard error.
Source: USDA. 2011. Goat 2009, Part I: Reference of Goat Management Practices in the United States, 2009. USDA-APHIS-VS, CEAH. Fort Collins, CO #574.1210. Page 23.

The primary reason reported by 57.7 percent of large operations that goats were raised was for income, which includes the sale of live animals, meat, dairy products, fiber, etc. Yet, only 29.3 percent of those large operations rated veterinarians and related health professionals as a very important source of goat health information. “Other goat producers” were reported by 42.1 percent of large operations to be a very important source of goat health information. Ironically, veterinarians and related health professionals were reported by very small, small, and medium operations to be an important source of goat health information, although their primary reason for raising goats was for fun/hobby, not as a source of income. Producers who raise goats solely, or partly, as “fun/hobby” may view goats in the same way in which more traditional companion animals (i.e., dog, cat) are viewed, and may be more willing to invest in the services of a skilled health professional. Three of four operations (74.5 percent) did not consider goat industry association meetings to be an important source of goat health information.

9.12 Primary Kidding Area

A segregated kidding area has been proposed as one measure to decrease transmission of Q fever on infected operations in the Netherlands. In the United States, does were allowed to deliver their kids in a variety of areas that included individual kidding pens or jugs, a barn or shed, special kidding pasture, other fenced pasture, open range, and dry lot. The majority of operations (55.9 percent) used a covered barn or shed without individual pens for the birth of at least one kid. Some operations used more than one kidding area, an example being “other types” of fenced pasture which was used by the second-highest percent of operations at 42.0 percent. Only 16.8 percent of operations used a specialized kidding pasture, of which the primary purpose was to enhance observation of kidding and/or provide shelter. The individual kidding pen or jug is the only kidding area that will create a potential barrier against the aerosol transmission of pathogens such as *C. burnetii* because of its frequently enclosed design, but this type of kidding area was used by only 24.1 percent of operations. Kidding pens generally separate kidding does from their herd mates, but the pens are not always enclosed. The remaining five types of kidding areas have open designs. Regardless of the primary type of kidding area, its use did not vary greatly by herd size. However, the primary type of kidding area did vary greatly among geographical regions. For example, 40.1 percent of operations in the West used fenced pasture for kidding, whereas only 7.5 percent of operations in the Northeast used fenced pasture. Individual kidding pens or jugs, and a barn or shed, were used by a much higher percentage of operations in the Northeast than in the West.

9.13 Summary of Goat Health Management Practices

- Goat producers' knowledge of infectious disease, including coxiellosis, is inadequate.
- Q fever was the least recognizable of five important zoonoses of goats.
- Goat producers solicit the services of a veterinarian infrequently.
- Goat producers solicit the services of a veterinarian less frequently than producers in nearly all other livestock sectors.
- The general public is allowed to visit goat operations frequently.
- Public visitors to goat operations are permitted to enter the production areas frequently, increasing the risk of direct contact with environmental pathogens.
- A high percentage of goat operations do not enforce biosecurity measures that could decrease the risk of transmission of infectious diseases.
- Visits away from goat operations frequently result in direct contact with other goats.
- Less than half of operations isolate new herd additions from their established herds.
- The duration of the isolation period for new goat additions barely meets the minimum recommend duration.
- Most operations that temporarily remove goats from the operation do not isolate the goats upon returning them to the operation.
- Veterinarians are not a key source of goat health information; other producers are.
- Most goat operations do not use kidding areas that are conducive to containment of an aerosol-transmitted infectious disease such as Q fever.

9.14 Conclusion in Regards to Goat Health and General Management

The likelihood is medium that the factor "Goat Health and General Management" would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population. An epidemic due to "Goat Health and General Management" is nearly as unlikely to occur as it is likely to occur. Reasons for a medium risk estimate due to this factor are lack of knowledge of transmissible infectious diseases, weak biosecurity practices, and infrequent solicitation of the services of a veterinarian by the industry.

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10. Laboratory Capacity to Diagnose Coxiellosis

10.1 Laboratory Diagnosis of Coxiellosis in the EU

A literature survey indicated that more than 30 different animal species susceptible to coxiellosis were reported in Europe (Sidi-Boumedine et al., 2010). Domesticated ruminants (cattle, sheep, and goat) represent the source most frequently associated with human outbreaks. There is no officially prescribed diagnostic test for coxiellosis in the EU. The laboratory diagnosis of coxiellosis in these animal species involves the use of multiple techniques and can be interpreted validly only at herd or flock level (Sidi-Boumedine et al., 2010). PCR is regarded as a sensitive and rapid method for direct detection of *C. burnetii*, whereas Enzyme-Linked Immunosorbent Assay (ELISA) tests are recommended to be used for serological testing. ELISA and immunofluorescence assay (IFA) tests are being used more frequently than in the past. However, IFA still is not used frequently for the diagnosis of coxiellosis in animals in EU because it is not convenient for screening a large number of samples. On the other hand, ELISA requires a single dilution of sera and can be automated. ELISA tests are best suited for testing large numbers of animals and flocks. At least three ELISA commercial kits for the diagnosis of coxiellosis in domestic ruminants are currently available. There is no commercially available IFA kit for veterinary investigations of coxiellosis.

The complement fixation test (CFT) was proposed as an alternative test for international trade by the Office International des Epizooties (OIE, 2008). However, the CFT's sensitivity was highly variable and weaker when compared to ELISA or IFA (Ruiz-Fons et al., 2010; Kittelberger et al., 2009; Rousset et al., 2007; Rousset et al., 2009b; Roest et al., 2008). Most CFT results were negative or weakly positive in animals that had undergone abortion due to coxiellosis (Rousset et al., 2007) and in animals that were shedding *C. burnetii* (Rousset et al., 2009a).

The EFSA consortium concluded that for the serological diagnosis of coxiellosis in the EU:

- It is highly advisable to use ELISA tests rather than CFT;
- ELISA tests are more sensitive and more specific than CFT;
- ELISA tests using antigens prepared from ruminant isolates are the most sensitive tests.

Although the serological methods are useful, they do not allow for the identification of animals that shed *C. burnetii*. Some infected animals can become seropositive without shedding *C. burnetii*, and other infected animals can shed the bacteria and remain seronegative; shedding bacteria in the absence of detectable antibody is of great concern and could have an important impact on both animal and public health. In addition, no serological test can distinguish between vaccinated and naturally infected animals.

Currently, the PCR is one of the most sensitive and rapid diagnostic tests for the direct detection of *C. burnetii* and for identification of animals that shed *C. burnetii*. PCR is adapted to a wide range of samples; it is sensitive and rapid, and is becoming increasingly common in diagnostic laboratories (Berri et al., 2000; Nicollet and Valognes, 2007). Moreover, the development of real-time PCR technology has recently enabled the quantification of *C. burnetii* in samples, and kits are available commercially. PCR tests are commonly used to detect the bacteria in EU Member States (Duquesne et al., 2008, EFSA, 210). It is generally accepted that risk of infectious disease transmission is a function of diagnostic test performance, which includes test sensitivity, specificity, positive predictive value, negative predictive value, etc. However, specific evaluation of coxiellosis diagnostic test performance was not a goal of this assessment. Instead, we chose to relegate evaluation of diagnostic test performance to laboratory diagnosticians with greater expertise in *C. burnetii* diagnostics.

The EFSA launched a project on the development of harmonized schemes for monitoring and reporting coxiellosis in animals in the EU in 2010. A consortium of scientists from France, Germany, Poland, the Netherlands, and the United Kingdom used a questionnaire survey to collect information about coxiellosis from the EU Member States. The results indicated that in most EU Member States there are no regulations on coxiellosis in ruminants, and thus no official surveillance or centralization of the data is organized. Twenty-four of 27 EU Member States responded to questions concerning a national reference laboratory for coxiellosis in animals; 19 of the 25 respondents reported operating a reference laboratory, or its equivalent. Two non EU Member States, Norway and Switzerland, reported operating a reference laboratory for animals.

Coxiellosis was reported as a notifiable disease in animals in 14 EU Member States and in Switzerland, but was not notifiable in 10 other EU Member States and Norway. The disease became notifiable in the Netherlands only in 2008, after the epidemic had already begun. National or local regulations for coxiellosis, other than notification, were sparse among the EU Member States through year 2007, at which point the Netherlands invoked a series of regulations involving abortion, crude milk, manure, and vaccination for coxiellosis. Serological diagnostic aids of one type or another were available in most EU Member States, the most common of which was the ELISA, followed by the CFT and the IFA. Eighteen of 24 EU Member States and one of two non EU Member States reported direct identification and isolation methods for *Coxiella burnetii*. The methods used for direct identification were staining via fluorescent in situ hybridization and immmunohistochemistry, traditional PCR, RT-PCR, cells, eggs, and animals (Table 22).

Table 22. Description of laboratory tests used for diagnosis of *Coxiella burnetii* infection in domestic ruminants.

	Detects	Analytical Se	Comparative Se	Comparative Sp	Purpose	Remarks
Direct						**-**
Culture	Viable bacteria	-	Culture < staining Staining < IHC IHC << PCR	Culture < staining Staining < IHC IHC << PCR	Research, clinical investigation	-
Staining	bacteria in situ	-			Clinical investigation	-
IHC	bacteria in situ	-			Clinical investigation	Pathology diagnosis
PCR	DNA	1 to 10 bacteria [99.99%]			Clinical investigation	Multicopy target more sensitive than single copy target
Serology						
CFT	Antibody	-	CFT < ELISA ELISA = IFA	CFT < ELISA ELISA = IFA	Herd testing, Individual testing	-
ELISA	Antibody	-			Herd testing, Individual testing	-
IFA	Antibody	-			Herd testing, Individual testing	The differentiation between antibodies to phase I and phase II antigens is possible; however, tests for animals are not available commercially

Se: Sensitivity; Sp: Specificity, IHC: immunohistochemical staining; PCR: Polymerase Chain Reaction (conventional as well as real time); CFT: complement fixation test; IFA: immunofluorescent assay.
Source: EFSA, EFSA Journal, 2010, 8(5): 1995, page 15.

The EFSA consortium concluded that the absence of a clear case definition of coxiellosis and the lack of apparent clinical symptoms was likely to lead to under-reporting of the disease. To overcome these challenges, the following case definitions were proposed (Table 23).

Table 23. Coxiellosis case definitions in animals.

The proposed case definitions are as follows:	
Confirmed case	**Probable case**
Clinical pattern of coxiellosis: • mainly abortion, stillbirth Confirmation of *Coxiella burnetii* presence • PCR-positive, isolation, staining, IFA • Positive serology	Clinical pattern of coxiellosis: • abortion, stillbirth • Positive serology
Source: Sidi-Boumedine, K., et al., 2010, page 11.	

10.2 Laboratory Diagnosis of Coxiellosis in the United States

Laboratory capacity to diagnose coxiellosis in goats will affect the risk of the infection spreading among flocks and among animals within a given flock. To evaluate diagnostic laboratory capacity, laboratories that are members of the National Animal Health Laboratory Network (NAHLN) were surveyed using a three-step process to collect information about the diagnostic services that are available for coxiellosis. First, the website of each laboratory was reviwed for any information that would indicate whether diagnostic services were available, the perusal being focused intensely on the fee schedule for each lab. Secondly, those laboratories for which the availability of services was unclear, based on information on the website, were contacted directly using an electronic mail survey to seek clarification about the availability of coxiellosis diagnostic services (Figure 10). The laboratories were asked whether they offered tests, the category of testing (e.g., direct detection), the specific types of tests (e.g., PCR), and lastly whether the service was available as a referral or a sub-contract to a different laboratory (e.g., the NVSL in Ames, IA). Both steps of the initial survey were completed during November 14 through November 30, 2011. Follow-up inquiries to non-respondents to the email survey were completed during January 18 to January 30, 2012. Survey activity was halted in December 2011 to minimize non-responsiveness due to extensive absences that are common during the holiday season.

Laboratories at 57 different sites were included in the NAHLN list of labs (Figure 11). The 57 different laboratory sites included the primary laboratory within a State as well as satellites of the primary laboratory. Six laboratory sites that were highly species- and/or industry-specific – such as the University of Delaware Lasher at Georgetown, a poultry-specific lab – were excluded from the survey. Fifty-one sites were accepted as eligible for inclusion in the survey. Twenty of the 51 sites offer diagnostic services at the site, and 16 of the 51 sites offer diagnostic services via referral or subcontract to a different site. Thus, diagnostic services are available with certainty at 36 (70.58 percent) of the 51 sites. Ten (19.60 percent) of the 51 sites did not respond to the email survey, but there was sufficient evidence on their respective websites to suggest that diagnostic services were available at those 10 sites. Finally, 5 of the 51 sites (9.8 percent) stated unequivocally that diagnostic services were not available at their sites and they made no reference to providing the services via referral (Figure 12). Both direct detection and serology are generally available, and the specific types of tests are PCR, RT-PCR, IHC, ELISA, CF, and IFA.

(Please select "Reply to All" when you reply to this message.)

Good afternoon Dr. Last Name,

The USDA APHIS Veterinary Services is preparing a risk assessment of Q fever (aka Coxiellosis) in domesticated goats in the United States in response to Q fever in goats in the Netherlands that eventually affected 4,000 humans. Diagnostic capacity in laboratories across the nation is an area of interest for our analysis. A search of the AVDL fee schedule suggests that your laboratory may offer Q fever diagnostic services. Would you be able to provide us with clarifying information regarding Q fever testing in your laboratory? Specifically, if you could answer these questions:

1. Does this laboratory offer diagnosis of Q fever (Coxiella burnetii), either through testing at the physical facility or through sub-contracting/referral?

2. If you offer testing for Q fever, which method do you use (PCR, ELISA, complement fixation, etc.)?

You are welcome to add any additional comments here.

Thank you for your assistance with this risk assessment!

Sincerely,

Sender's Full Name

USDA APHIS Veterinary Services

Centers for Epidemiology and Animal Health

Fort Collins, Colorado

Figure 10. Electronic mail survey instrument sent to 51 NAHLN laboratories.

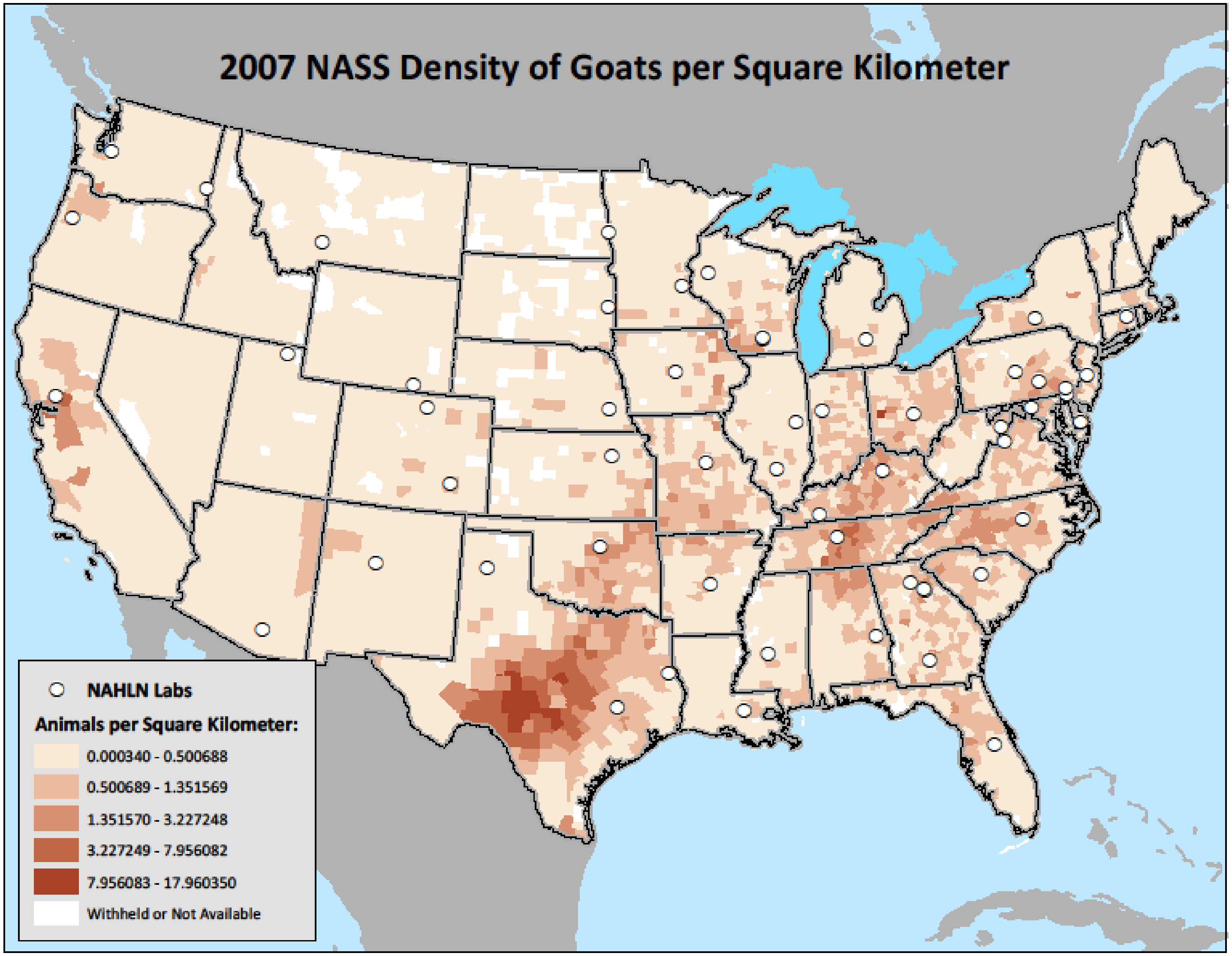

Figure 11. Geographical distribution of 51 NAHLN labs versus the U.S. goat population.

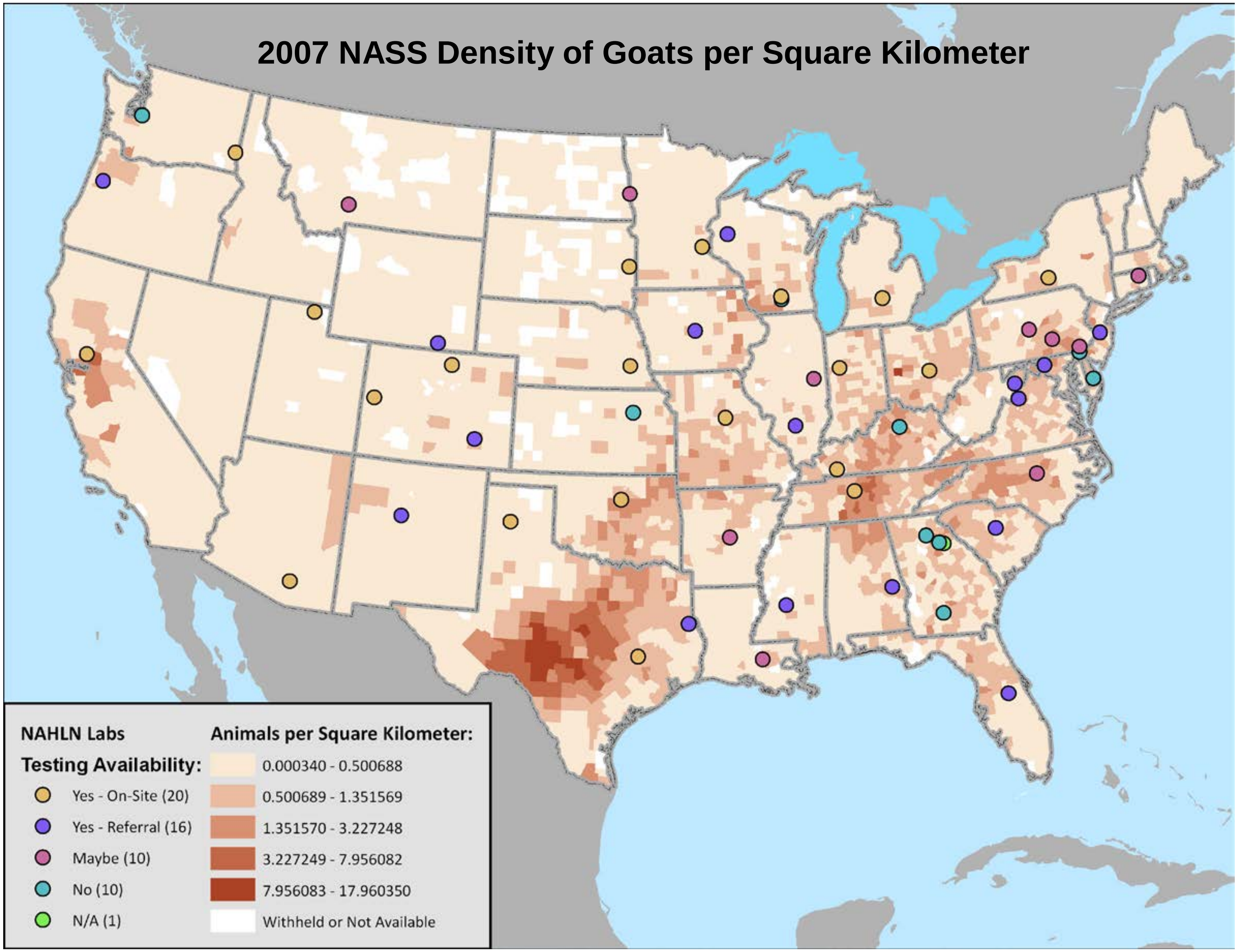

Figure 12. Geographical distribution of various types of diagnostic testing availability at 51 NAHLN labs versus the U.S. goat population.

10.3 Summary of Laboratory Capacity to Diagnose Coxiellosis in Goats in the United States

- The EFSA recommends the ELISA as the preferred serological test for coxiellosis.
- Diagnostic services for coxiellosis in goats in the United States are available at as much as 92.16 percent of 51 member laboratories in the NAHLN.
- Many NAHLN laboratories that do not offer diagnostic services on-site do offer referral services to other laboratories.
- Direct detection of *C. burnetii* and serology are offered by most laboratories.
- Direct detection methodologies include PCR, RT-PCR, and IHC.
- Serological methodologies include ELISA, CF, and IFA.

10.4 Conclusion in Regards to Laboratory Capacity to Diagnose Coxiellosis

The likelihood is low that the factor "Laboratory Capacity to Diagnose Coxiellosis" would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population. An epidemic due to "Laboratory Capacity to Diagnose Coxiellosis" is unlikely to occur. Reasons for a low risk estimate due to this factor are the widespread availability of diagnostic services in U.S. laboratories and the variety of diagnostic tests that are available.

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11. Reporting and Monitoring Coxiellosis and Q fever

11.1 Reporting and Monitoring Coxiellosis in Animals in the EU

Q fever in the EU is a list B zoonosis in accordance with Directive 2003/99/EC, and amendment of Directive 2009/99/EC (Makela, 2010). The disease was first included in the EU Community Summary Reports on zoonoses in 2005. The Directive 2009/99/EC on the monitoring of zoonotic agents requires EU Member States to monitor and report on cases of coxiellosis in animals if warranted by the epidemiological situation. By 2010, data from EU Member States reporting coxiellosis cases in animals had improved over year 2005 and the preceding years. The number of EU Member States reporting coxiellosis increased from 2 States in 2005 to 17 States in 2008; in addition, two non EU Member States submitted reports on coxiellosis in animals (Makela P., 2010). The primary species of interest were cattle, sheep, and goats, with cattle being the most frequently tested species. The number of samples per country varied from as few as 200 (e.g., Portugal) to as many as 12,000 (e.g., Germany) during the 2-year period from 2007 to 2008. The sampling scheme utilized by most EU Member States was purposive in that the samples were collected to support clinical investigations in which there was suspicion (e.g. abortion) of an outbreak of coxiellosis in flocks; however, six EU Member States reported data from monitoring, surveillance, and specific surveys (Table 24).

Table 24. The notification status or requirement of coxiellosis in 29 European countries, in domestic ruminants.

Notification Status		
Notifiable	**Not Notifiable**	**No Response**
Bulgaria	Belgium	Austria
Czech Republic	Cyprus	Ireland
Denmark	Estonia	Malta
Finland	France	
Germany	Hungary	
Greece	Luxembourg	
Italy	Portugal	
Latvia	Romania	
Lithuania	Slovakia	
Netherlands (since 2008) +	United Kingdom	
Poland	Norway	
Slovenia		
Spain		
Sweden		
Switzerland		

+ Notifiable in dairy sheep and goats beginning 2008.
Source: adapted from EFSA, EFSA Journal 8(5), 2010, table 2, page 17.

Serological diagnostic tests such as ELISA, CFT, and PCR were used to measure the immune response to *Coxiella burnetii*. The individual animal seroprevalence in cattle from 12 EU Member States was 7.5 percent in 2007 and 10.0 percent in 2008. The State-specific range in seroprevalence in cattle was 1.5 to 33.2 percent in 2007 and 0.0 to 40.1 percent in 2008. The individual animal seroprevalence in goats from 12 EU Member States was 9.7 percent in 2007 and 15.7 percent in 2008. The State-specific range in seroprevalence in goats was 0.0 to 30.0 percent in 2007 and 1.5 to 31.9 percent in 2008. The individual animal seroprevalence in sheep from 12 EU Member States was 7.9 percent in 2007 and 6.3 percent in 2008. The State-specific range in seroprevalence in sheep was 0.0 to 40.3 percent in 2007 and 0.0 to 26.7 percent in 2008 (Makela P., 2010,).

Regarding the Netherlands specifically, no laboratory test results were recorded in 2006. Test results for goats were reported in 2007 and 2008 and the percent seropositive was 9.5 percent (7 of 74) and 31.9 percent (51 of 160), respectively (EFSA, 2010).

The conclusions drawn by the EFSA about their 2008 coxiellosis data were as follows:

1. Monitoring and reporting coxiellosis in the EU was not harmonized.
2. The source of most data was clinical investigations.
3. Evidence of coxiellosis was present in ruminant populations in all 18 EU Member States that reported findings during 2007 to 2008.
4. There was substantial variation in seroprevalence among EU Member States.
5. Evidence of coxiellosis was not uncommon in cattle, sheep, and goats.
6. The prevalence of coxiellosis in healthful ruminants was unknown.

The conclusions that disease reporting from EU Member States was not harmonized, and that the level of information available varied considerably, led the European Food Safety Authority to issue a request for grant proposals that would support the development of harmonized schemes for monitoring and reporting coxiellosis in animals in the EU (EFSA, 2010). The project objectives were to evaluate the current disease situation and the national level of monitoring and reporting, to identify animal species to monitor, to identify the most suitable diagnostic methods to use, to define sample sizes, specimen types, and sampling techniques, and, lastly, to propose harmonized monitoring and reporting schemes. A questionnaire survey was distributed to the EU Member States in order to obtain relevant information. The results indicated that in most EU Member States there are no regulations on coxiellosis in ruminants; thus, there is no official surveillance or centralized organization of the data. The disease in animals is notifiable in 14 EU Member States, but a clear case definition is not available and the lack of apparent clinical symptoms is likely to lead to under-reporting. A literature survey indicated that more than 30 different animal species susceptible to *Coxiella burnetii* infection were reported in Europe. However, domesticated ruminants (goat, sheep, and cow) represent the source that is more often identified and associated with human outbreaks than other animal species. Consequently, it was proposed to focus monitoring schemes on domesticated ruminants.

11.2 Reporting and Monitoring Coxiellosis in the United States

11.2.1 Requirements for Reporting Coxiellosis by States

Most States publish a list of diseases that are reportable to the leading animal health agency in the State. States that are exceptions to this rule are Connecticut and Delaware, as well as the District of Columbia. Similarly, all 50 States publish a list of diseases that affect humans and thus are reportable to the chief public health agency. In either case, some of the published lists are much more readily accessible on their websites. Whether coxiellosis or Q fever is a reportable disease to animal health or public health agencies, respectively, varies by State and in accordance with State laws. Currently, coxiellosis is reportable to the chief animal health agency in 34 of 50 States (68 percent) and is not reportable in 16 States or the District of Columbia (Table 25 and Figure 13 and Figure 14). Q fever in humans is reportable to the chief public health agency in 45 States (90 percent) and is not reportable in 5 States or the District of Columbia (Table 25 and Figure 15). The five States in which Q fever in humans is not reportable are Arkansas, Delaware, New Hampshire, Pennsylvania, and Vermont. In the four States of Arkansas, Delaware, New Hampshire, and Vermont, coxiellosis and Q fever are not reportable to an animal health agency or to a public health agency.

Table 25. States in which coxiellosis and Q fever are reportable to a State's animal health agency, a State's human health agency, or both types of agencies in 2011.

Animal Health Agency		Human Health Agency	
Reportable	**Not Reportable**	**Reportable**	**Not Reportable**
Alaska	Alabama	Alabama	Arkansas
Arizona	Arkansas	Alaska	Delaware
California	Colorado	Arizona	New Hampshire
Georgia	Connecticut	California	Pennsylvania
Hawaii	Delaware	Colorado	Vermont
Illinois	Florida	Connecticut	
Indiana	Idaho	Florida	
Iowa	Kansas	Georgia	
Kentucky	Maryland	Hawaii	
Louisiana	Missouri	Idaho	
Maine	New Hampshire	Illinois	
Massachusetts	New Mexico	Indiana	
Michigan	Ohio	Iowa	
Minnesota	Tennessee	Kansas	
Mississippi	Texas	Kentucky	
Montana	Vermont	Louisiana	
Nebraska	District of Columbia	Maine	
Nevada		Maryland	
New Jersey		Massachusetts	
New York		Michigan	
North Carolina		Minnesota	
North Dakota		Mississippi	

Animal Health Agency		Human Health Agency	
Reportable	**Not Reportable**	**Reportable**	**Not Reportable**
Oklahoma		Missouri	
Oregon		Montana	
Pennsylvania		Nebraska	
Rhode Island		Nevada	
South Carolina		New Jersey	
South Dakota		New Mexico	
Utah		New York	
Virginia		North Carolina	
Washington		North Dakota	
West Virginia		Ohio	
Wisconsin		Oklahoma	
Wyoming		Oregon	
		Rhode Island	
		South Carolina	
		South Dakota	
		Tennessee	
		Texas	
		Utah	
		Virginia	
		Washington	
		West Virginia	
		Wisconsin	
		Wyoming	
Source: Data are the result of an exhaustive internet search of one or more websites of animal health and public health agencies of each State, 2011.			

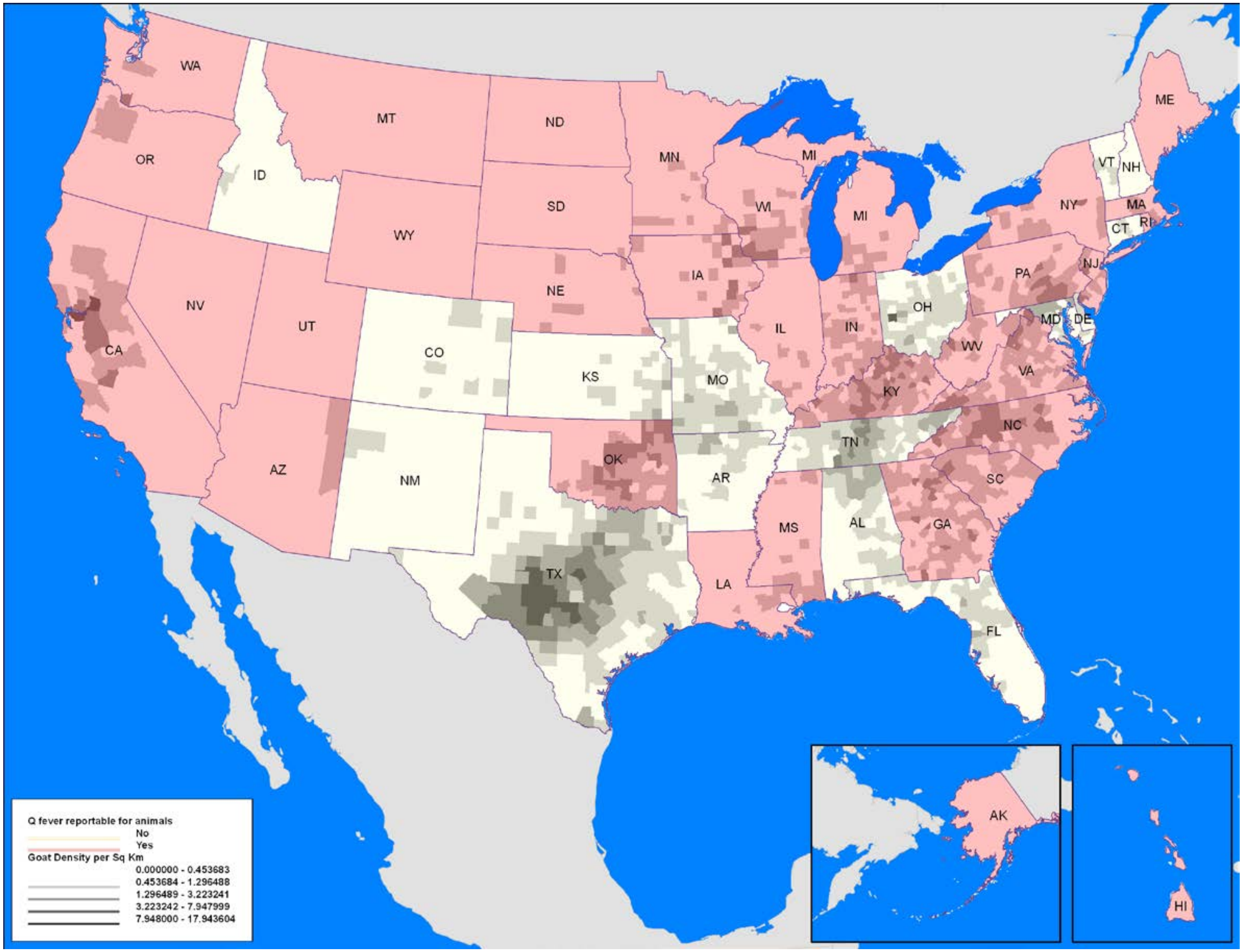

Figure 13. States in the United States in which coxiellosis is reportable to the State's chief animal health agency, versus goat density.

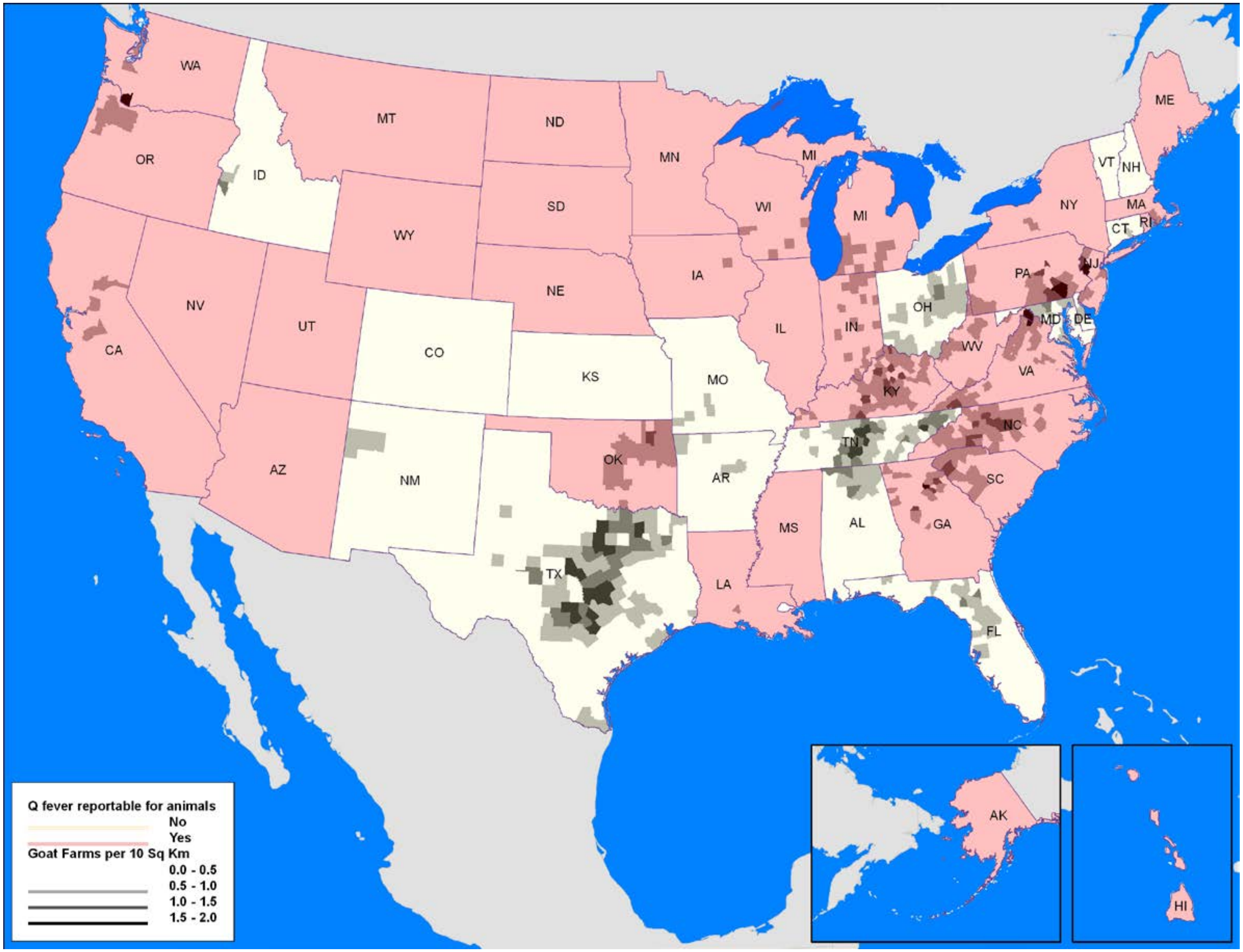

Figure 14. States in the United States in which coxiellosis is reportable to the State's chief animal health agency, versus goat farm density.

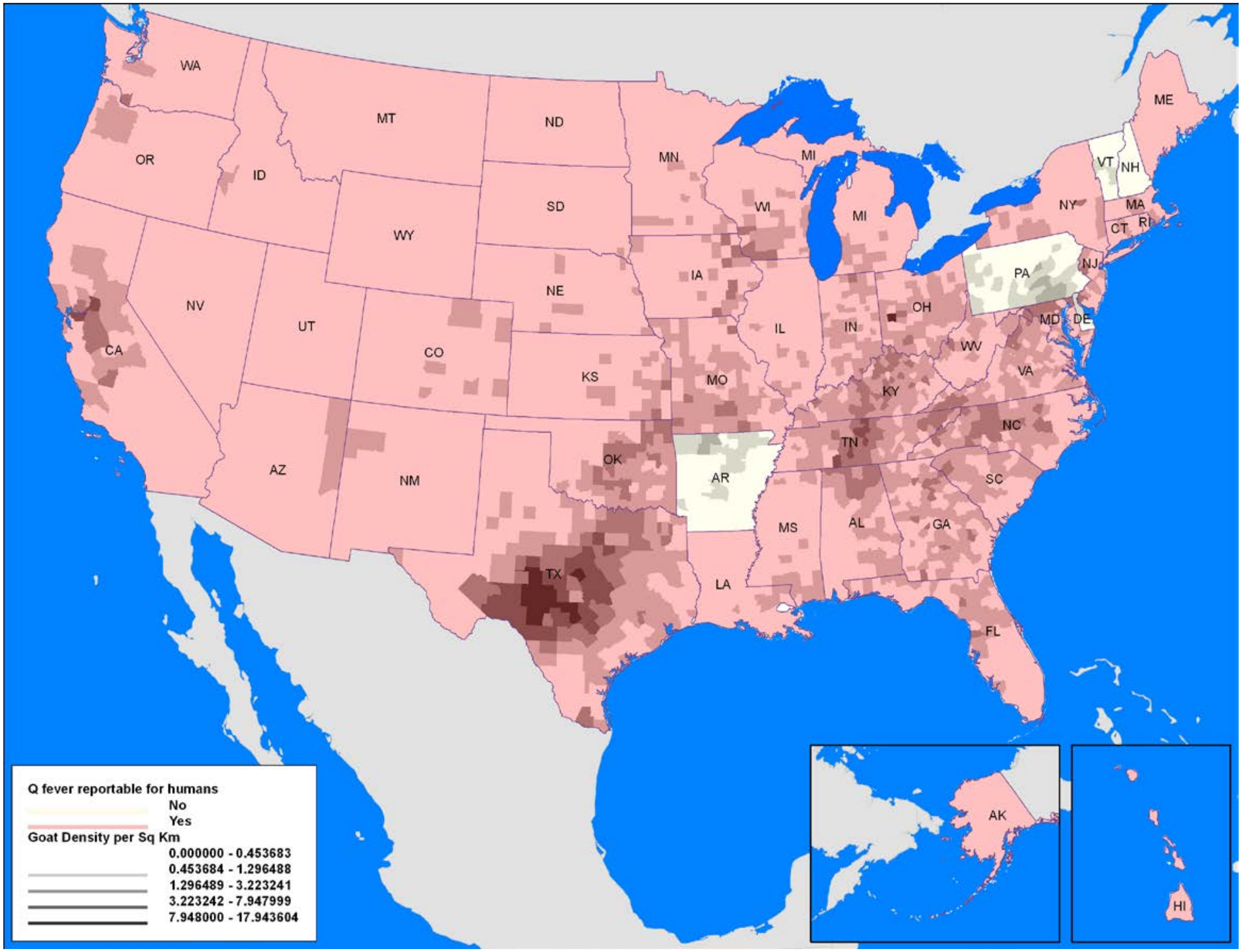

Figure 15. States in the United States in which Q fever is reportable to the State's chief human health agency, versus goat density.

11.2.2 Agreement Between Reporting Coxiellosis and Q fever

Ideally, important zoonoses such as Q fever would be reportable to both animal health and human health agencies within a given State, but a high level of agreement between the reporting requirements of the two branches may not occur for a variety of reasons. An ideally designed reporting system would be described as the scenario in which a diagnosis of coxiellosis in domestic ruminants would be reportable to the chief animal health and human health agencies in a given State. Such a scenario would suggest that there is a high level of cooperation and communication between animal and human health agencies in the fight against the disease. Inter-agency cooperation and communication are generally associated with a reduction in relative risk of both animal and human populations.

A poorly designed reporting system would be described as the scenario in which a diagnosis of coxiellosis in domestic ruminants would be reportable neither to the chief animal agency nor to the chief human health agency in a given State, thus representing somewhat of a worst-case scenario. Cooperation and communication under this scenario would be expected to be ineffective, and the risk associated with the disease relatively higher. Lastly, there are situations in which coxiellosis could be reportable to an animal health agency, but not to a human health agency, or vice versa (i.e., reportable to a human health agency, but not reportable to an animal health agency). This latter scenario would represent an “intermediate” level of risk.

To evaluate the potential risk associated with whether coxiellosis is reportable or not, the extent of agreement between reportage of coxiellosis and Q fever diagnosis to animal health and human health agencies was evaluated. Reportage of coxiellosis and Q fever was assigned to one of four mutually exclusive categories. Coxiellosis and Q fever were: (1) reportable to both the animal health and public health agencies in 33 States, (2) reportable to the public health agency but not the animal health agency in 12 States, (3) reportable to the animal health agency but not the public health agency in 1 State, and (4) not reportable to the animal health or the public health agency in 4 States (Table 26). The overall level of agreement of requirements for reporting coxiellosis and Q fever diagnosis between animal health and human health agencies was “fair,” based upon Kappa analysis.

Table 26. Extent of agreement between State animal health and State public health agencies regarding reporting diagnosis of coxiellosis and Q fever in domestic animals and humans in the United States in 2011.

			Human Health Agency Reportable	
			Yes	**No**
Animal Health Agency	**Reportable**	**Yes**	33	1
		No	12	4

Data in each cell are the result of an internet search of websites of each State, November 2011.

11.3 Reports of Q fever and Coxiellosis

11.3.1 Reports of Q fever in Humans

The number of cases per year of Q fever reported to the Centers for Disease Control and Prevention during years 1998 to 2005 was 5 to 145 (CDC, 2012). The number of cases in 2006 and 2007 was the same each year, 165 (Figure 16 and Figure 17).

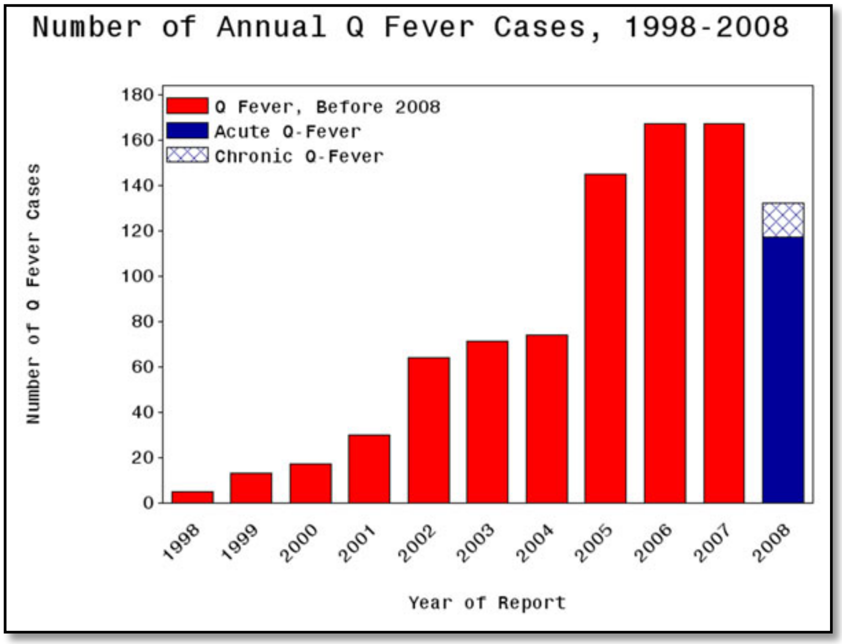

Figure 16. Annual Q fever cases in United States, as reported by the CDC (CDC, 2008).

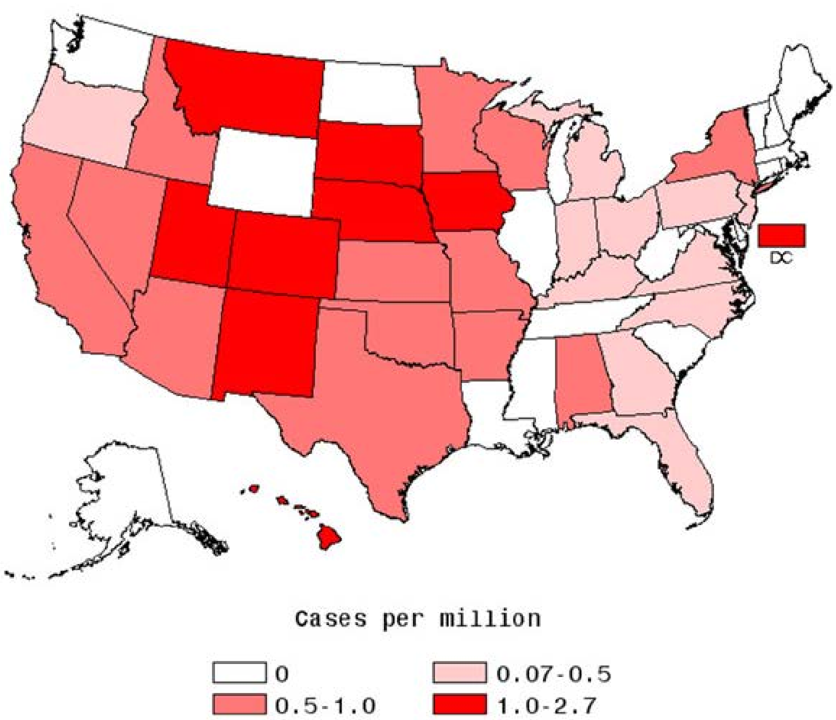

Figure 17. Incidence of reported Q fever in humans, 2008 (CDC, 2008).

11.3.2 Reports of Coxiellosis in Animals

The United States Animal Health Association (USAHA) approved Resolution #10 in 2008, the purpose of which was to assign the National Animal Health Reporting System (NAHRS) Steering Committee to develop a national list of reportable animal diseases in the United States. The NAHRS program is designed to provide summary level data on the confirmed presence (presumptive or definitive level of certainty) of diseases that are reportable by the United States to OIE. NAHRS is a voluntary, collaborative effort among participating States, the American Association of Veterinary Laboratory Diagnosticians (AAVLD), the USAHA, and the USDA APHIS. The proposed National List of Reportable Animal Diseases (NLRAD) includes diseases that also are listed by various animal and human health organizations as being reportable. The organizations and their respective lists are:

- OIE List of Reportable Diseases
- National Veterinary Stockpile (NVS) List
- U.S. Department of Health and Human Services (HHS)/USDA Select Agent List
- Veterinary Services regulations and memoranda

Either coxiellosis or Q fever is included on the OIE List, the NVS List, and the HSS/USDA Select Agent List. It is reportable to either the chief animal health agency or the chief human health agency in 45 of 50 States in the United States. A presumptive diagnosis of coxiellosis is based on compatible clinical signs plus histopathology and/or positive serology (i.e., CF, IFA, or ELISA). A definitive diagnosis requires isolation and identification of *Coxiella burnetii* (i.e., culture, PCR, IHC). During 2007 to 2010, a diagnosis of coxiellosis in goats and sheep was reported by 5 to 7 States each year, and a diagnosis of coxiellosis in cattle was reported by 2 to 4 States each year (Table 27).

Table 27. Number of States with at least one report of diagnosis of coxiellosis in domestic sheep, goats, and cattle to the National Animal Health Reporting System, United States, 2007— 2010.

	Number of States	
	Diagnosis in Goats and Sheep	Diagnosis in Cattle
2007	6	3
2008	6	4
2009	7	2
2010	5	2
2011†	1	-----

† January to June, 2011.
Source: Personal communication, Stanley D. Bruntz, USDA APHIS VS, 2011.

11.4 Summary of Reporting and Monitoring Coxiellosis in Animals

Netherlands and EU:

- Coxiellosis was not reportable in the Netherlands in 2008.
- Monitoring and reporting of coxiellosis in the EU in general was not harmonized as of 2008.
- The sources of most data in the EU were clinical investigations.
- Evidence of coxiellosis was present in ruminant populations in all 18 EU Member States that reported findings during 2007 to 2008.

United States:

- Monitoring and reporting of coxiellosis in the United States varies among States.
- Coxiellosis and Q fever are reportable to many of the chief animal health agencies in the States and to nearly all of the chief human health agencies in the States.
- There are a few States in which coxiellosis and Q fever appear to be un-reportable.
- Animal health agencies within a State also can report diagnosis of coxiellosis to the NAHRS, but reporting to NAHRS is not a requirement.
- Less than 15 percent of States reported diagnosis of coxiellosis to NAHRS during 2007 to 2010.
- Although there is no “central repository” for reports of coxiellosis in the United States, the legal requirements for reporting generally are widespread among States. However, there is room for improvement in reporting.

11.5 Conclusion in Regards to Reporting and Monitoring Coxiellosis

The likelihood is low that the factor “Reporting and Monitoring Coxiellosis” would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population. An epidemic due to “Reporting and Monitoring Coxiellosis” is unlikely to occur. The reason for a low risk estimate due to this factor is the generally high level of legal requirements to report coxiellosis to State animal and/or human health officials. (For those States in which coxiellosis in ruminants appears un-reportable to any public agency, the likelihood in those States is medium.)

11.6 Bibliography

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12. Caprine Health Professionals

12.1 American Association of Small Ruminant Practitioners

The mission statement of the American Association of Small Ruminant Practitioners (AASRP) is

> "To improve the health and welfare of sheep, goats, camelids, and cervids to further the professional development of the members, provide resources to elevate the standards of small ruminant practice, and to be the voice for small ruminant issues." (AASRP, 2007)

Given that mission statement, it would appear that small ruminant veterinarians would be playing a pivotal role in all phases of goat production throughout the United States by providing technical expertise on disease prevention and control, biosecurity, and zoonoses such as Q fever. However, only 30 percent of U.S. goat operations reported that veterinarians (in combination with nutritionists and paid consultants) were "very important" sources of goat health information (USDA, 2011). More than 70 percent reported that veterinarians were only somewhat important (34.3 percent) or not important (36.0 percent) sources of goat health information. Thus, there is a clear disparity between the AASRP mission statement and goat producers' perceptions of the value of services potentially offered by small ruminant veterinarians.

12.2 Professional Interest of AASRP Members in Goats

To evaluate the disparity between the AASRP mission statement and producers' perceptions, we examined several aspects of the population distribution of the membership of the AASRP and the distribution of the goat population. Specifically, we studied the geographical distribution of members of the AASRP relative to the distribution of the domestic goat population and goat farms. Small ruminants include goats, sheep, as well as camelids, deer, and elk. The percent of interest of an individual member of the AASRP in each of these five groups of animals is solicited routinely by the AASRP during periodic surveys of its membership, so those data also provided an opportunity to compare the self-reported percent of interest by small ruminant species to the distribution of the goat population and goat farms. Our working hypothesis was the "percent of interest" of AASRP members in goats is low in comparison to the other species.

There were 748 members of the AASRP in the 50 States and the Territories of Puerto Rico, U.S. Virgin Islands, and Guam. The number of members per State varied significantly from as few as 0 in Nevada to 49 in California. The five States with the largest number of members were California, Pennsylvania, Ohio, New York, and Wisconsin, and the five States with the fewest number of members were Mississippi, North Dakota, West Virginia, Alaska, and Hawaii (Figure 18 and Figure 19). The median number of members per State was 12. The strength of the relationship between the density of goats per State, the density of goat farms per State, and the number of members of the AASRP per State was weak (Table 28, Section 1). Only 22 percent of the variation in the number of members of the AASRP was explained by the density of the goat population; likewise, only 26 percent of the variation in the number of members of the AASRP was explained by the density of goat farms. Because the State of Texas was an outlier in the data set, the analysis was repeated while excluding Texas data from the analysis. Although the correlation coefficients between the goat and goat farm densities and number of members did increase, the coefficients of determination did not change (Table 28, Section 2). These results suggest that the goat industry has very little influence on the number of members of the AASRP (Figure 20 and Figure 21).

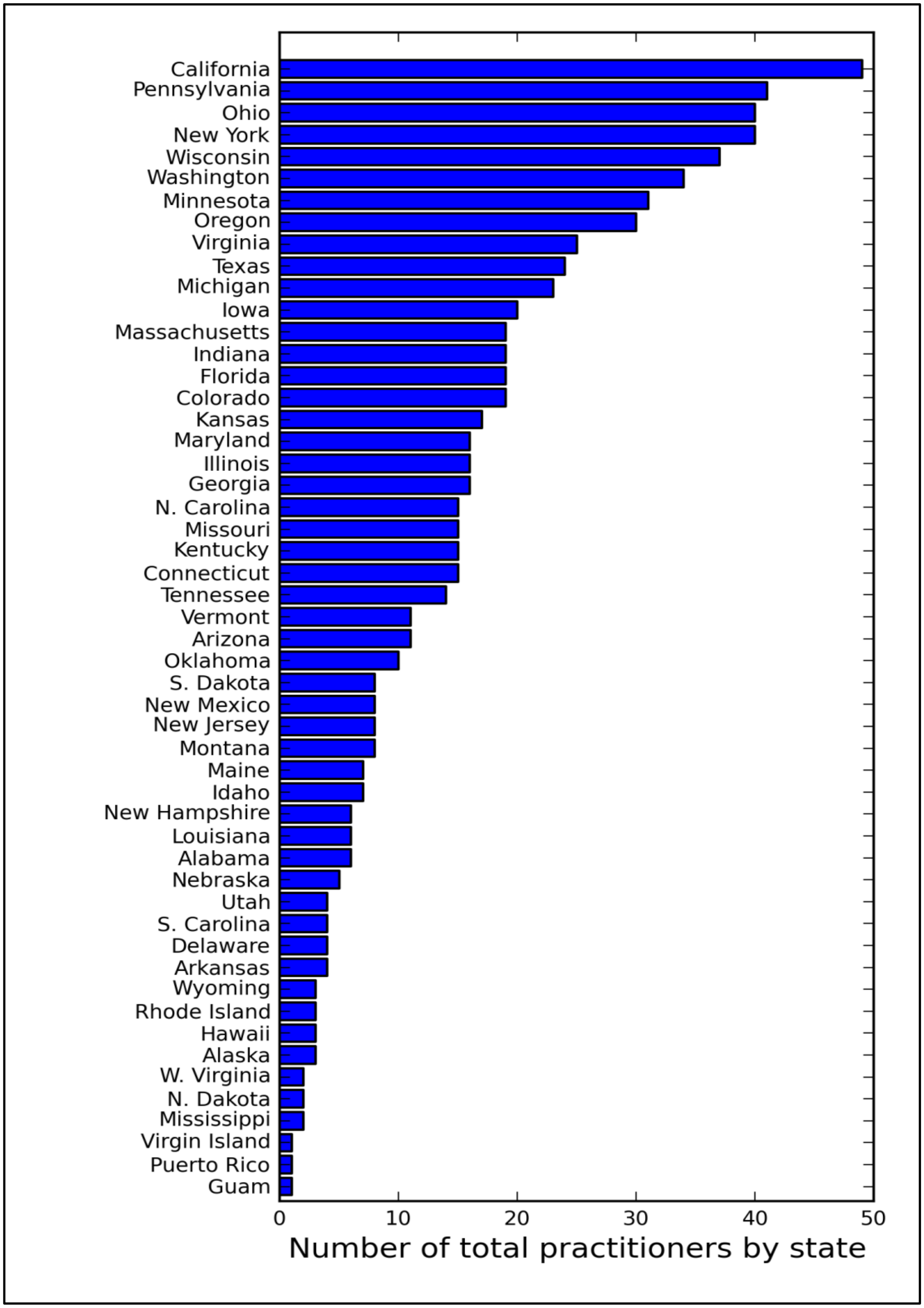

Figure 18. AASRP members by State. (Source: AASRP Membership Directory 2007—2009).

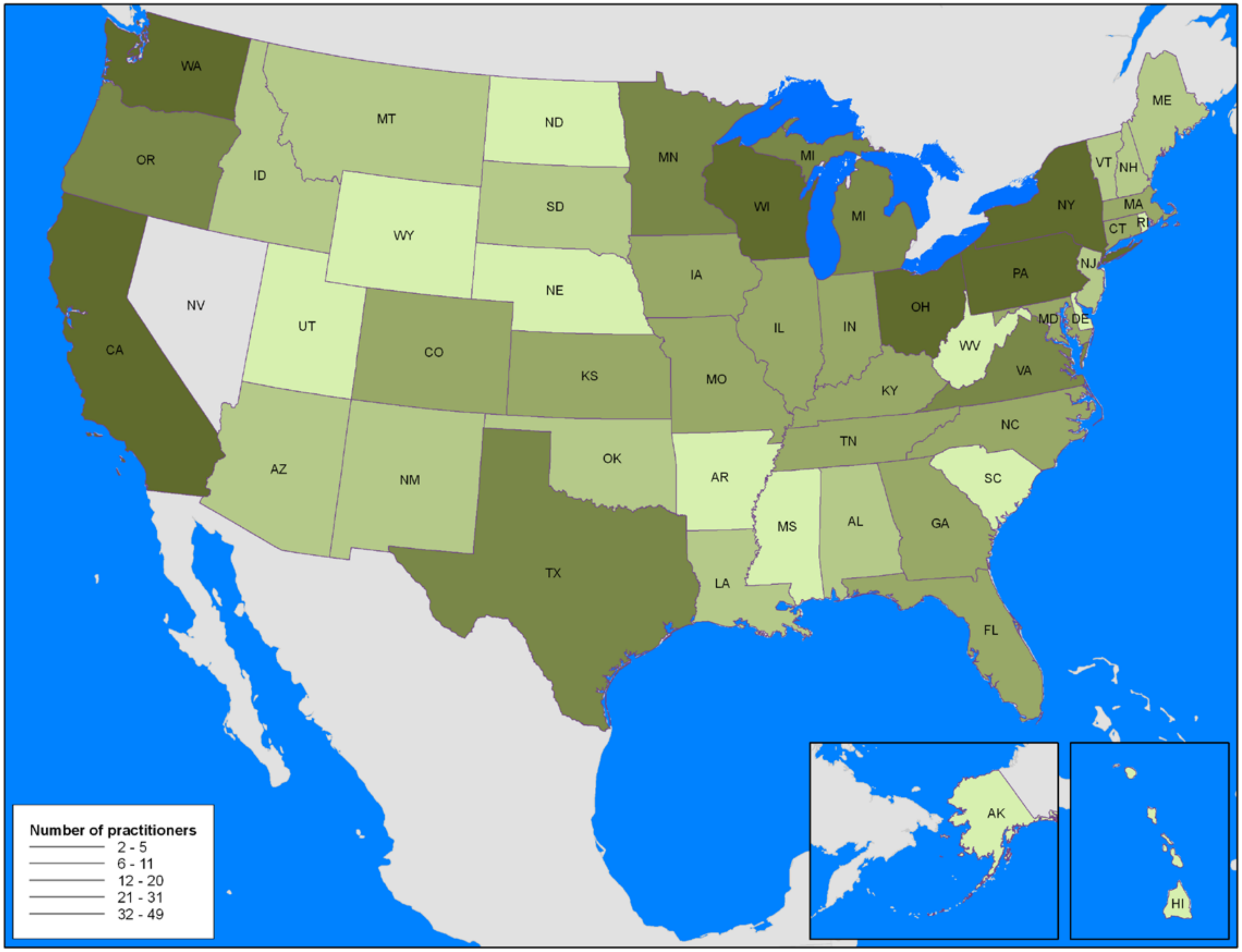

Figure 19. AASRP members by State. (Source: AASRP Membership Directory 2007—2009)

Table 28. Statistical analysis of the relationship between the density of goats per State and the density of goat farms per State versus the number of members of the AASRP per State.†

	Section1. Results Include All 50 States		
	Correlation Coefficient	**Coefficient of Determination**	**P value**
Number of Goats	0.1962	22.97	0.000
Number of Goat Farms	0.3241	26.99	0.000
	Section 2. Results Exclude the State of Texas *		
	Correlation Coefficient	**Coefficient of Determination**	**P value**
Number of Goats	0.4247	22.87	0.000
Number of Goat Farms	0.5045	26.65	0.000
†Analysis using R2.10.1, 2009. *The State of Texas was an outlier in this portion of the analysis.			

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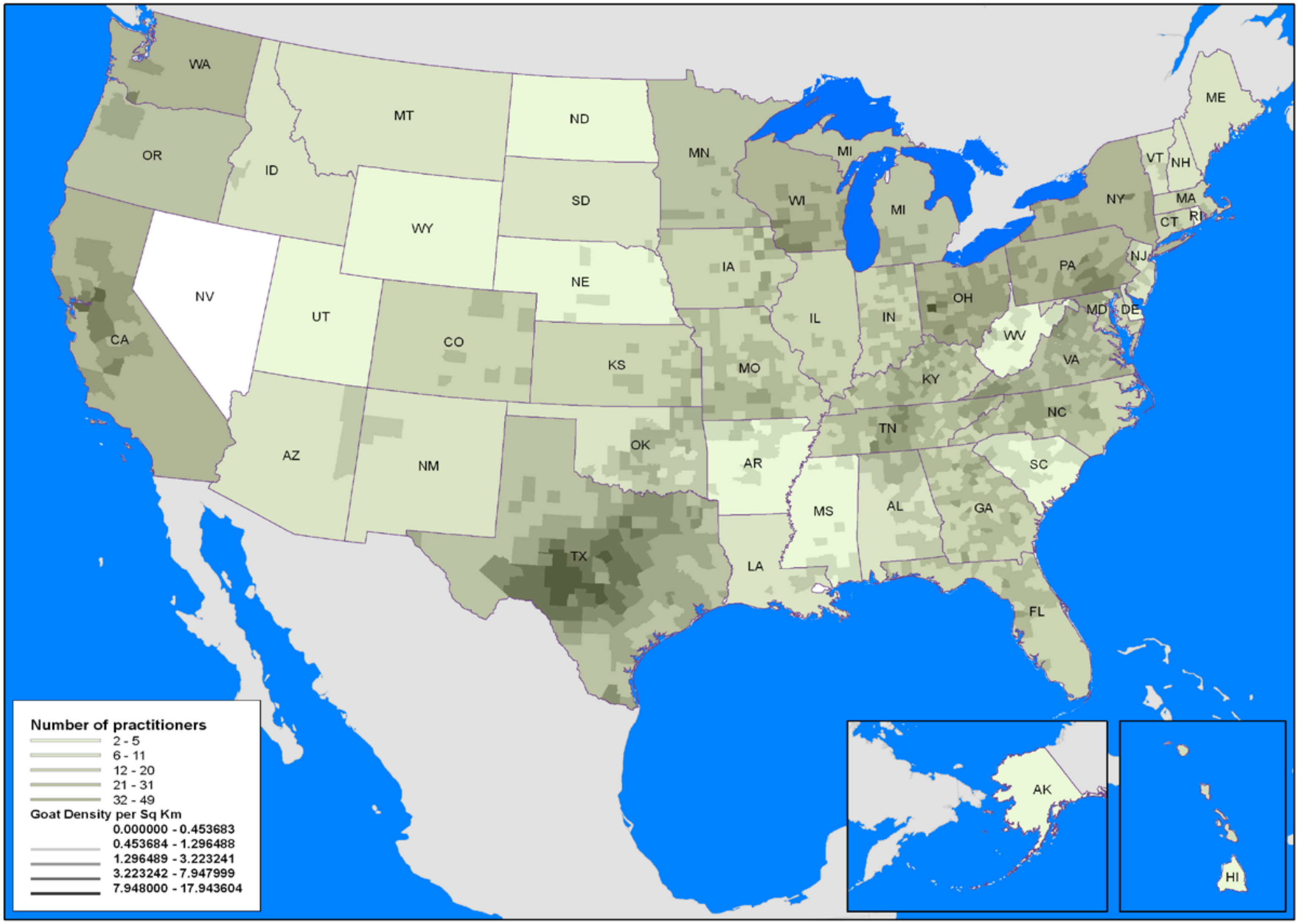

Figure 20. AASRP members versus density of U.S. domesticated goat population (Source:AASRP Membership Directory 2007—2009).

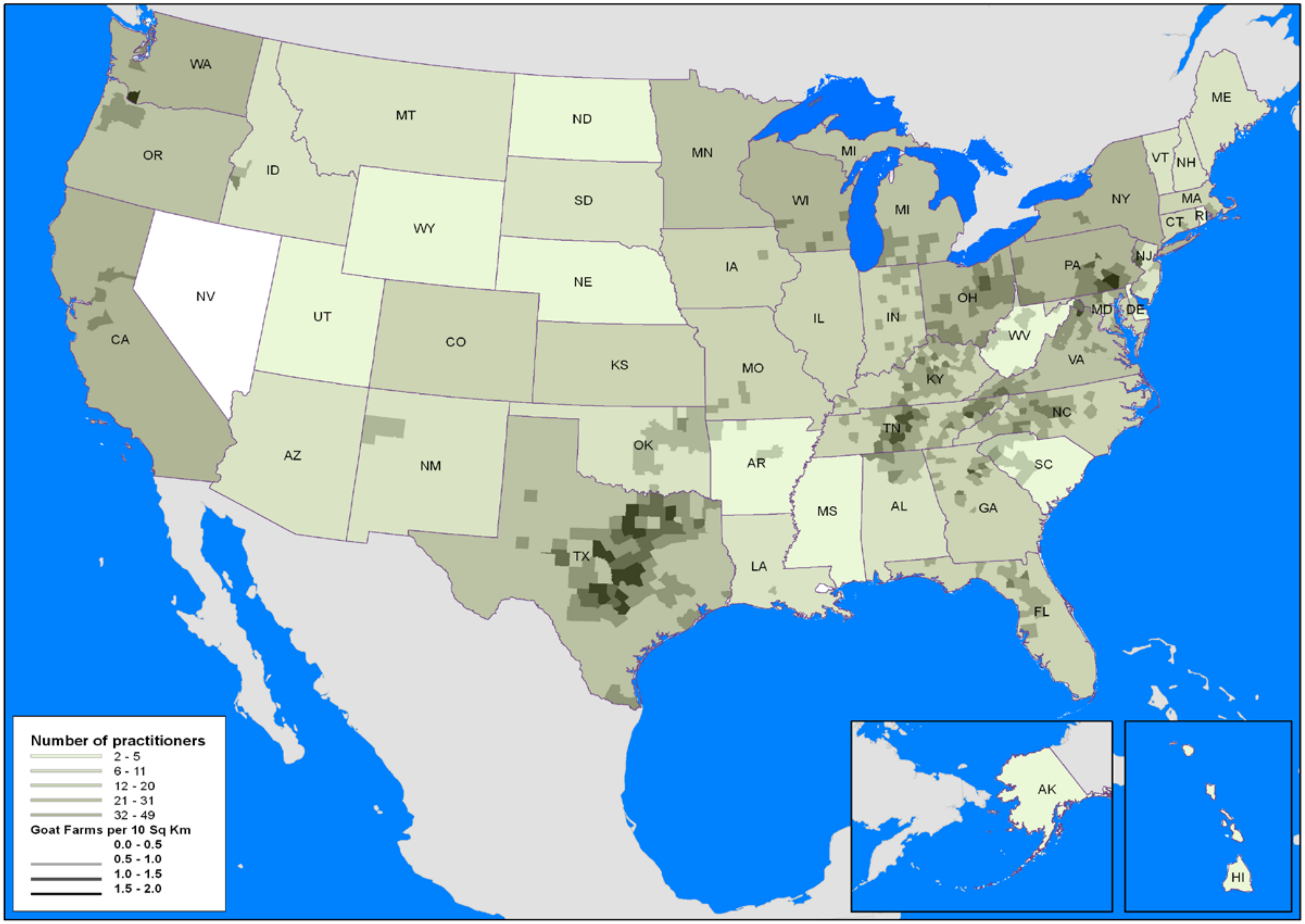

Figure 21. AASRP members versus density of U.S. goat farm operations (Source: AASRP Membership Directory 2007—2009).

The “percent interest” in goats that was self-reported by AASRP members was very low. Approximately 383 (51.2 percent) members reported that their “percent interest” in goats was less than 10 percent; 90 of those 383 members, or 12 percent of the total members, reported a zero “percent interest” in goats. Another 122 (16.3 percent) members reported that their interest in goats was 10 to 20 percent. Sixty-one (8.1 percent) members reported that their interest in goats was greater than 50 percent. Only 14 (1.87 percent) of the 748 members reported that their interest in goats was 100 percent (Figure 22).

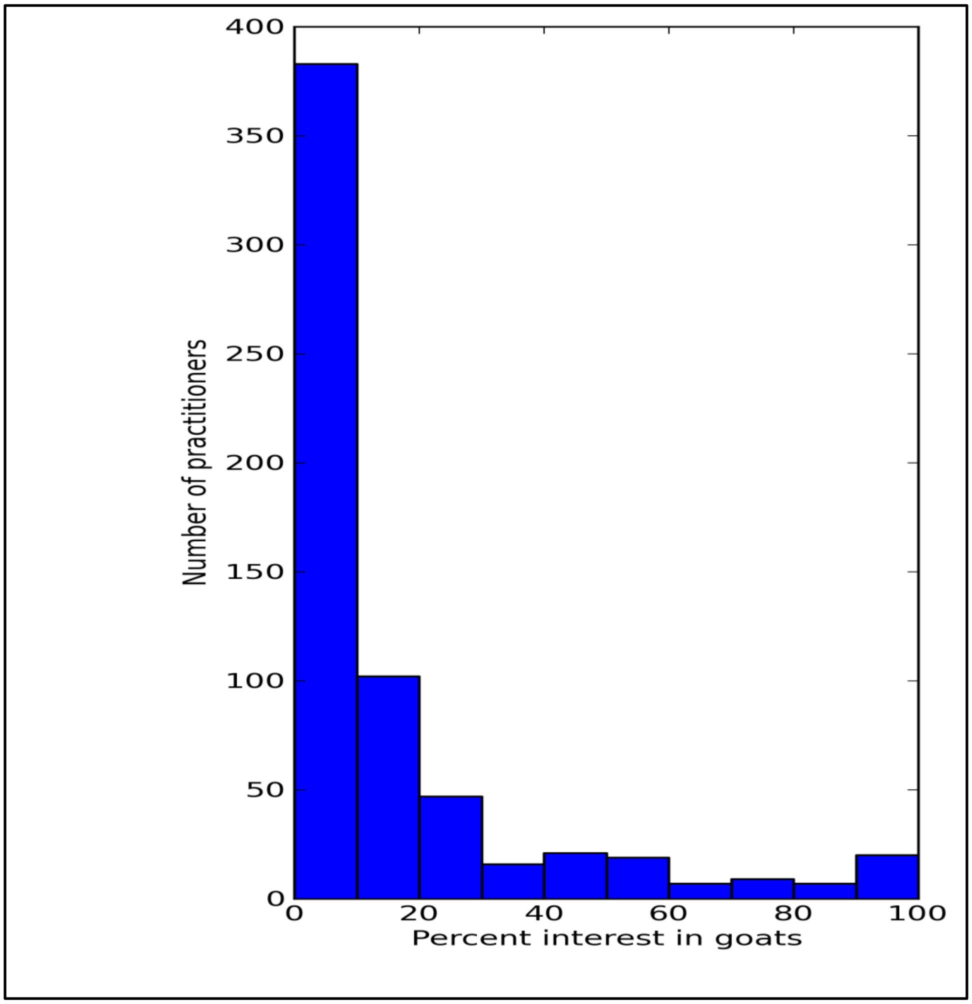

Figure 22. Percent of professional interest in goats by 748 members of the AASRP. (Source: AASRP Membership Directory 2007—2009).

The paucity of interest in goats on the part of veterinarians in general, and on the part of small ruminant practitioners specifically, has significant implications for the future health and productivity of the U.S. domesticated goat population. The lack of self-reported interest in goats may be a suitable proxy for veterinarians’ knowledge about goat production, non-zoonotic diseases, zoonotic diseases, and important biosecurity practices of this livestock sector. A low level of knowledge would explain why: (1) goat producers are more reliant on other goat producers than veterinarians as a source of health information, (2) the low level of familiarity of goat producers with the most common infectious disease of goats, and (3) 76 percent of goat producers were not familiar with Q fever (USDA, 2011).

12.3 Summary of Small Ruminant Health Professionals in the United States

- The AASRP as a veterinary specialty embraces the concept of serving as a key provider of health services for small ruminants, including goats.
- There are 748 members of the AASRP in 50 States in the United States and 3 Territories.
- The median number of AASRP members per State is 12. The interval is 0 to 49 members.
- The State with the largest number of AASRP members is California. The State with the smallest number is Mississippi.
- The statistical relationship between the number of members per State and (1) the density of the U.S. goat population and (2) the density of U.S. goat farm operations is weak, which suggests that membership in this specialty group is driven by their interest in small ruminant species other than goats.
- 51.2 percent of AASRP members reported that their professional interest in domestic goats is less than 10 percent.
- Only 1.87 percent of AASRP members reported that their professional interest in domestic goats is 100 percent.
- The paucity of animal health professionals with an interest in goats should elevate concerns that transmissible infectious diseases (e.g., Q fever) of this livestock sector are more likely to undergo delayed diagnosis, or remain undiagnosed for a protracted period.
- Delayed diagnosis of some goat diseases may have significant implications for the well-being of animal health and human health in the United States.

12.4 Conclusion in Regards to Accessibility to Caprine Health Professionals

The likelihood is medium that the factor “Accessibility to Caprine Health Professionals” would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population. An epidemic due to “Accessibility to Caprine Health Professionals” is as unlikely to occur as it is likely to occur. Reasons for a medium risk estimate due to this factor are the paucity of health professionals with an interest in goats, which in turn could lead to delayed diagnosis, misdiagnosis, or non-diagnosis of many goat diseases.

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13. Responses to Coxiellosis Diagnosis in Domesticated Ruminants

13.1 Responses to Coxiellosis Diagnosis in the Netherlands

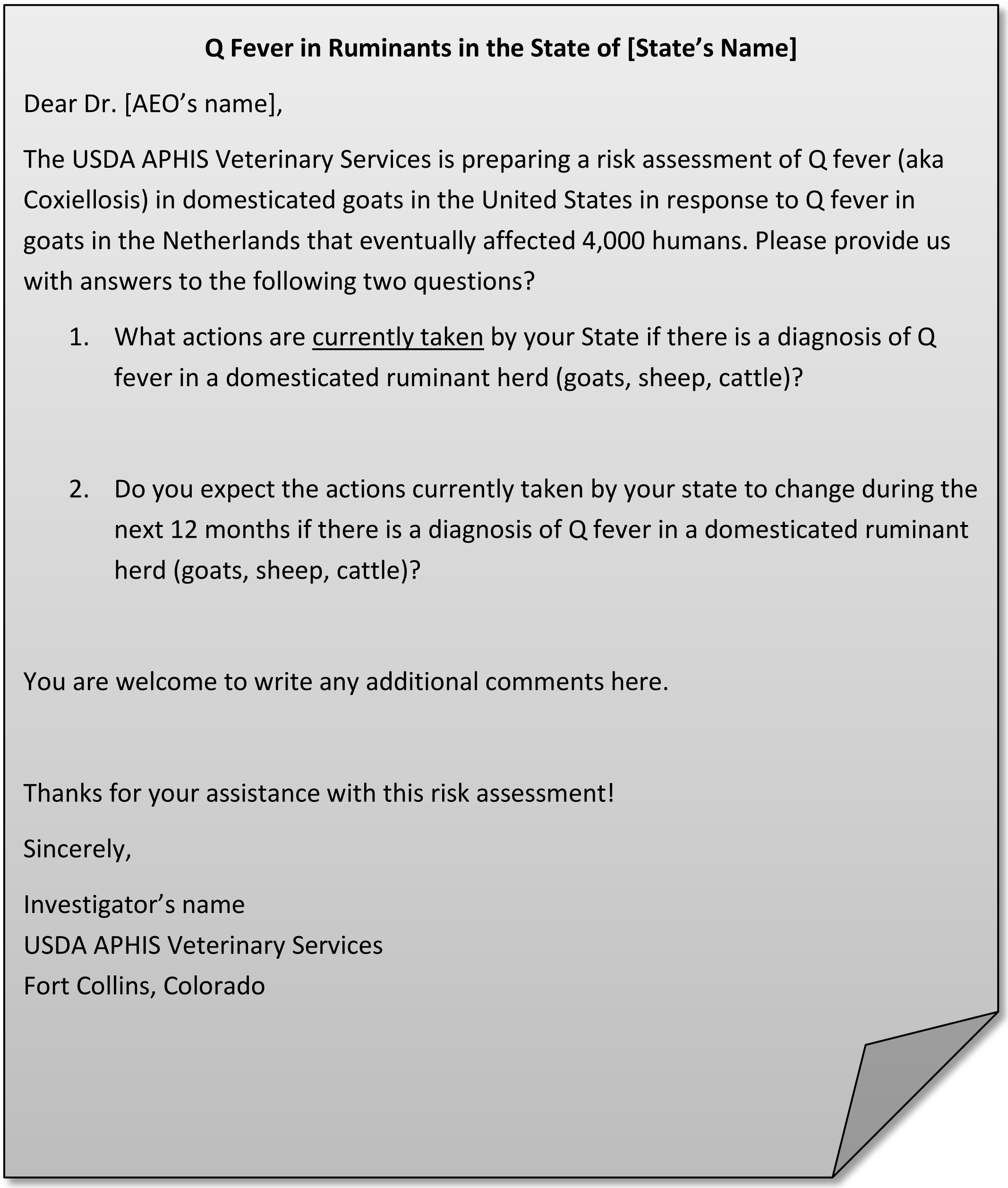
A list of control options was prepared by the EFSA in response to the epidemic of coxiellosis in domesticated ruminants in the Netherlands and other EU Member States. Some of the control options are focused specifically on small ruminants (i.e., goats and sheep) versus cattle, given that the role of cattle in the spillover of *C. burnetii* from domestic ruminants to humans appears to be minor. The 16 control options include:

1. Vaccination (two strategies)
2. Antimicrobial therapy
3. Removal of high-risk biological materials, placenta, aborted fetuses
4. Manure management systems (three systems)
5. Culling pregnant animals
6. Identification and culling shedders
7. Temporary breeding ban
8. Control of animal movement between farms of differing infection status
9. Stand-still measures
10. Segregated kidding and lambing areas
11. Wool shearing management
12. Tick control
13. Stamping out, depopulation
14. Enhanced general biosecurity, including a ban of visitors
15. Changes to farm characteristics (number of animals, farm size, farm location)
16. Control of other animal reservoirs of infection

The limitations and an assessment of the effectiveness and sustainability of each of these options in decreasing herd-to-herd transmission and decreasing within-herd transmission of *C. burnetii* also was explored by EFSA (Table 29). Twelve of the 16 control options were implemented to one extent or the other by the Netherlands after its experience with its Q fever epidemic.

13.2 Responses to Coxiellosis Diagnosis in the United States

There is no singular response to coxiellosis diagnosis in ruminants in the United States. Our initial inquiries suggested that responses to a diagnosis vary greatly by State and because they do vary, a survey of actions taken by States subsequent to a diagnosis was administered. The USDA's Area Epidemiology Officer (AEO) in each Area Office was asked to provide feedback to two questions related to actions taken by its State. The survey instrument contained two open-end questions and was administered by electronic mail to the AEOs during the period from January 12 to January 26, 2012 (Figure 23). AEOs were given the freedom to collect the data about their respective States by the method that they viewed as most appropriate. We made the assumption that many AEOs would seek input from their State counterparts; thus, no constraints were placed on the response time. Respondents also were given the opportunity to submit comments about our request beyond their responses to the specific questions.



Q Fever in Ruminants in the State of [State's Name]

Dear Dr. [AEO's name],

The USDA APHIS Veterinary Services is preparing a risk assessment of Q fever (aka Coxiellosis) in domesticated goats in the United States in response to Q fever in goats in the Netherlands that eventually affected 4,000 humans. Please provide us with answers to the following two questions?

1. What actions are <u>currently taken</u> by your State if there is a diagnosis of Q fever in a domesticated ruminant herd (goats, sheep, cattle)?

2. Do you expect the actions currently taken by your state to change during the next 12 months if there is a diagnosis of Q fever in a domesticated ruminant herd (goats, sheep, cattle)?

You are welcome to write any additional comments here.

Thanks for your assistance with this risk assessment!

Sincerely,

Investigator's name
USDA APHIS Veterinary Services
Fort Collins, Colorado

Figure 23. Questionnaire sent to all U.S. States in 2012 to inquire about responses to diagnosis of Q fever in domestic ruminants.

The response rate was 68 percent, meaning that the AEOs were able to provide feedback about actions taken by 34 States. Responses from AEOs were received in a period of time that was as brief as one hour or as long as 12 days. Responses were of three types: (1) a response based exclusively on solicitation of feedback from their State counterparts, (2) a response based on a combination of feedback from State counterparts and from the AEO and/or AVIC, and (3) a response based solely on current knowledge and experience of the AEO. Some responses were relatively lengthy and other responses were quite abbreviated (222 words versus 6 words, respectively). Of the 34 States/Territory from which responses were received, only 2 States indicated that their future actions would be different than their current actions, if a flock were diagnosed during the next 12 months. Comments received from respondents beyond their responses to the two specific questions were infrequent, and those comments were usually directed towards briefly describing plans for an enhanced response to coxiellosis diagnosis. General themes of the current actions taken, the changes expected in current actions, and comments are summarized below.

General themes regarding current actions that could be or would be taken by States:

- Inform State public health officials; collaborate with public health as needed.
- No action. No plan.
- State Public Health Veterinarian will notify producer and Department of Agriculture.
- Educate producer about Q fever in humans.
- Educate producer about coxiellosis in animals.
- Guide producer in seeking medical help if needed.
- Conduct epidemiological investigation to assess extent of human illness.
- Impose quarantine on affected premises.
- Will not impose quarantine on affected premises.
- Agriculture department would inform SPHV and USDA’s AVIC.
- Internet webpage distribution of coxiellosis and Q fever fact sheets.
- Outreach seminars about coxiellosis and Q fever, including diagnostic options and prevention.
- Diagnostic tests of raw milk specimens.
- Prohibit sale of milk.
- Record diagnosis in Board of Animal Health database.
- State Veterinarian would contact the producer’s private practitioner.
- Board of Animal Health advises producer’s private practitioner regarding zoonosis.
- USDA’s AVIC would notify the Regional Office.
- Not reportable in livestock, so no action.
- Discuss humane euthanasia as an option for producer.

General themes regarding changes in actions during next 12 months by States:

- No change.
- Distribute a fact sheet to the producer’s private practitioner.
- Distribute a fact sheet to the producer.
- Looking forward to any changes recommended by USDA and CDC.
- Vaccine approval in the United States may lead to changes in our State’s current actions.
- No change, unless a virulent strain is introduced.

- No change, as long as resources remain available to educate producers.
- State Livestock Board is creating a zoonotic diseases cooperative agreement with the Department of Public Health.

General themes of the comments by States:

- Concerned about acute cases that escape diagnosis, especially abattoir employees
- If we elevate the response, we may drive the disease underground
- Was unaware of the high prevalence of *Coxiella burnetii* in domestic ruminants

After collecting data from the States, we then compared the actions that would or could be taken by the U.S. States to those actions that were adopted by the Netherlands during its response to the coxiellosis epidemic in small ruminants (Table 29). The Netherlands implemented both preventive vaccination and outbreak vaccination because vaccination was thought to be effective and sustainable, especially when combined with other control measures. Neither type of vaccination can be implemented in the United States because vaccine has not been approved by the USDA. A temporary ban on breeding goats and sheep on infected premises was implemented in the Netherlands, but a ban on breeding was not listed as a possible action by any State in the United States. Likewise, selective culling, specifically culling all pregnant does and ewes on infected premises, was implemented in the Netherlands, but no States in the United States listed culling pregnant does and ewes on infected premises as an action that would be taken by them as of January 2012. Identification and culling shedders is not an action that will be taken by the Netherlands or any State in the United States because of the difficulty of identifying shedders with currently available diagnostic tests.

At least three different manure management systems with varying degrees of effectiveness in decreasing transmission of *C. burnetii* are employed on goat and sheep operations in the Netherlands. Composting manure for three months, treating manure slurry with cyanamide calcium followed by soil deposition, and depositing untreated manure in the soil are methods used. No State in the United States listed specific manure management methods among its list of actions recommended for infected premises. Regardless of current actions taken by States, all goat producers should establish a manure management system of one type or another as a standard farm management practice. Removal of manure and waste bedding after each doe delivers her kids is recommended by goat husbandry experts, but only 25.7 percent of goat producers engage in this practice (USDA, 2012). Also, 47.7 percent of goat producers removed manure and waste bedding only once, at the end of the kidding season, or they never removed manure and waste bedding. Producers in the West and Southeast were far less likely to remove manure and waste bedding than producers in the Northeast. Improper disposal of manure and waste bedding has potentially significant implications for transmission of *C. burnetii* because of the level of contamination of feces by this pathogen.

Control of animal movement among premises of differing infection status was implemented in the Netherlands to decrease herd-to-herd transmission. Animals from infected premises are permitted to move to other infected premises only, but not to uninfected premises. However, vaccinated animals are permitted to move to infected premises. A major limitation of control of animal movement is that it requires knowledge of the infection status of each premises. In turn, knowledge of the infection status would require mass screening of numerous herds, along with all associated costs to the country to screen the ruminant livestock population. The major difference between quarantine and control of animal movement is that quarantine is a non-voluntary action that is frequently applied to a widespread geographical region, and a legal basis such as a State statue to impose the quarantine as well as to remove it usually is required. Although implementation of quarantine was utilized minimally or not at all in the Netherlands, thirteen States in the United States reported that quarantine would or could be imposed on an infected herd within its borders, albeit under varying conditions. The duration of quarantine as well as the guidelines for termination of quarantine probably will be unique to each of the 13 States.

Culling pregnant does and ewes was implemented in the Netherlands, but it is unclear if depopulation of entire flocks was implemented. Only one State in the United States reported that they may recommend depopulation of the flock, but depopulation was not described as mandatory by that State, or any other State.

Biological products such as placenta and aborted fetus contain large numbers of *C. burnetii* that may contaminate the environment and serve as a source of infection for other animals and humans. Although 100 percent removal of these contaminants from infected premises was viewed by EFSA as "unlikely," safer disposal methods were implemented in the Netherlands. Producers are required to render the placenta and fetus. There were no States in the United States that reported they would implement specific policies for disposal of biological contaminants from infected herds. Disposal of aborted fetuses and placenta continues to be at the discretion of each producer. Aborted fetuses and placenta were never removed from birthing areas on 40.6 percent of goat operations in the United States (USDA, 2012).

It was somewhat surprising that a rigorous educational campaign for livestock producers was not listed specifically among the 16 control options proposed by the EFSA. It is possible that control options such as disposal of biological contaminants, segregated housing for kidding and lambing, wool shearing practices, and limiting the numbers and types of farm visitors can be broadly classified as options that would be incorporated into an educational campaign. Ironically, education of livestock producers about coxiellosis in animals and Q fever in humans was one of the most frequently reported actions that would be taken by U.S. States in response to a diagnosis. Fourteen States reported that education of livestock producers would be a high priority, especially education about the zoonotic nature of coxiellosis.

Table 29. Goals, effectiveness, sustainability, limitations, and implementation of various control options for *C. burnetii* in domestic ruminants in the Netherlands and the United States.

	Goal				Level of Implementation		
	Decrease herd-to-herd transmission	Decrease within-herd transmission			Netherlands		States in the US
Control Option	**Effectiveness**	**Effectiveness**	**Sustainability**	**Limitations**	**Before epidemic**	**After epidemic**	**Current practice?**
Preventive vaccination (vaccination precedes infection)	High	High	High	Vaccine supply. Costs to producer. Vaccine s should be combined with other measures. Requires a regional strategy.	No	Yes	No
Outbreak vaccination (infection precedes vaccination)	Medium	Medium	High	Vaccine supply. Benefits may be delayed due to environmental contamination. No short-term benefits.	No	Yes	No
Antimicrobial therapy	None	None	Low	Will not decrease shedding; antimicrobial resistance.	No	No	No
Temporary breeding ban	High	High	Low	Cost will increase if ban is prolonged. Cost is greater in sheep versus goats.	No	Yes	No
Cull all pregnant does, ewes	High	High	Low	Extremely high costs; lost replacements and milk production; ethical issues; biological waste; delayed benefit due to contaminated environment.	No	Yes	No
Identify shedders and cull them	Low	Low	Low	Shedders are difficult to identify with current diagnostic tools.	No	No	No

Control Option	Goal: Decrease herd-to-herd transmission	Goal: Decrease within-herd transmission	Sustainability	Limitations	Level of Implementation: Netherlands		States in the US
	Effectiveness	Effectiveness			Before epidemic	After epidemic	Current practice?
Manure management (deep litter system, composting for 3 months)	High	None	High	Costs associated with storage.	No	Yes	Unlikely
Manure management (slurry treated with cyanamide calcium; soil deposition)	High	Low	High	None	No	Yes	Unlikely
Manure management (untreated slurry, soil deposition)	Low	-		Effectiveness of limiting spillover to neighbors and humans depends on spreading method and treatments.	No	Yes	Unlikely
Control of animal movement among farms of differing infection status	Medium	Low	Low	Successful only if infection status of each premises is known; requires mass screening of all herds participating in trade, identification, certification; regulations if compulsory	No	Yes	Unlikely
Stand still (a quarantine)	Medium	Low	Low	Incompatible with coxiellosis, since *C. burnetii* is widespread. Lost benefits from trade; Successful only if infection status of regions or zones is known; requires certification of animals and legal basis; will not limit short-distance spread.	No	No	AK, CT, FL, GA, HI, ID, IL, KS, MA, MI, NH, RI, VT
Depopulation (stamping out)	Medium	None		Depends on level of environmental contamination; policy for repopulation of flock should be defined.	No	Yes	GA

Control Option	Goal: Decrease herd-to-herd transmission – Effectiveness	Goal: Decrease within-herd transmission – Effectiveness	Sustainability	Limitations	Level of Implementation: Netherlands – Before epidemic	Level of Implementation: Netherlands – After epidemic	Level of Implementation: States in the US – Current practice?
Control of other animal reservoirs of *C. burnetii* (e.g, wildlife)	Low	Low	High	Effectiveness against coxiellosis difficult to measure. Option should be part of standard biosecurity.	No	Yes	Unlikely
Tick control	Low	Low	High	Environmental pollution and acaracide resistance; special authorizations required	No	No	Unlikely
Disposal of biological contaminants (placenta, aborted fetus)	Medium	Medium	High	Biological waste; feasibility will depend on the farming system; 100% removal is unlikely.	No	Yes	Unlikely
Segregated kidding & lambing areas	Medium	Medium	High	Depends on the extent of the separation. Costs to producer to construct areas.	No	?/Yes	Unlikely
Wool shearing management (goats and sheep)	Low	Low	High	No guidelines for decontamination or disposal of contaminated hair and wool; effectiveness related to distance between farms.			Unlikely
Visitors ban	None	Low	High	None	No	Yes	Unlikely
Changes to farm characteristics (density; location)	Medium	Low	High	Thresholds of “safe” density and proximity to neighbors not defined; high initial costs	No	Yes	Unlikely

Sources: From EFSA scientific opinion on Q fever, 2010, Table 14; page 77 to 79. Revised.
From Roest et al., 2011. Epidemiology and Infection 139, page 8, Table 3.

There were 15 U.S. States that reported “education” of producers as an action that would be taken by them in response to an outbreak of Q fever. They are listed below for quick reference: AK, AL, AR, FL, GA, ID, IA, IN, IL, MN, NJ, NM, ND, SC, WI.

13.3 Summary of Actions Taken in Response to Coxiellosis Diagnosis in Ruminants

Netherlands:

- A list of 16 potential control options was developed by the EFSA, after the epidemic of coxiellosis in the Netherlands.
- Each control option was evaluated by an expert panel for its effectiveness in decreasing transmission of coxiellosis in domestic ruminants.
- The Netherlands implemented numerous control options in response to the epidemic.
- Many of the control options were the result of a series of legislative mandates issued from June 12, 2008 to December 18, 2009.
- Vaccination of dairy goats and dairy sheep on farms with more than 50 animals was required by law.

United States:

- There is no singular response to coxiellosis diagnosis in domestic ruminants in the United States. Responses vary greatly by State.
- A national survey of actions taken by States in the United States in response to diagnosis of coxiellosis in ruminants was administered.
- Education of livestock producers about coxiellosis was one of the most frequently cited actions taken by States in the United States.
- Exercising the legal authority to impose quarantine on infected herds also was reported by States as a possible action, if necessary.
- Most potential control options are not mandated by individual States.
- Goat producers in the United States should be encouraged to play a pivotal role in control of coxiellosis on their operations.
- Results of a 2009 survey by the NAHMS suggest that there must be improvements in some on-farm biosecurity practices by goat producers to decrease the risk of transmission of coxiellosis, especially on infected premises.

13.4 Conclusion of Responses to Diagnosis of Coxiellosis in Goats

The likelihood is medium that the factor “Responses to Diagnosis of Coxiellosis” would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population. An epidemic due to “Responses to Diagnosis of Coxiellosis” is as unlikely to occur as it is likely to occur. Reasons for a medium risk estimate due to this factor are the need for on-farm improvements in biosecurity practices, few of the control options that were implemented during the Netherlands epidemic are also implemented in the United States, and the need for a more unified and stronger response by States.

13.5 Bibliography

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14. Coxiellosis Vaccine for Use in Animals

14.1 Description of Vaccines

Coxiellosis vaccines vary both in their preparation processes and in their composition, including the strain of *C. burnetii*, possible combinations of strains, and the *C. burnetii* phase incorporated (Arricau-Bouvery, 2005b). The most important element is the phase. Vaccines prepared from phase I *C. burnetii* organisms are more protective against coxiellosis in laboratory animals than those prepared from phase II. In animals, the most effective vaccines appear to be those prepared with inactivated, whole phase I bacteria. Bacterial shedding in placental tissue and milk was strongly inhibited in experimental infection or in naturally acquired *C.burnetii* infection of ewes and cows vaccinated by phase I vaccines (Brooks et al., 1986; Sadecky et al., 1975, Sadecky and Brezina, 1977). However, several studies report that phase I vaccines failed to prevent shedding in milk by cows that became naturally-infected prior to vaccination (Biberstein et al., 1977; Schmeer et al., 1987), highlighting the role of the vaccine in protecting uninfected animals but not in treating infected animals. Vaccination efficacy will depend on whether immunization precedes infection *(preventive vaccination)* or does not precede infection *(outbreak vaccination)*.

Three coxiellosis or Q fever vaccines are currently available for unrestricted or restricted use in animals and humans (Kadra, 2010). None of these vaccines has been licensed for use in the United States as of 2012. The vaccines are:

1. Chlamyvax FQ, a combined vaccine containing *C. burnetii* Phase II and *Chlamydophyla abortus* for animals;
2. Coxevac, inactivated, purified whole cells of Nine mile strain of *C. burnetii* Phase I for animal use (under temporary market approval); and
3. Q-Vax, inactivated, purified whole cells of Henzerling strain of *C. burnetii* Phase I for human use.

14.2 Vaccine Use in the Netherlands and in France

Coxiellosis vaccine was prohibited in the Netherlands prior to October 2008. On October 16, 2008 “Special dispensation for Coxevac, (CEVA) Q fever vaccine to be used in The Netherlands.” was initiated as directed by legislative document TRCJZ/2008/2817 (Roest, 2011). A voluntary vaccination program was implemented in dairy goats and dairy sheep at farms with more than 50 goats or sheep, petting zoos, and nursing farms in the restricted 45-km zone around infected premises. A mandatory vaccination program was implemented in the same 45-km zone around infected premises on April 20, 2009.

In France, disease control measures in case of abortions due to coxiellosis are based on a combination of vaccination and herd/flock hygiene (Rodolakis, 2010). The number of doses increased four-fold during years 2006 to 2008. There were 108,000 doses administered in 2006, 319,000 doses in 2007, and approximately 400,000 doses in 2008 (Figure 24). The increase in vaccine doses used in France was due to their favorable experiences from the outbreaks in Chamonix and Florac in 2002 and 2007, respectively. The goal of vaccination is to decrease *C. burnetii* shedding into the environment. One of the challenges with coxiellosis, and other infectious diseases, is differentiation of susceptibility from immunized animals in herds previously vaccinated, and differentiation of susceptibility from infected animals in infected but not previously vaccinated flocks. The French developed an intradermal test to differentiate the two populations.

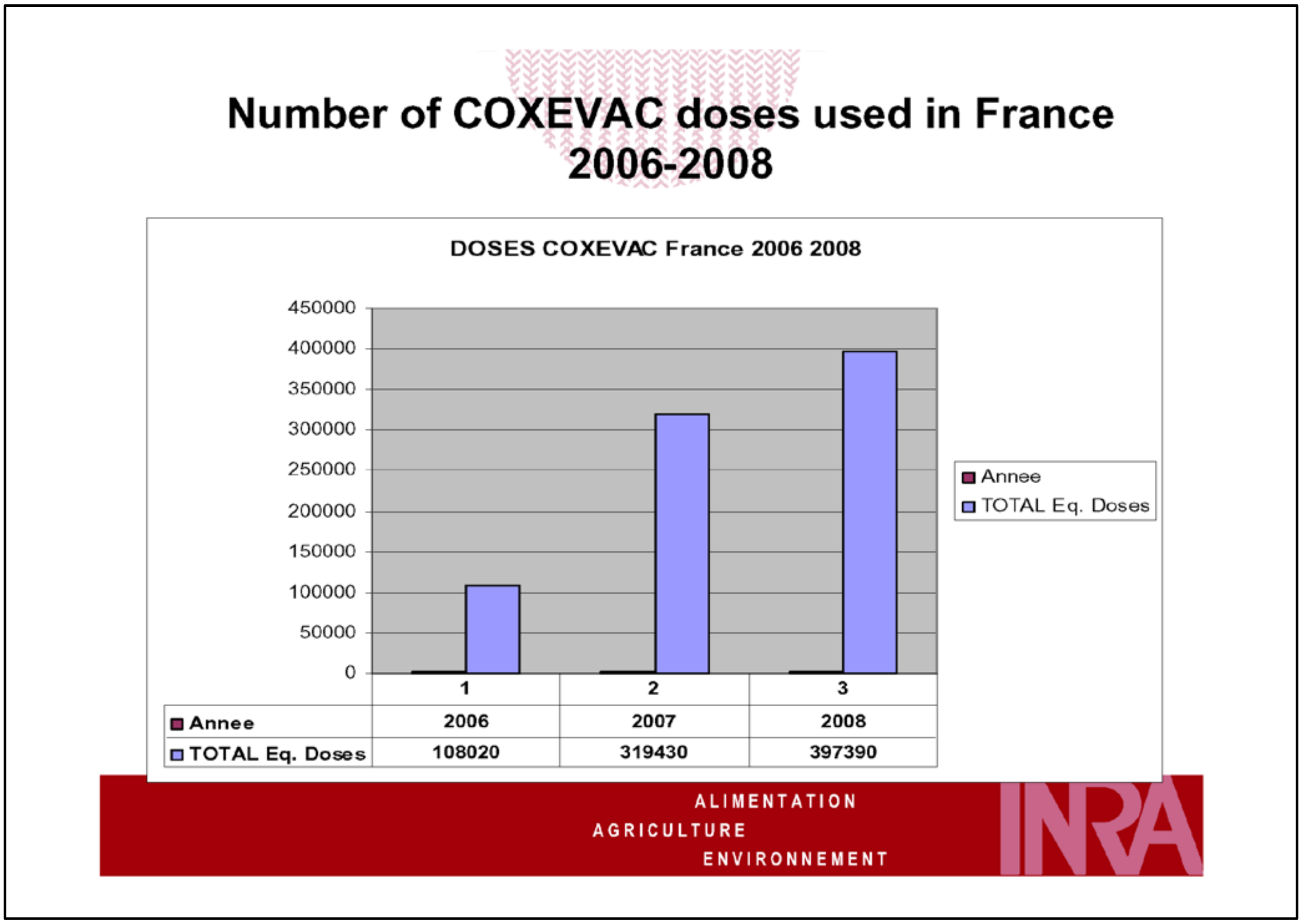

Figure 24. Coxevac doses used in France during years 2006—2008 (Rodolakis, 2010).

14.3 Vaccine Use in the United States

Coxiellosis vaccines are not licensed for use in animals in the United States. The primary reason for this is that there has been very little demand for vaccine on the part of livestock producers. Human cases of Q fever are diagnosed in the United States annually, but the magnitude of outbreaks in the United States has never approximated the magnitude of outbreaks that have occurred in some Member States of the European Union, especially the Netherlands.

14.4 Evaluation of Vaccine Trials in Goats

Given that coxiellosis in goats and sheep is considered a significant source of Q fever in humans, several attempts have been made to evaluate the efficacy of coxiellosis vaccine in goats and sheep during recent years, the ultimate goal being to use vaccine to decrease the number of incident cases in humans. Although the general principles in the design and conduct of clinical trials to successfully evaluate vaccines have been established for decades, rarely are two trials designed in sufficiently similar fashion so that the outcomes are easily comparable. Thus, we undertook a detailed comparison of the design, methods, and results of three “trials” in which the general goal was to evaluate the efficacy of coxiellosis vaccine in small ruminants. The results of trials conducted in Spain, France, and the Netherlands are described and summarized below.

14.4.1 Spain, 2011

Methods*:* A field trial was conducted in Spain during the 2008/2009 lambing season to evaluate *C. burnetii* shedding and environmental contamination at lambing in two naturally infected dairy sheep flocks (Astobiza et al., 2011). Both flocks had experienced epidemic abortions during the 2007/2008 lambing season. *C. burnetii* had been confirmed as the likely cause of abortion, based on histopathological examination, Smith-stained placental smears, and complement fixation titers. The incidence of abortion in flock 1 was 6.3 percent, and the incidence in flock 2 was 5.2 percent. The seroprevalence in flock 1 was 35.7 percent and in flock 2 it was 43.8 percent, based on ELISA. The hypothesis was that vaccination would reduce the level of excretion and percentage of animals in the herd that shed bacteria. The four endpoints that were measured were: (1) percentage of *C. burnetii* shedders, (2) the bacterial excretion burden, (3) the rate of seroconversion, and (4) level of bacteria in aerosols inside and outside housing facilities. Sheep were assigned to a vaccinated group or to an unvaccinated control group via systematic random assignment. The sample size in flock 1 was 189, and in flock 2 it was 178. The ratio of vaccinates to controls was 3:1. Ewes and yearlings were vaccinated in May and June 2008 with a commercially available, inactivated phase I vaccine six weeks prior to artificial insemination. All sheep were vaccinated again three weeks after the initial injection. Producers recorded the number of sheep that aborted during the 2008/2009 reproductive season. Vaginal specimens were collected 30 days after lambing from ewes and yearlings, and serological specimens were taken from yearlings to assess seroconversion against *C. burnetii* via ELISA. Aerial specimens were collected from inside and outside the housing facilities monthly, during the period from lambing through lactation.

Abortions in flock 1 decreased from 6.3 to 1.9 percent, and abortions in flock 2 decreased from 5.2 to 1.8 percent. Aborted fetuses were not recovered because the sheep were grazing on mountain pastures; however, *C. burnetii* was recovered from vaginal swabs from several ewes that aborted, indicating that pathogens other than *C. burnetii* probably were not the cause. There were only marginal differences between rates of vaginal shedding in vaccinated and control groups. The high prevalence of animals infected with *C. burnetii* was offered as one explanation of the "… low efficiency of the vaccine…." in this trial. Also, the phase I vaccine schedule was in accordance with the manufacturer's instructions, i.e., in 2 doses, 6 weeks and 3 weeks preceding artificial insemination in the case of ewes, or 6 weeks and 3 weeks prior to natural mating in the case of yearlings. By adhering strictly to the manufacturer's instructions, the author suggested that some yearlings already may have been infected prior to vaccination. Thus, it may be possible to achieve a higher level of protection, if yearlings are vaccinated at an age earlier than recommended by the manufacturer. In future trials, the author will vaccinate yearlings/replacement lambs at three months of age initially, and that will be followed by a booster injection at mating to provide immunity before natural infection is given opportunity to establish itself.

The aerial specimens collected indoors and outdoors at flock 1 were positive shortly after lambing. One month after lambing, *C. burnetii* remained present in indoor aerosol specimens, but not in outdoor specimens. The bacterial load decreased gradually each month after lambing and was negative by the third month. The aerosol specimens collected indoors and outdoors at flock 2 were negative shortly after lambing, and they remained negative during the lactation period. The role that vaccination may have played in aerosol concentrations of *C. burnetii* in these two flocks is unclear, but given that Q fever in humans is frequently acquired by inhalation of contaminated aerosols, the lower concentrations of *C. burnetii* outdoors can only be beneficial in decreasing the risk to human health.

***Conclusion**:* Vaccination of heavily infected commercial flocks did not have a significant benefit in decreasing the number of shedders and the bacterial load excreted during the first year after an outbreak of abortion (Table 31).

14.4.2 France, 2005

***Methods**:* The only vaccine available in France prior to early 2004 was an inactivated combination vaccine prepared from *Chlamydophila abortus* and phase II of *C. burnetii* (Chlamyvax-FQ, Merial, France). Chlamyvax-FQ was shown to be poorly effective against bacterial shedding in milk in one flock of goats. Because a second vaccine became available in 2004, a phase II clinical trial was conducted in France in 2004 to compare the efficacy of two vaccines (Arricau-Bouvery, 2005b): (1) *Coxiella* phase I vaccine (Coxevax, CEVA, Sante Animale, France) and (2) *Coxiella* phase II vaccine (Chlamyvax-FQ, Merial, France). The Coxevac vaccine was an inactivated phase I vaccine provided by CEVA, Sante Animale specifically for this trial. Goats one and two years old, originating from herds that were serologically negative for *C. burnetii* and *C. abortus*, and with no history of abortion, were assigned randomly to three experimental groups. Goats in groups I and II were vaccinated subcutaneously at the left shoulder with Coxevax or Chlamyvax-FQ after estrus synchronization and prior to mating. A booster dose was injected three weeks after the first injection. A third group of goats served as an unvaccinated control group. All three groups of goats were challenged by subcutaneous injection of 10^4 CbC1 strain at the right shoulder at 84 days of gestation, or 105 days after the booster injection. All three groups were confined in a level 3 biosecurity facility.

Four criteria were used to evaluate the consequences of the challenge on gestation in the three groups of goats: (1) mean duration of gestation, (2) percentage of abortions, (3) percentage of goats with contamination of placenta, and (4) percentage of infected fetuses or kids. Generally, "…. phase I vaccine induced highly significant protection….." in group I compared to the unvaccinated control and to the animals vaccinated with phase II vaccine. The gestation period of goats vaccinated with Coxevac, then challenged with *C. burnetii* was normal (mean 153 days), the same as those goats that were not challenged (mean 150 days). Goats vaccinated with Chlamyvax-FQ aborted between 26 and 63 days after the challenge, and goats that were not vaccinated but challenged with *C. burnetii* aborted between 39 and 61 days after the challenge. Nearly all goats vaccinated with Coxevac became seropositive after vaccination, and the antibody responses were consistent with responses to vaccination, not infection. The antibody responses of goats vaccinated with Chlamyvax-FQ and unvaccinated goats were consistent with responses to infection, not vaccination.

The number of goats that shed *C. burnetii* in feces was lower in the Coxevac vaccinates than in the Chlamyvax-FQ vaccinates and unvaccinated goats. The duration of shedding was shorter in Coxevac vaccinates. The median duration of excretion was 1 day for Coxevac vaccinates, 28 days for Chlamyvax-FQ vaccinates, and 27 days for unvaccinated goats.

The number of goats that shed *C. burnetii* in vaginal excretions was lower in the Coxevac vaccinates than in the Chlamyvax-FQ vaccinates and unvaccinated goats. The duration of shedding was shorter in Coxevac vaccinates. The median duration of excretion was 0 days for Coxevac vaccinates, 14 days for Chlamyvax-FQ vaccinates, and 21 days for unvaccinated goats.

The number of goats that shed *C. burnetii* in milk was much lower in the Coxevac vaccinates than in the Chlamyvax-FQ vaccinates and unvaccinated goats. No excretion was detected in milk from Coxevac vaccinates (i.e., median duration was 0 days). The median duration of excretion was 7 days of Chlamyvax-FQ vaccinates, and 7 days for unvaccinated goats.

***Conclusion**:* Vaccination of goats under experimental conditions with phase I *C. burnetii* vaccine protected goats against abortions, decreased placental colonization, eliminated shedding in milk, decreased shedding in vaginal excretions, and decreased shedding in feces. Phase II vaccine provided no protection (Table 31).

14.4.3 Netherlands, 2010

***Methods**:* In 2007, a major epidemic of Q fever occurred in the general population in the Netherlands, which resulted in more than 2,300 reported human cases in 2009. Reduction in the number of human cases was considered essential by public health authorities. One of the interventions was vaccination of dairy goats against *C. burnetii*. The assumption was that vaccination would decrease abortions and bacterial levels, and that those reductions would decrease the number of human cases the following year. Vaccination began in 2008 and was intensified in 2009. As the number of cases of *C. burnetii* in humans doubled in 2009, public health authorities applied a precautionary principle and decided to cull all pregnant dairy goats or sheep on infected farms prior to the 2010 kidding/lambing season. Culling was implemented at the end of 2009 and thereby precluded any analysis of vaccine efficacy in the Spring of 2010. However, Animal Health Service in the Netherlands took advantage of an opportunity to collect specimens from goats and sheep as they were humanely killed (Hogerwerf et al., 2011). The purpose of this investigation was to quantify the effect of vaccination on bacterial load in excreta of pregnant goats and sheep.

The vaccine used was Coxevac (Ceva Sante Animale, Libourne, France). Coxevac vaccine had not been registered in the Netherlands when this study was initiated, but authorities had issued a temporary exemption. Although efficacy in dairy goats had not been established, the expected effects in vaccinated animals were decreased infection, abortion, and bacterial shedding, if animals became infected after vaccination.

Convenience sampling was used to select unvaccinated dairy goats from five farms, vaccinated dairy goats from seven farms, and unvaccinated dairy sheep from one farm. The number of animals per farm from which specimens were collected was 100, of which 50 were mature (i.e., pregnant and lactating) and the remaining 50 were immature (i.e., nulliparous) animals. The goal of the sample size was to detect a 20 percent difference in the chosen outcomes between vaccinated and unvaccinated animals and detect a 20 percent difference between mature and young animals. Laboratory specimens were uterine fluid, vaginal mucus, and milk. The specific specimens were collected to detect animals with a high risk for shedding during the peri-parturient period, to be consistent with other investigations, and because herds were monitored based on results of bulk-milk tests. Specimens were analyzed using a commercial quantitative real-time PCR (TaqMan Quantitative PCR, Laboratoire Service International, Lissieu, France) or a non-commercial real-time PCR specific for the *C. burnetii* insertion sequence 1111a gene.

The crude results of the study are presented below (Table 30). The prevalence of positive samples from Coxevac vaccinates was much lower than the prevalence in goats that had not been vaccinated. Prevalence within vaccinated herds and unvaccinated herds varied substantially. It was suggested that, because shedding may be highest during parturition, abortion, and post-parturition, the results of vaccination may decrease environmental contamination, thereby contributing to a reduction in risk for human exposure and a decrease in human cases.

***Conclusion**:* Vaccination of dairy goats against coxiellosis with Coxevac decreased the percentage of animals in which bacteria were detected and decreased bacterial loads in uterine fluid, vaginal swabs, and milk (Table 31).

Table 30. Efficacy of vaccination against *Coxiella burnetii* in an observational study of 957 mature and immature goats and sheep in 13 small ruminant herds, the Netherlands, 2010.

	Positive		Efficacy (%)	
Source	**Vaccinated (%)**	**Not Vaccinated (%)**	**Mature (%)**	**Immature (%)**
Uterine	0.4	25	98	90
Vaginal	30	76	57	28
Milk	4	33	72	NA

NA = not applicable.
Source: Hogerwerf et al., 2011. "Reduction of Coxiella …..", EID 17(3) 379-385.

Table 31. Comparison of design and results of scientific studies to evaluate efficacy of *Coxiella burnetii* vaccine in small ruminants.

	1	2a*	2b*	3
FACTOR	**TRIAL DESIGN**			
Study type	Phase 3/Field trial	Phase 2	Phase 2	Observational
Author name	Astobiza	Arricau-Bouvery	Arricau-Bouvery	Hogerwerf et al.
Year	2011	2005	2005	2011
Location	Spain	France	France	Netherlands
Goal stated	Yes	Yes	Yes	Yes
Hypothesis stated	Yes	No	No	No
Species	Sheep, dairy	Goat	Goat	Goat and sheep, dairy
Sample size (flocks)	2	1	1	13 (5 + 7 + 1)
Sample size (animals)	647	28	27	957
Group assignment	Systematic random	Random	Random	Convenience
Vaccinates	442	16	15	470
Controls	205	12	12	487
Pretrial seroprevalance	35.7%; 43.8%	0%	0%	NA
Endpoints defined	Yes	Yes	Yes	Yes
Endpoint 1	Percentage shedders	Shedding	Shedding	NA
Endpoint 2	Bacterial excretion burden	Abortion	Abortion	Shedding
Endpoint 3	Rate of seroconversion	NA	NA	NA
Endpoint 4	Bacteria in aerosols	NA	NA	NA
Vaccine name	Coxevac	Coxevac	Chalamyvax-FQ	Coxevac
Manufacturer	CEVA, France	CEVA, France	Merial, France	CEVA, France
Vaccine Phase I or Phase II	Phase I	Phase I	Phase II	Phase I
Doses (#)	2	2	2	2
Placebo control	No	No	No	NA
Statistical methods	Chi square; Student's t	Kruskal-Wallis	Kruskall-Wallis	regression analysis, survival analysis
Software	SAS 9.1	StatXact	StatXact	R software

	1	2a*	2b*	3
FACTOR	**TRIAL RESULTS**			
Abortion (%)	Decreased	Decreased	No difference	NA
Vaginal shedders (%)	Marginally decreased	Decreased	No difference	NA
Bacterial load in vaginal secretions	Decreased	NA	NA	Decreased
Bacterial load in uterine secretions	NA	NA	NA	Decreased
Seroconversion in yearlings	Increased	NA	NA	NA
Bacterial load in aerosols, outdoors	Decreased	NA	NA	NA
Bacterial load in aerosols, indoors	No change	NA	NA	NA
Seroconversion post-vaccination	NA	Increased	Increased	NA
Fecal shedding	NA	Decreased	No difference	NA
Milk shedding	NA	Decreased	No difference	Decreased
Goats with contaminated placenta (%)	NA	Decreased	No difference	NA
Infected goat kids	NA	Decreased	No difference	NA
Adverse reactions	NA	None observed	None observed	NA
Efficacy, uterine specimen	NA	NA	NA	90 to 98%
Efficacy, vaginal specimen	NA	NA	NA	28 to 57%
Efficacy, milk specimen	NA	NA	NA	72%

*Vaccinates compared to the controls (unvaccinated+challenged). NA = Data not available.
Source: Astobiza et al., 2011; Arricau-Bouvery et al., 2005; Hogerwerf et al., 2011.

14.5 Summary of Vaccination to Combat Coxiellosis in Small Ruminants

Netherlands and European Union

- Coxiellosis vaccine was prohibited in the Netherlands prior to the epidemic and through 2008.
- The coxiellosis epidemic in the Netherlands led to licensing of vaccine and eventually to mandatory vaccination in 2009 to control the epidemic.
- Coxiellosis vaccine has been granted full approval in the European Union.
- Clinical trials provide evidence that phase I vaccine has superior efficacy to phase II vaccine.
- Preventive vaccination is far superior to outbreak vaccination.
- Vaccination of nulliparous animals is more efficacious than vaccination of multiparous animals.
- Vaccination of low-prevalence herds is more efficacious that vaccination of high-prevalence herds.

- Vaccination protects against abortion, colonization, and contamination of a variety of caprine tissues.
- Vaccination decreases contamination of the environment, which may decrease transmission of Q fever to animals and humans.

United States

- Coxiellosis vaccines are not licensed for use in the United States.

14.6 Conclusion in Regards to Vaccines

The likelihood is medium that the factor “Accessibility to Coxiellosis Vaccines” would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population. An epidemic due to “Accessibility to Coxiellosis Vaccines” is nearly as unlikely to occur as it is likely to occur. The reason for a medium risk estimate due to this factor are inability of the industry and animal health professionals to incorporate vaccination into a multi-faceted, on-farm disease control strategy because coxiellosis vaccines are not licensed for use in the United States.

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15. Risk Estimation

Risk estimation consists of integrating the results to produce summary measures of risks associated with hypothetical hazards identified at the outset of the assessment (Murray et al., 2004). No single method of risk analysis has proven to be applicable in all situations, and different methods may be appropriate in different circumstances. A qualitative risk assessment is an assessment in which the outputs on the likelihood of the outcome or the magnitude of the consequences are expressed in qualitative terms such as negligible, low, medium, or high. A quantitative risk assessment is an assessment in which the outputs are expressed numerically.

A qualitative risk assessment is essentially a reasoned and logical discussion of the relevant factors and epidemiology of a hazard in which the likelihood of its release and exposure and the magnitude of its consequences are expressed using non-numerical terms such as high, medium, low or negligible (Murray et al., 2004). The qualitative approach is suitable for many risk analyses and is currently the most common type of assessment undertaken to support decisionmaking in import risk analysis. Although a quantitative risk analysis involves numbers, it is not necessarily more objective, neither are the results necessarily more precise than a qualitative risk analysis.

We selected the qualitative method to summarize our findings of this assessment. Recall that our working hypothesis was "The likelihood is non-negligible that one or more of the evaluated factors would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States." The risk estimates are presented below, with this working hypothesis in mind.

15.1 Risk Estimates

Risk estimate in regards to the factor "Goat Industry Structure"

- The likelihood is **low** that the factor "Goat Industry Structure" would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.

  (However, there are several locations in the United States where the likelihood is medium that "Goat Industry Structure," (i.e., goat density, specifically) would initiate and/or propagate an epidemic of coxiellosis.

Risk estimate in regards to the factor "Laboratory Capacity to Diagnose Coxiellosis"

- The likelihood is **low** that the factor "Laboratory Capacity to Diagnose Coxiellosis" would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.

Risk estimate in regards to the factor "Reporting and Monitoring Coxiellosis"

- The likelihood is **low** that the factor "Reporting and Monitoring Coxiellosis" would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.

  (For those States in which coxiellosis in ruminants appears un-reportable to any public agency, the likelihood in those States is medium. In the absence of reporting, there will be no response, increasing the likelihood of further transmission.)

Risk estimate in regards to the factor "Responses to Coxiellosis Diagnosis"

- The likelihood is **medium** that the factor "Responses to Coxiellosis Diagnosis" would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.

Risk estimate in regards to the factor "Goat Health and General Management"

- The likelihood is **medium** that the factor "Goat Health and General Management" would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.

Risk estimate in regards to the factor "Accessibility to Caprine Health Professionals"

- The likelihood is **medium** that the factor "Accessibility to Caprine Health Professionals" would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.

Risk estimate in regards to the factor "Accessibility to Coxiellosis Vaccines"

- The likelihood is **medium** that the factor "Accessibility to Coxiellosis Vaccine" would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.

Risk estimate in regards to "All Seven Factors"

- The likelihood is **medium to low** that all seven factors would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States, when considered together (Table 32).

Table 32. Factors evaluated and the likelihood that each factor would initiate and/or propagate an epidemic of coxiellosis in the domesticated goat population in the United States.

	Likelihood			
Factors Evaluated†	**Negligible**	**Low**	**Medium**	**High**
Goat Industry Structure*				
Laboratory Capacity to Diagnose Coxiellosis				
Reporting and Monitoring Coxiellosis§				
Responses to Coxiellosis Diagnosis				
Goat Health and General Management				
Accessibility to Caprine Health Professional				
Accessibility to Coxiellosis Vaccines				
All Seven Factors				

† Sequence of factors in this table is different than the sequence of factors throughout the text.
* Likelihood is higher for some locations where goat density is higher.
§ Likelihood is higher for some locations where coxiellosis is not reportable.

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