THESIS

A STUDY OF SMALL-SCALE FARMS IN THE UNITED STATES: CHARACTERISTICS AND PRACTICES RELEVANT TO ANIMAL DISEASE PREVENTION AND CONTROL

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ABSTRACT

A STUDY OF SMALL-SCALE FARMS IN THE UNITED STATES: CHARACTERISTICS AND PRACTICES RELEVANT TO ANIMAL DISEASE PREVENTION AND CONTROL

Although farm sizes have been increasing over time in the United States (US), small-scale operations still contribute substantially to US animal agricultural production, and have an important role in local food production systems. Therefore, small-scale operations should not be overlooked when planning and preparing for animal disease outbreaks and evaluating disease prevention and control strategies. This study was conducted to evaluate three factors that are relevant to disease prevention and control on US small-scale operations: availability and use of veterinarians, use of biosecurity practices, and movement practices. Knowledge of these topics is critical for understanding disease spread dynamics, preparing for potential foreign animal disease (FAD) incursions, and educating producers to reduce the spread of endemic and zoonotic diseases.

Data were collected using a cross-sectional mixed-mode (mail and phone) producer survey conducted by the US Department of Agriculture's (USDA) National Animal Health Monitoring System in 2011. A nationally representative stratified systematic sample of 16,000 animal operations with annual sales between $10,000 and $499,999 was selected from a USDA National Agricultural Statistics Service list frame. A total of 8,186 small-scale operations (response 'rate' = 51.2% [including operations in all 50 US states]) completed the study questionnaire. Respondents raised a variety of farm animals, including beef cattle, dairy cattle, horses, sheep, goats, swine, poultry, and other farm animals for sale or home use. The majority of respondents (80.1%) primarily raised beef cattle. Population estimates were generated to

make inferences to the population of all small-scale US farm animal operations. A subset of operations—those that primarily produced food animals (equine operations were excluded) — was also analyzed to make inference to small-scale food animal operations.

An estimated 82.1% of small-scale food animal operations had a veterinarian available ≤ 29 miles from the operation; 1.4% did not have a veterinarian available within 100 miles of the operation. This equated to an estimated 4,799 (95% confidence interval, 3,833 to 5,765) small-scale food animal operations in the US for which a veterinarian was ≥ 100 miles away or not available, and these operations were located in 40 US states. Overall, an estimated 61.7% of operations used a veterinarian during the 12 months prior to the survey. Operations located 30 to 99 miles from the nearest veterinarian were less likely to use veterinarians (OR = 0.81, P = 0.013), compared with operations that had a veterinarian available ≤ 29 miles away. Dairy operations were more likely to use a veterinarian (88.5%) than beef cattle operations (60.2%), while poultry and swine operations were less likely to use a veterinarian (39.3% and 59.4%, respectively). Producers with college degrees were significantly ($P < 0.001$) more likely to use a veterinarian (67.5%) compared to those who did not complete high school (52.9%).

This study also collected information on use of biosecurity practices, which are important for preventing the spread of infectious diseases on farms and ranches. An estimated 43.3% of small-scale operations added new animals or had animals leave the operation and return in the 12 months prior to the survey, and only 40.3% of these operations always quarantined the new or returning animals. Producers who always quarantined new or returning animals had higher annual farms sales, and use of quarantine varied by animal species and geographic region. Dairy operations were less likely to always quarantine new or returning animals (22.4%) than beef cattle operations (41.5%; $P < 0.001$). The most common reason for not quarantining animals (cited by 65.3% of quarantine non-users) was that the producer trusted the source of the animals, or the place from which the animals were returning. Very few non-users of quarantine reported they lacked belief in the benefit or effectiveness of quarantine (5.4%). An estimated 73.9% of producers believed additional training on biosecurity would be somewhat (44.7%) or very (29.2%) useful to themselves and their farm business; preferred channels for receiving training or additional information were the local extension office (56.1%) and written publications (49.4%).

The geographic distribution of small-scale operations and animals on these operations was consistent with the distribution of commodity production across all operation sizes in the US for most animal species. However, small-scale dairy operations were primarily located in the Northern Crescent region, even though the majority of US milk is produced in California. Operations were distributed across the entire rural-urban continuum, from highly rural to highly urban counties. Distances were described for movement of animals or products for sale, movement of animals to slaughter facilities, and movement of animal feed. Most food-animal operations reported the farthest distance to these destinations was < 40 miles, but 9 operations reported very long distances (≥ 2,000 miles). Across all small-scale food animal operations, 75% of operations reported the farthest distance animals or products were transported for sale was ≤ 60 miles, and 95% of operations reported ≤ 150 miles. For distance to slaughter facilities, a key element of the livestock supply chain, 75% of operations reported the farthest distance was ≤ 40 miles, and 95% of operations reported ≤ 90 miles.

This study demonstrated that most small-scale food animal operations had adequate access to veterinarians during 2011, but there seemed to be localized shortages of veterinarians in many states. Although biosecurity practices are critical for preventing the spread of endemic and foreign animal diseases, less than half of small-scale operations that had new or returning animals quarantined them to reduce disease spread. This study identified factors associated with use of quarantine and reasons for not using quarantine, which can be used to target education and understand high risk demographics for disease spread. Finally, this study described the locations of small-scale food animal operations across geographic regions and the rural-urban continuum, and described movement distances that are useful for understanding disease dynamics and informing disease spread models.

ACKNOWLEDGMENTS

I dedicate my thesis to Steve and Loki, you two give me inspiration and strength. I'd like to thank Francisco Olea-Popelka, Lindsey Garber, Dawn Thilmany, David Van Metre, Jason Lombard, Chris Kopral and Bruce Wagner for your encouragement and mentoring.

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CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

Although there has been a shift toward larger farm sizes in the United States (US) contributing the greatest share of farmgate sales, 95.1% of farms in the US are small-scale operations with gross annual sales <$500,000. Operations with sales <$10,000 are considered non-commercial farms; and although they constitute 54.2% of US farms, they contribute only 1.2% of US agricultural production (Hoppe, 2010). However, small-scale operations with annual sales between $10,000 and $499,999 account for 36.6% of the total value of US agricultural production and comprise 40.9% of all US farms (Hoppe, 2010). In addition, small-scale operations located near urban centers produce most of the locally-marketed food in the US. Local food systems are a growing phenomenon and are gaining support from Federal, State and local governments (Martinez, 2010). Because of their sizeable share of agricultural production and their role in local food production, small-scale commercial operations should not be overlooked when planning and preparing for animal disease outbreaks.

Biosecurity practices, use of veterinarians and movement practices on agricultural operations are all of critical importance to animal health and can affect the spread of endemic and foreign animal diseases. An evaluation of these practices is needed to understand disease spread dynamics, to provide targeted education to improve animal health and welfare on US farms and ranches, and to prepare for a potential foreign animal disease (FAD) incursion in the US. Preparation for FAD incursions is important because FAD outbreaks can have an enormous impact on individual producers and the US economy, and can rapidly exhaust available resources. For example, the 2001 foot and mouth disease (FMD) outbreak in the United Kingdom (UK) cost over 3 billion pounds (approximately 4.5 billion USD), and more than 6 million head of livestock were culled (NAO, 2002). The 2002-2003 US outbreak of exotic Newcastle disease required the euthanasia of 3.2 million birds at a cost of $160 million, and caused an estimated $121 million in trade losses (Hietala et al., 2004). Endemic diseases, such as bovine viral diarrhea and Johne's disease, also cause economic losses in animal production (Hutchinson, 1996; Stott et al., 2003).

This chapter contains a summary of previous research on three topics that are critical to disease prevention and control on small-scale US agricultural operations: veterinarian availability and usage, biosecurity practices, and movement practices.

1.2 AVAILABILITY AND USE OF FOOD ANIMAL VETERINARIANS

Food animal veterinarians, as key resources to address animal health, play an important role in agricultural production and the broader meat and dairy marketing system because animal health impacts productivity, animal welfare, and food safety. Private veterinarians would also play a critical role in the event of an FAD incursion into the US, since they are likely to be the first resource contacted if a producer observes serious illness in his or her herd (USDA, 2008b, 2009a). Two important factors are necessary in order for producers and veterinarians to work together to ensure the health of the national livestock herd. First, a veterinarian who is familiar with the relevant species must be available within a reasonable distance. Second, the producer must decide to utilize the services of a veterinarian.

Factors affecting use of veterinarians—Volk et al. (2011a, b) provided first insights into client motivations for utilizing veterinary services in the US with regard to small animals. The authors identified several client-related factors responsible for a decline in companion animal patient visits, such as the cost of veterinary services and a lack of understanding of the importance of preventive or routine veterinary care. The researchers also identified three environmental factors: use of the internet rather than a veterinarian for help with pet health issues, the economic recession, and an increased variety in types of veterinary services being offered along with an increased variety in the types of facilities providing veterinary care (Volk et al., 2011a). However, in these studies data were collected through qualitative interviews and focus groups, as well as a quantitative on-line survey using a research panel for sampling. These methods can be subject to bias if panel members and focus group members differ from the general population.

Literature on factors affecting use of veterinarians by food animal producers in the US is not available to the author's knowledge; however, research has been done in other countries. Giger et al. (1994) conducted a survey of dairy producers in Canada, to assess producer access to veterinary services and explore producers' use of these services. Participating operations had between 18 and 150 milking cows; these would be considered small-scale operations in the US. The authors found 34% (73/213) of operations participated in a veterinary herd health program, which was based on the producer's perception of being on a herd health program. Farms that were on a herd health program had larger herd sizes than farms that were not on a program. The authors concluded herd health programs had not been implemented on the majority of operations, and suggested further research to investigate socio-demographic factors associated with the decision to use veterinary services, and to investigate producer's reasons for not adopting herd health programs (Giger et al., 1994).

Lamichhane and Shrestha (2012) researched factors associated with selection of veterinary health care providers by livestock owners in Nepal, and Turkson (2004, 2009) investigated delivery of livestock veterinary services in Ghana. Both countries have transitioned from government-provided veterinary services to privately-provided services. Distance to the service provider and producer gender, age and education level all were associated with the choice of veterinary service care provider in Nepal, while income level and herd size were not (Lamichhane and Shrestha, 2012). Similarly, distance to a veterinarian was negatively associated with veterinarian usage in Nepal (Turkson, 2009). Due to cultural and economic differences between Nepal, Ghana and the US, it is unlikely that these results can be extrapolated to US producers. Understanding factors affecting veterinary care usage by US food animal producers, and their reasons for not using veterinarians, could be useful to veterinary practitioners who own or work in private practices that serve this population, and to other agricultural stakeholders.

Veterinarian shortage or surplus?—In the past 10 years, a possible shortage of food supply veterinarians has been widely discussed in the veterinary medical field, with contradictory conclusions about the presence or absence of a shortage. Food supply veterinary medicine encompasses veterinarians working in food animal private practice, as well as veterinarians in positions relating to public health and food safety (AVMA, 2012). It has been suggested that veterinary shortages could impede the United States' ability to rapidly detect a FAD incursion and could also affect the ability to ensure the safety of the food supply (NRC, 2012).

Some authors reported shortages of food supply veterinarians in the US (DeHaven and Goldberg, 2006; Prince et al., 2006; Sterner, 2006; Narver, 2007; USGAO, 2009). Other countries, including Australia, New Zealand, the UK, Japan and the Netherlands had similar concerns (ADAFF, 2003; Jackson et al., 2004; Lowe, 2006; Kimura et al., 2008; Haarhuis et al., 2009). McLaughlin et al. (1976) used a supply projection model to compare supply and demand for veterinarians in the US from 1976 to 2020. The initial model assumed no increases in enrollments of veterinary students, and the researchers also considered the addition of 3 additional veterinary schools, each enrolling 80 students per year. The authors concluded shortages would exist during the entire time period, even with the addition of 3 additional veterinary colleges. Prince et al. (2006) used the Delphi method to forecast potential veterinary shortages between 2004 and 2016 using expert opinion, and predicted shortages of food supply veterinarians, especially in mixed animal practice and in several areas of the US federal government. However, these results were dependent upon the opinions of the experts who were consulted.

DeHaven and Goldberg (2006) cited recent public health events in which veterinarians played an important role, demonstrating the importance of veterinarians in public health and food safety. The authors expressed concerns about current and projected shortages of veterinarians for government employment, and discussed development of the National Animal Health Emergency Response Corps (NAHERC). NAHERC was developed by the US Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) in 2001, to provide additional veterinary staff in the event of an animal health emergency that requires more manpower than available through APHIS employees. In 2005, it was estimated the US federal government would need an additional 6,000 veterinarians, in excess of current state and federal veterinarians, in the event of a very contagious disease outbreak (Masters, 2005). The US Government Accountability Office (USGAO) similarly reported in 2009 that a number of government agencies had identified current or future concerns about the supply of veterinarians for government service in public and animal health. Furthermore, the USGAO found an insufficient veterinarian workforce had been a problem during the federal response to four recent zoonotic disease outbreaks (USGAO, 2009).

Other authors have concluded a veterinary shortage does not exist, or have projected a surplus of food animal veterinarians. Brown and Silverman (1999) used econometric models to project supply and demand dynamics for veterinary medicine between 1999 and 2015, and concluded the demand for companion animal veterinarians would increase, but the demand for food supply veterinarians would not increase. Furthermore, the authors' economic models predicted a surplus of large animal veterinarians. In 2011, the American Association of Bovine Practitioners Ad Hoc Committee on Rural Veterinary Practice (AABP, 2011) similarly concluded there was not a shortage of veterinarians for rural food supply veterinary private practice. Likewise, after an in-depth examination of veterinary workforce needs, a National Research Council committee found "little evidence of widespread workforce shortages in veterinary medicine (NRC, 2012)." The committee identified issues with "unmet needs" for food animal veterinary services, particularly for small-scale operations in rural areas, but distinguished this problem as different from a workforce shortage (NRC, 2012). Namely, rural communities may be unable to financially support a veterinarian, due to changes in animal agriculture and changes in the rural communities themselves (NRC, 2012).

In 2010, the US began implementation of the Veterinary Medicine Loan Repayment Program (VMLRP) to address shortages of veterinarians in specific areas by assisting in repayment of student loans for veterinarians who practice in underserved areas. Wang et al. (2012) analyzed the performance of the VMLRP in identifying shortage areas, and found the 2010 program performed well in identifying counties with a relative imbalance between number of livestock and number of veterinarians. However, controversy on the subject of food supply veterinarian shortages persists, and it is unclear whether the shortages are real or perceived in the various segments of food supply veterinary medicine.

Factors affecting the supply of veterinarians—In response to concerns about a shortage of food supply veterinarians, several researchers investigated factors affecting the success of food animal private practices, and factors associated with veterinarians' decision to enter or leave rural practice. When interpreting the literature, the terms food supply veterinary medicine, food animal private practice, rural veterinary practice should not be used interchangeably, since reasons for veterinarian shortages may differ between the different segments (Villarroel et al., 2010a).

Lenarduzzi et al. (2009) surveyed veterinary students and recent graduates from the Texas A&M College of Veterinary Medicine, to investigate factors associated with choosing a career in food animal private practice. An interest in pursuing food animal practice was associated with previous work experience in a large animal practice, agricultural experience, and experience working on a farm or ranch (Lenarduzzi et al., 2009). Similarly, in another on-line survey of US veterinarians and veterinary students, Villarroel et al. (2010a) found that having relatives with a farm background, being mentored by a veterinarian in rural veterinary practice (RVP) and exposure to RVP while in veterinary school were the factors rated highly important in the development of an interest in RVP by the highest percentage of respondents. Villarroel et al. (2010a) also reported men, people from the baby boomers generation, people with a rural background, and people with previous livestock experience were more likely to have an interest in RVP as compared to women, people from Generation X or Y, people with an urban background, and people with no previous livestock experience, respectively. Similarly, Schmitz et al. (2007) noted previous experience on a farm or ranch, being male, and expressing a primary interest in food animal medicine upon entering veterinary school were all associated with selecting a career in food animal practice in Nebraska. Similar findings were seen in Canada; veterinary students who selected food animal private practice were more likely to have previous livestock experience and/or a rural background (Jelinski et al., 2008; Jelinski et al., 2009).

Villarroel et al. (2010b) also reported factors associated with the decision to leave RVP. Five factors were rated highly important in the decision to leave RVP by the highest percentage of veterinarians: emergency duty, time off, salary, practice atmosphere, and family concerns. The next type of employment after leaving RVP was urban practice, academia and retirement for 33.7%, 29.3% and 2.8% of respondents who left RVP, respectively (Villarroel et al., 2010b).

Brusk et al. (2010) explored factors associated with the success of food animal private practices using an on-line survey of veterinarians. The growth rate of these practices differed by species focus, frequency at which prices were adjusted, use of a marketing plan, and utilization of a client newsletter.

For these on-line surveys, response rates were low (Lenarduzzi et al., 2009; Brusk et al., 2010) or not measurable, but presumed to be low (Villarroel et al., 2010a, b). Soliciting survey responses by email or through advertisements typically results in a low response rate, and the possibility of self-selection bias because of study design. Nonetheless, these studies provided insight into veterinarians' career path choices, which was useful for understanding challenges for food supply veterinary medicine, especially if a shortage of veterinarians exists.

Measuring the availability of food animal veterinarians—Few researchers have collected data to define or measure the adequacy of producer access to food animal veterinarians. Several reports compared inventory of livestock from the USDA National Agricultural Statistics Service (NASS) Census of Agriculture to the number of food animal practitioners using the

American Veterinary Medical Association's membership list (AVMA, 2012; Wang et al., 2012). However, it is difficult to define the number of food animal veterinarians needed to provide care for a given number of food animals. Furthermore, food animal production systems and types of species raised are diverse. For instance, poultry operations have different veterinary needs than cow-calf operations.

Jensen et al. (2009) explored producer-perception of the supply of veterinarians by surveying Tennessee livestock producers, and found 81.4% of producers surveyed in 2006 had not perceived a problem in accessing veterinary services in the previous 12 months. Several factors were associated with experiencing a problem accessing veterinary services: higher producer education level, younger producer age, higher farm income, and having dairy cattle. Interestingly, the study found that the number of large animal veterinarians per 10,000 head of cattle in the producer's county was not associated with experiencing a problem in accessing veterinary services. Membership lists for the American Veterinary Medical Association were used to determine the number of large animal veterinarians in a county.

Tennessee producers who reported a problem in accessing veterinary services in the previous 12 months were asked to further specify the type of problem (Jensen et al., 2009). The majority (51.7%) experienced a delay in obtaining a farm visit from the veterinarian; 38.6% reported the expense of the veterinary care was too high relative to the animal's value, and 18.8% reported they couldn't afford the cost of the services. Only 18.8% of respondents who had a problem accessing a veterinarian were unable to obtain services because of lack of veterinarian availability – these producers believed no veterinarian was available who possessed the specialization needed to treat their animal's illness. A limitation of this study was a low response rate (21.9%), which could result in non-response bias. Although the authors described veterinary access for Tennessee producers, literature describing producers' access to food animal veterinarians at a national level is not available to the author's knowledge.

1.3 BIOSECURITY PRACTICES OF SMALL-SCALE OPERATIONS

Use of biosecurity practices—Biosecurity practices on farming and ranching operations are intended to prevent the introduction of disease and prevent spread of endemic diseases on the farm (Dargatz et al., 2002). Biosecurity also has an important role in preventing the spread of an FAD in the event of an outbreak. According to the National Association of State Departments of Agriculture (NASDA, 2001):

> "Biosecurity itself is more than a buzzword; it is the vital work of strategy, efforts, and planning to protect human, animal, and environmental health against biological threats. The primary goal of biosecurity is to protect against the risk posed by disease and organisms; the primary tools of biosecurity are exclusion, eradication, and control, supported by expert system management, practical protocols, and the rapid and efficient securing and sharing of vital information. Biosecurity is therefore the sum of risk management practices in defense against biological threats."

Examples of on-farm biosecurity measures include: keeping a closed herd in which animals from outside sources are not introduced; restrictions on sources for new animals; quarantine and testing of new animals; reducing contact with outside animals, such as rodents or animals from other operations; requiring disease prevention precautions for human and vehicle traffic; not sharing farm equipment with other operations; and vaccination and herd health programs (USDA, 2009b).

Previous studies described the use of biosecurity practices on US cow-calf, dairy, swine, sheep, goat and poultry operations through individual commodity-focused studies (USDA, 2001, 2007, 2008b, 2009a, 2011b, 2012). However, these studies did not focus specifically on small-scale operations, and did not compare operations that raise different animal species. In addition, none of these studies closely explored producers' reasons for non-adoption of biosecurity practices. For the USDA studies, a nationally representative sample of livestock producers was surveyed. These studies may be subject to reporting bias, since producers may over-report use of biosecurity practices, especially if they believe they should be using them or feel guilty about not using them. For instance, Nespeca et al. (1997) found a gap between biosecurity behavior as reported on a questionnaire and actual biosecurity behavior on poultry farms; 28-37% of questionnaire responses differed from actual biosecurity behavior on farms. Nonetheless, most research on biosecurity relies on producer responses to a questionnaire, since observing behavior is more challenging and costly.

Although biosecurity is important in preventing disease introduction (Dargatz et al., 2002), a low percentage of US livestock operations have adopted biosecurity practices. For instance, about 40% of US dairy operations added new cattle in 2006, but less than half of them quarantined new animals upon arrival; and the percentage of operations that quarantined did not change significantly between 1996 and 2007 (USDA, 2008a). For cow-calf operations, 34.5% of operations added new cattle during 2007, and only one-third of these quarantined the new cattle (USDA, 2009a). On goat operations, 21.5% of operations added new goats during the 12 months prior to a 2009 survey, and 39.5% of these never quarantined new goats (USDA, 2011a).

Smaller operations were less likely to use certain biosecurity practices, such as quarantine and testing of new animals when compared to larger operations (Hoe and Ruegg, 2006; USDA, 2008b, 2009a). However, smaller operations were also less likely to engage in activities that are considered biosecurity risks, such as acquisition of new animals or exposure of resident animals to outside animals (USDA, 2009a, 2011a; Traub-Dargatz et al., 2012). For instance, in a 2009 survey of goat producers, small operations with fewer than 10 goats were less likely to add new goats compared to larger operations with 100 or more goats (13.3% and 31.0% had added new goats in the previous 12 months, respectively; USDA, 2011a). For cow-calf operations, large operations with 200 or more beef cows were more likely (12.0%) to have cattle leave the operation to attend a fair, show, rodeo or other event, compared with small operations with 1-49 beef cows (5.7%; USDA, 2009a).

Factors affecting the adoption of biosecurity practices—Several researchers investigated factors affecting a producer's decisions about the implementation of biosecurity practices. Both qualitative (Gunn et al., 2008; Heffernan et al., 2008; Palmer et al., 2009; Ellis-Iversen et al., 2010; Delgado et al., 2012) and quantitative (Delabbio et al., 2005; Casal et al., 2007; Benjamin et al., 2010; Fraser et al., 2010; Kristensen and Jakobsen, 2011; Valeeva et al., 2011; Racicot et al., 2012) research methods were utilized, and some researchers incorporated social cognitive models. These models are commonly used in sociology research and have recently been used in veterinary epidemiology to investigate producer behavior for disease reporting and control (Elbers et al., 2010; Delgado et al., 2012), use of biosecurity practices (Gunn et al., 2008; Heffernan et al., 2008; Ellis-Iversen et al., 2010), use of antimicrobials (McIntosh, 2009) and estrus detection (Garforth, 2006). Social cognitive models are theoretical frameworks, diagramed as flow charts, that identify cognitive factors affecting behavioral decisions, and the pathways through which the factors act in influencing behavior. Examples are the health belief model (Becker, 1974), the theory of reasoned action (Ajzen and Fishbein, 1980), and the Theory of Planned Behavior (Ajzen, 1991). It has been argued that a theoretic framework should be used when trying to explain human behavior (Aneshensel, 2002).

Producer education and training may increase implementation of biosecurity measures (Ellis-Iversen et al., 2010; Young et al., 2010a; Valeeva et al., 2011; Racicot et al., 2012). In a quantitative study (Racicot et al., 2012), video recordings were used to track biosecurity behavior, and the authors analyzed the relationship of personality traits and demographics with footwear biosecurity compliance when entering poultry houses in Canada. Training in animal production was associated with better footwear biosecurity compliance, and employees with less than 5 years of experience in the poultry industry were less likely to comply. Furthermore, employees and visitors who had not completed high school were less likely to comply than those who had completed high school or college. Similarly, lack of knowledge played a role in the failure to implement zoonotic disease control programs for some producers on cattle farms in the UK (Ellis-Iversen et al., 2010). Valeeva et al. (2011) studied factors affecting adoption of biosecurity practices by Dutch pig producers, and concluded educational campaigns emphasizing the efficacy of biosecurity practices could increase adoption of practices. Producers who were risk averse in other areas of their lives were more likely to utilize biosecurity, and therefore the authors proposed combining educational campaigns for other risk-prevention behaviors with biosecurity promotion campaigns. In Canada, dairy producers were more likely to utilize good production practices if they had attended a food-safety course (Young et al., 2010a). In several studies, private veterinarians were cited as important resources for educating producers about good production practices and biosecurity, and prompting them to implement these practices (Ellis-Iversen et al., 2010; Marvin et al., 2010; Young et al., 2010b).

In other studies, knowledge about biosecurity was not reported to affect adoption of biosecurity practices in the US and Canada (Delabbio et al., 2005), and educational documents were described as ineffective for increasing compliance in Australia (Palmer et al., 2009). In the UK and Australia, educational documents were especially ineffective when they came from government sources (Heffernan et al., 2008; Palmer et al., 2009).

Although national data were available on biosecurity practices used by US producers, previous studies did not focus on small-scale operations. Furthermore, most studies on factors affecting use of biosecurity practices were conducted in countries other than the US.

1.4 SPATIAL DISTRIBUTION AND MOVEMENT PRACTICES OF SMALL-SCALE OPERATIONS

Spatial distribution of small-scale operations—NASS publishes the geographic distribution of operations and animals by commodity for all operation sizes (USDA-NASS, 2007; e.g., Figures 1.1-1.4). However, regional distribution may differ between large-scale and

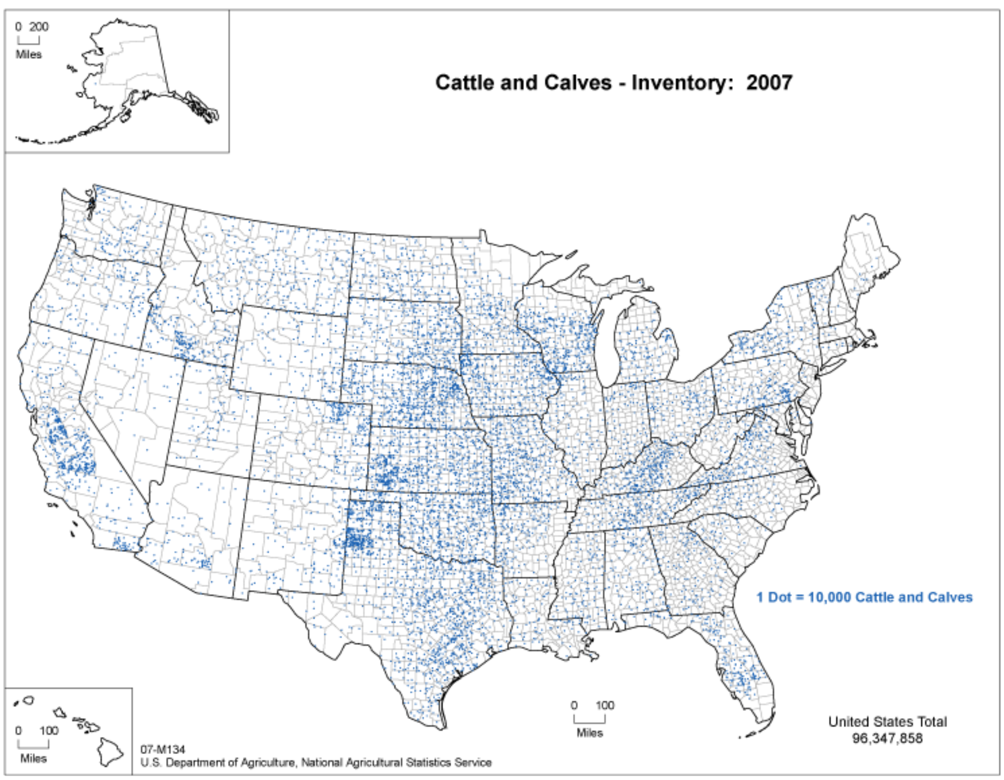

Figure 1.1—Cattle and Calves Inventory, 2007 Census Agriculture Atlas Maps, USDA National Agricultural Statistics Service
(http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Livestock_and_Animals/)

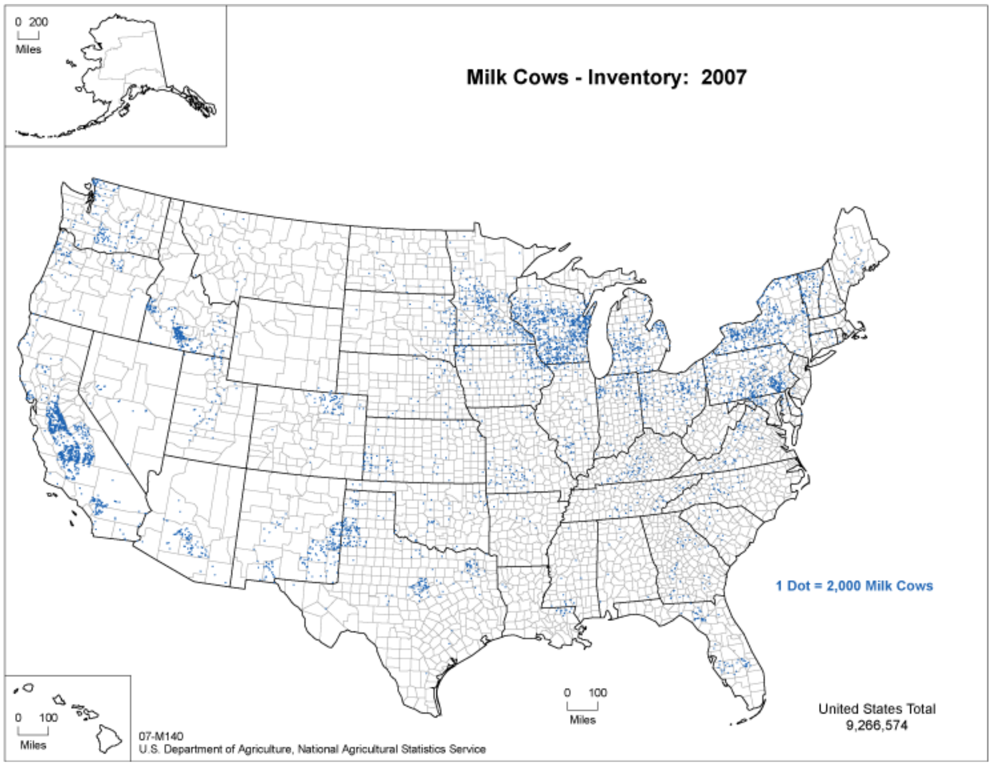

Figure 1.2—Milk Cows Inventory, 2007 Census Agriculture Atlas Maps, USDA National Agricultural Statistics Service

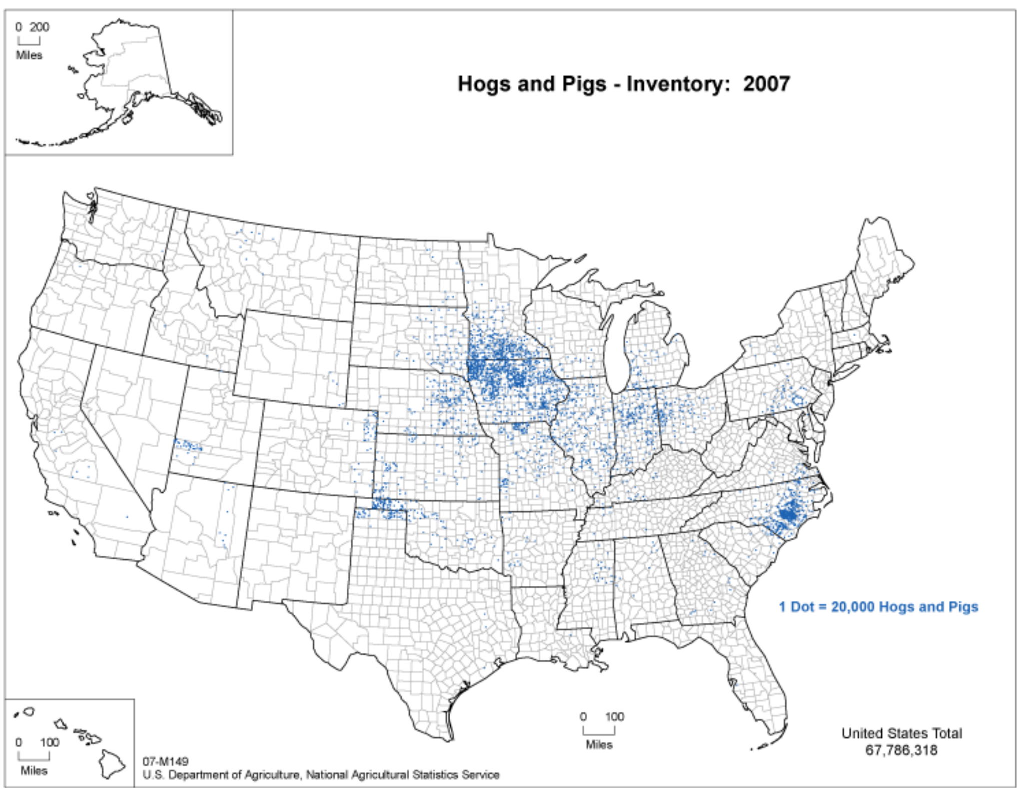

Figure 1.3—Hogs and Pigs Inventory, 2007 Census Agriculture Atlas Maps, USDA National Agricultural Statistics Service

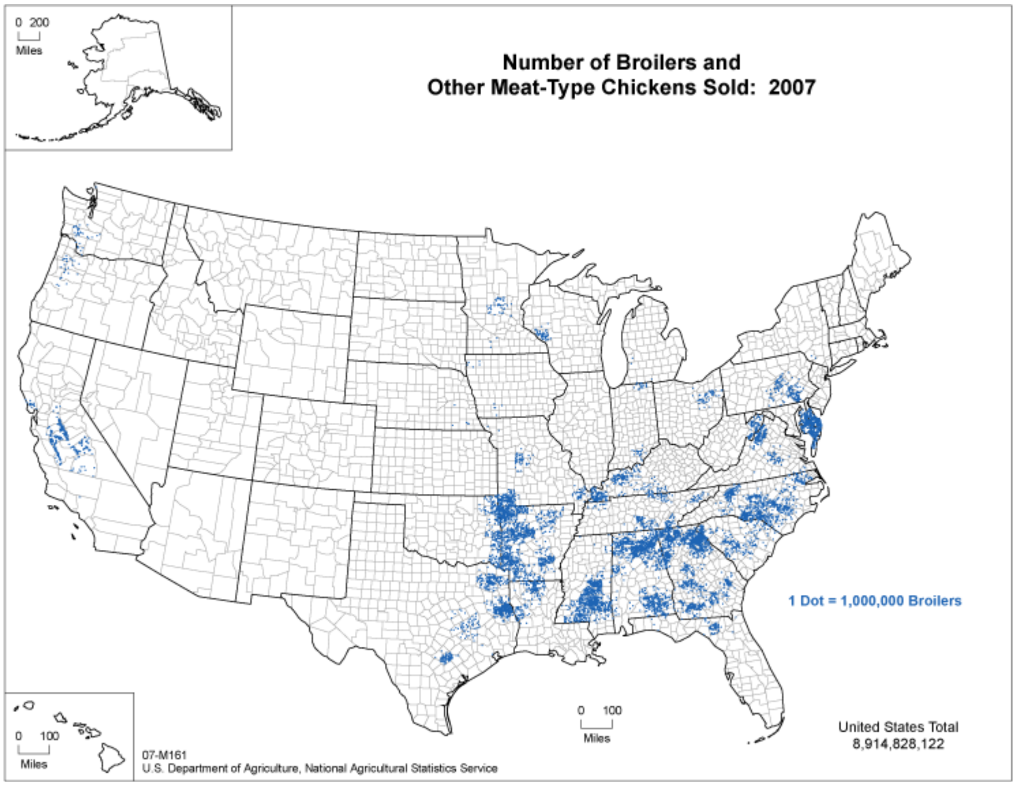

Figure 1.4—Number of Broilers and Other Meat-Type Chickens Sold, 2007 Census Agriculture Atlas Maps, USDA National Agricultural Statistics Service

small-scale operations. For example, the majority of US milk in 2006 was produced in California by large-scale dairy operations; while most small-scale dairy operations were located in the Northeastern US (MacDonald et al., 2007). Understanding the geographic distribution of small-scale operations is important in planning for animal disease outbreaks and selecting areas to focus educational campaigns targeted at these producers.

Urban proximity is another spatial factor that is important to disease spread on small-scale food-animal operations. Rural-urban continuum (RUC) codes[1] (Table 4.1, Chapter 4) describe the degree of urban influence at the county level. Counties with RUC code 1 contain portions of a metropolitan area that collectively has 1 million or more people. However, these

[1] For more information see: http://www.ers.usda.gov/data-products/rural-urban-continuum-codes/documentation.aspx

counties may also have areas that are quite rural, particularly in the Western US where county sizes are large. RUC codes are also based on proximity to a neighboring county that contains a metro area. In 2000, 82.6% of the human population in the US lived in metro counties (RUC code=1, 2 or 3), while only 4.9% of the US human population lived in the most rural counties (RUC=7, 8 or 9; 2000 US Census). Despite perceptions to the contrary, Thomas and Howell (2003) demonstrated that livestock and poultry production are not restricted to highly rural areas. In fact, metropolitan fringe counties were the second-highest contributor to total livestock and poultry sales from 1978 to 1997 (Thomas and Howell, 2003). Nehring et al. (2006) suggested urban influence had both positive and negative implications for agricultural operations. Although urban proximity increased access to markets for selling products directly to consumers, it also increased the cost of agricultural production (Nehring et al., 2006). Urban proximity for livestock operations may also play a role in disease spread dynamics for foreign animal diseases, since commerce and trade are more concentrated in urban areas. For example, the metropolitan areas of New York City and Baltimore were considered high risk areas for introduction of Rift Valley Fever into the US because of their port locations for international trade, as well as climate and other factors (Konrad and Miller, 2012). Literature is not available, to the author's knowledge, describing locations of small-scale US food-animal operations relative to geographic region or the rural-urban continuum.

Movements of animals, products and feed— Movement practices refer to the movement of animals, animal products, equipment, vehicles and people to and from agricultural operations. Movements are an important biosecurity risk for operations, and can play a role in the spread of endemic and foreign animal diseases (e.g., Kao et al., 2007; Halvorson, 2009). Animal movement from one farm to another is called a direct contact between the two operations, while movement of people, equipment or vehicles is called an indirect contact. Direct contacts pose the highest risk of disease introduction (Dunowska et al., 2007), but indirect contacts have also been implicated in causing disease spread (McQuiston et al., 2005).

Data on frequency and distance of movements can assist in preparing for and responding to animal disease outbreaks, and inform disease spread models such as the North American Animal Disease Spread Model (NAADSM, 2013). Stochastic models such as NAADSM have become an important tool in epidemiologic and economic modeling of disease outbreaks (e.g., Schoenbaum and Disney, 2003; Karsten et al., 2005; Patyk et al., 2013). In the 2001 outbreak of FMD in the UK, sheep movements through livestock markets were implicated in causing the widespread dissemination of disease (NAO, 2002). Long travel distances are important because they can increase the risk of wide geographic spread of epidemic disease (Ferguson et al., 2001; Shields and Mathews, 2003). In the UK and several other countries, data are available on livestock movements because of national farm identification-and-registration mandates (Sanson, 2005; Baptista and Nunes, 2007; Lentz et al., 2009; Lindstrom et al., 2009; Aznar et al., 2011; Vernon, 2011). In the US, movement of livestock is not as well documented.

Certificates of veterinary inspection (CVIs), which are required for interstate movement of livestock, were used for several US studies on livestock movement (Forde et al., 1998; Shields and Mathews, 2003; Wayne, 2011; Lindstrom et al., 2013). Studies that use CVIs have several important limitations. First, they are unable to describe intrastate movement of livestock, because veterinary inspection is not required for these movements. However, intrastate movements are important for understanding disease transmission risks. Also, the usefulness of CVI data varies by state, due to differences in record keeping and compilation of data (Forde et al., 1998). Furthermore, animals moved for slaughter are not included in these analyses, only animals moved for feeding or breeding.

USDA-NASS publishes an annual report estimating the number of cattle and swine shipped into each US state. The estimates are based on NASS data on animal inventory and animal marketing, and data from other sources such as state branding programs. Although the reports demonstrate substantial interstate movement of livestock, no information is provided on the source of the animals or the distance travelled. Shields and Mathews (2003) compiled data from these NASS annual reports with data from state CVIs to further describe livestock movement, and found livestock were often shipped long distances. Furthermore, livestock that originated in one state were distributed to many other states for feeding or breeding. For example, cattle from North Carolina were shipped to at least 44 other states in 2000 and 2001, based on certificates of veterinary inspection. The authors concluded a disease outbreak could affect many regions of the US, because of the wide distribution of livestock movement (Shields and Mathews, 2003).

Lindstrom et al. (2013) utilized Bayesian methods to develop a network model for cattle movement in the US using CVI data. Although the network was extrapolated to include intrastate movements, the authors expressed concerns about the accuracy of the network for intrastate movement. Wayne (2011) also utilized CVIs to perform a network analysis of pig movements in Minnesota. The median distance for interstate movement of breeding and feeder swine into and out of Minnesota ranged from 205 to 465 km (Wayne, 2011). However, both of these studies had the same limitations as previous studies using CVIs, since intrastate movements are not captured on CVIs.

Other researchers have collected data on animal movements using producer surveys. In several studies, travel distances for animals were farther on large cattle operations than on smaller operations (Dominguez, 2007; Marshall et al., 2009; USDA, 2009a). Marshall et al. (2009) conducted a cross sectional survey of beef cattle operations to describe cattle movement in California during 2005-2006. This study included all livestock movements, including movements to slaughter and intrastate movements. Sale barns or auctions were the destination for about 40% of cattle shipments leaving California beef operations, and 22.5% of movements were to another place where the operation kept its cattle. Overall, 30.9% of operations kept cattle at more than one location during the course of a year. The median distance travelled by the most recent cattle shipment leaving the operation was 34 miles for smaller operations (<250 head) and 81 miles for larger operations (≥250 head); median distances for the most recent arriving shipment were 34 miles for small operations and 91 miles for large operations (Marshall et al., 2009).

The USDA also published animal movement data from producer surveys. In a 2007 study of cow-calf operations in 24 states, about half of animal shipments (56.7%) leaving cow-calf operations travelled 10 to 49 miles, while 17.7% traveled 100 or more miles (USDA, 2009a). Only 8.2% of shipments from smaller operations (50-99 beef cows) travelled 100 or more miles, compared with 31.3% of shipments from larger operations with 200 or more beef cows (USDA, 2009a).

Dominguez (2007) studied the frequency of contacts and distances traveled for animal movements on extensively managed livestock operations in Texas, using a survey of producers. For animals moving to other operations, the median distance travelled ranged from 25.8 km to 375.5 km depending on operation type and herd size. The maximum distance traveled for animals moving to other operations was higher for large cow-calf operations (≥100 head, 804.7 km) than for small cow-calf operations (<100 head, 152.9km). The median distance traveled to slaughter was also reported, but these values were based on data from only 3 farms (Dominguez, 2007). Study participants were selected from a list of producers who had attended county extension agent meetings, so the external validity for extrapolating results to all Texas producers was questionable.

Movement of animals from farms to slaughter facilities can also be a route for disease spread between farms, since trucks and equipment used to transport animals to slaughter may be reused for other purposes on other farms, allowing indirect dissemination of disease. Long-distance transport also has welfare, food safety and meat quality implications. In several studies, the effects of long-distance transport (100 miles or more) on welfare and meat properties were evaluated. Broiler chickens that travelled 102.5 miles (165 km) to slaughter had higher stress and lower meat quality than broilers transported 40.4 miles (65 km) or 71.5 miles (115km) (Yalcin and Guler, 2012). Longer transport distance reduced carcass yield and increased live weight losses and mortality in pigs in Spain (Gosalvez et al., 2006). Transport distances can also affect food safety; Dewell et al. (2008) reported a higher risk of *E. coli* 0157 on cattle hides when the cattle were transported more than 100 miles to slaughter.

In some parts of the US, access to slaughter facilities may be a challenge for small-scale operations that wish to directly market their meat products to consumers (Goodsell et al., 2010; Lewis and Peters, 2012). Nonetheless, few peer-reviewed publications are available on distance to slaughter facilities for US agricultural operations (Dominguez, 2007; Marshall et al., 2009). In Canada, pigs from small farms were transported longer distances to slaughter facilities than pigs from larger farms (Haley et al., 2008). Several local and regional US studies were conducted by university extension offices to describe producer access to slaughter facilities in the context of local meat production. In a Massachusetts survey of 112 livestock and poultry producers, the average distance to slaughter facilities was 52 miles one-way (CISA, 2008). Having a slaughter facility located closer to the farm was the most commonly cited attribute that producers desired in a new slaughter facility (CISA, 2008). Similarly, the highest percentage of New England livestock and poultry producers (n=117) reported a distance of 20-50 miles to slaughter facilities; however, the exact percentage of respondents who reported this distance was not included in the report (Bonelli et al., 2009). In Connecticut, Massachusetts and Rhode Island, 7, 9, and 9 percent of producers, respectively, reported travelling over 100 miles to slaughter facilities (Bonelli et al., 2009). In a study of 69 producers in the Northwestern US (Oregon, Washington and Idaho), 55% transported animals ≥ 90 miles one way to the processing plant, and 32% travelled over 150 miles one way (Durham, 2009). In Maryland, 50.0% of producers (n=18) reported a distance of ≥ 60 miles to the processing facility they used most often, and 11.1% reported a distance of ≥ 100 miles (Shepstone, 2006). However, these small studies used convenience samples of producers, so results may not have been representative of all farms in the study areas, but the large differences in findings may illustrate how different regions may face very different animal movement dynamics. Studies describing slaughter movement distances for small-scale operations at a national level are not available to the author's knowledge.

Movement of feed can also be a route for disease spread to livestock operations. For instance, contaminated feed was linked to outbreaks of bacterial (Moreno-Lopez, 2002; Wagner et al., 2005; Osterberg et al., 2006; Torres et al., 2011; Fasanella et al., 2013; Koyuncu et al., 2013), parasitic (Jenkins et al., 2013) and prion diseases (Windl and Dawson, 2012). Feed delivery trucks were identified as a likely mechanism for spread of avian influenza between poultry operations (Dorea et al., 2010). However, no literature was available describing distances for movements of feed to US farms and ranches.

1.5 CONCLUSIONS

An understanding of veterinarian availability and usage, biosecurity practices, and movement practices on US agricultural operations is critical for preparing for potential FAD incursions and educating producers to reduce the spread of endemic animal diseases. This chapter summarized previous research on these important topics. However, we found few studies described these practices for small-scale US operations. Therefore, the specific objectives of this study were to describe factors affecting use of a veterinarian, including barriers such as distance to veterinarians (Chapter 2), to describe biosecurity practices and factors affecting the use of biosecurity practices (Chapter 3), and to describe spatial movements relevant to disease spread (Chapter 4) at a national and regional level for US small-scale operations. This information is needed for targeting education, parameterizing disease spread models, and preparing for disease outbreaks.

Each chapter of this thesis will focus on a slightly different inference population of small-scale operations. Because concerns about shortages of veterinarians are primarily for food animal veterinarians, Chapter 2 focuses on the population of small-scale operations that primarily raise food animals. Thus, operations that primarily raise horses or other non-food animal species are excluded from analysis in Chapter 2. Chapter 3, which describes biosecurity, includes all small-scale operations regardless of animal species raised. Subsequently, operations raising horses, mink, or other non-food animal species are included in the analysis for Chapter 3. Chapter 4, which focuses on spatial features that are relevant to disease spread, includes only operations with at least one head of cattle, swine, poultry, sheep or goats, because we considered these to be the core livestock species of interest for disease spread modeling.

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CHAPTER 2: FACTORS AFFECTING USE OF VETERINARIANS BY SMALL-SCALE FOOD ANIMAL OPERATIONS[2]

2.1 SUMMARY

Objective—To identify factors associated with use of a veterinarian by small-scale food animal operations.

Design—Cross-sectional descriptive survey.

Sample—16,000 small-scale farm or ranch operations in 50 US states.

Procedures—Surveys were conducted via mail or telephone during 2011 for small-scale operations (gross annual agricultural sales between $10,000 and $499,999 during 2007-2009) in which an animal or animal product comprised the highest percentage of annual sales.

Inference population for this chapter—Small-scale operations that primarily raised a food animal species, and had sales below $500,000 in 2010.

Results—8,186 (51.2%) operations responded to the survey; 7,849 surveys met the inclusion criteria for this chapter. For 6,511 (83.0%) respondents, beef cattle were the primary animal species. An estimated 82.1% of operations (95% confidence interval [CI], 81.1% to 83.0%) had a veterinarian available ≤ 29 miles away; 1.4% (95% CI, 1.2% to 1.7%) did not have a veterinarian available within 100 miles of the operation. Operations for which the nearest veterinarian was ≥ 100 miles away or for which a veterinarian was not available were located in 40 US states. Overall, 61.7% of operations (95% CI, 60.6% to 62.9%) had used a veterinarian during the 12 months prior to the survey. Producers with college degrees were significantly ($P < 0.001$) more likely to use a veterinarian (67.5%) versus those who did not complete high school (52.9%).

[2] Beam A, Thilmany D, Garber L, Van Metre D, Pritchard R, Kopral C, Olea-Popelka F, 2013. J Am Vet Med Assoc. Nov 1; 243(9):1334-44.

Conclusions—Results of this study indicated most small-scale operations had adequate access to veterinarians during 2011, but there seemed to be localized shortages of veterinarians in many states.

2.2 INTRODUCTION

Veterinarians perform various roles in US food animal industries. For example, in 2007, cow-calf operations primarily used veterinarians for diagnosis, treatment, and prevention of disease in animals (USDA, 2009a). In 2006, 83.2% of dairy operations used veterinarians for palpation of cows to detect pregnancy (USDA, 2009b). In 2005, 49.5% of swine operations used the services of a local veterinary practitioner, and 18.0% of such operations used an on-staff veterinarian [typically for treatment of individual pigs or to provide medications or vaccines] (USDA, 2007). In 2006, > 90% of US broiler chickens were produced under a production contract with a poultry integrator company (MacDonald, 2008), and producers typically used veterinarians provided by the company (NRC, 2012).

Results of other studies of companion animal veterinary care use indicate that various factors, such as financial concerns and client perceptions of the value of preventive medicine, influence an owner’s decision regarding use of veterinary services (Volk et al., 2011a; Volk et al., 2011b). Similarly, identification of the reasons small-scale food animal producers use or don’t use veterinarians could be useful information for veterinarians and other agricultural industry personnel. Such information may indicate the sociological, geographic, and demographic factors that influence the demand for food animal veterinarians, and may be useful for decisions regarding the veterinary profession.

Other authors (DeHaven and Goldberg, 2006; Prince et al., 2006; Sterner, 2006; Narver, 2007) have expressed concerns regarding current and future shortages of veterinarians working in food supply veterinary medicine (FSVM), which includes veterinarians working in various disciplines such as food animal private practice; corporate practice; federal, state, and local governments; laboratories; and universities. The factors that influence veterinarian supply and demand may differ substantially among such FSVM disciplines; therefore, the phrases food supply veterinarian, large animal veterinarian, and food animal veterinarian should not be used interchangeably in discussions regarding veterinary shortages (Villarroel et al., 2010).

In 2010, the Veterinary Medicine Loan Repayment Program (VMLRP ; USDA-NIFA, 2013) was implemented in the US to help alleviate perceived shortages of veterinarians in certain disciplines; this program assists in the repayment of student loans for veterinarians who practice in such disciplines. Each year, the VMLRP receives nomination forms submitted by state animal health officials to identify geographic areas in the US with a shortage of veterinarians. In 2011, the American Association of Bovine Practitioners Ad Hoc Committee on Rural Veterinary Practice (AABP, 2011) concluded that there is not a shortage of food animal veterinarians in rural private practice in the US. Similarly, a committee of the National Research Council did not find substantial evidence of widespread workforce shortages in veterinary medicine (NRC, 2012). That committee identified unmet needs for food animal veterinary services, particularly for small-scale operations in rural areas, but indicated that problem was different from an overall veterinary workforce shortage (NRC, 2012). Therefore, it is unclear whether shortages of veterinarians working in various FSVM disciplines are real or perceived. There is limited evidence of private practice food animal veterinarian shortages, particularly for small-scale farms in rural areas (NRC, 2012).

The study reported here was conducted to identify factors associated with the use of veterinarians by small-scale food animal operations in the US and various regions in the US. The objectives of the study were to determine associations between producer demographic variables and operation characteristics with the use of a veterinarian, identify reasons producers did not use a veterinarian, and identify the producer-reported distance to the nearest veterinarian (as a measure of producers' access to veterinarians who work with the species of animals on their operation).

2.3 MATERIALS AND METHODS

Sample—Data for this study were collected as part of a cross-sectional (retrospective [outcomes occurred before the survey was conducted]) survey of small-scale livestock operations conducted by personnel of the United States Department of Agriculture (USDA) National Animal Health Monitoring System (NAHMS) and USDA National Agricultural Statistics Service (NASS). The operations surveyed were selected from a list frame of US agricultural operations developed by the NASS. The NASS filtered the list frame so that it included only operations that met the study inclusion criteria.

Two inclusion criteria were used to select livestock operations for inclusion in this study; these criteria were determined on the basis of list frame data collected by the NASS during 2007, 2008, and 2009. Operations were eligible for inclusion if the list frame indicated they had gross annual farm sales from $10,000 to $499,999 during 2007 through 2009 and the list frame indicated an animal or animal product comprised the highest percentage of gross farm sales. Operations eligible for inclusion in the NAHMS survey had cattle, small ruminants (sheep and goats), poultry, equids, swine, aquaculture species, or other farm animals raised for sale or home use. The most recent NASS Census of Agriculture (USDA, 2012) indicated 349,792 operations met the inclusion criteria for the NAHMS survey. Operations in all 50 US states were eligible for inclusion in the list frame. During January 2011, a stratified systematic sample of 16,000 operations was selected from the NASS list frame. The 4 strata used for selection of operations included annual sales between \$10,000 and \$99,999 and 1 to 3 types of agricultural commodities produced; annual sales between \$10,000 and \$99,999 and ≥ 4 types of agricultural commodities produced; annual sales between \$100,000 and \$249,999; and annual sales between \$250,000 and \$499,999. To ensure diverse geographic locations of operations included in the study, the NASS list frame data were sorted by state and county in each stratum. Although the NAHMS survey included operations with non-food–producing animal species (e.g., horses and mink), such operations were excluded from analysis in this study; therefore, analysis was performed only for food animal operations.

Survey development—Focus group discussions and personal interviews with livestock veterinary medicine stakeholders including government employees, university researchers and extension agents, livestock producers, agricultural economists, veterinarians, and spatial and business analysts were conducted to obtain recommendations regarding the development of objectives and questionnaire design for this study. The final version of the questionnaire[3] consisted of 35 multi-part questions in the following 9 sections: livestock inventory, crop inventory, marketing, future plans, resources, use of veterinarians, general management, federal livestock and poultry compensation, and producer (ie, primary operator for a facility)

[3] Study questionnaire available in Appendix I. Also available at http://www.aphis.usda.gov/animal_health/nahms/ smallscale/smallscaleques.shtml

demographics and operation characteristics. Some sections of the questionnaire were designed for objectives unrelated to the present study.

The first section of the questionnaire was used to collect information regarding animal inventory (number of animals in the herd) during the 12 months prior to the survey for the following animal types: beef cattle, dairy cattle, swine, sheep, goats, chickens and other poultry, horses and other equids, bison, and other species. Producers who indicated they had other types of animals were asked to identify the species.

The second section of the questionnaire was used to collect information regarding the types of crops grown on the operation during the 12 months prior to the survey. The third section of the questionnaire was used to collect information regarding the total value (in US dollars; gross sales [the total amount of money earned from all sales before subtraction of expenses or payment of taxes]) of agricultural products sold from the operation during 2010 via a multiple choice question with the following 7 categories: $0, > $0 to < $10,000, $10,000 to $49,999, $50,000 to $99,999, $100,000 to $249,999, $250,000 to $499,999, and ≥ $500,000. The > $0 to < $10,000 and ≥ $500,000 categories were included because farm sales likely varied among years.

The fourth section of the questionnaire included a question (yes or no) regarding whether the producer expected to continue farming during the next 5 years. A follow-up multiple-choice question was used to ask producers to rank the importance of a list of factors in their decision to continue farming or to stop farming. The fifth section of the questionnaire included a question (yes or no) regarding whether anyone in the household, including the producer, earned income from an off-farm job. The fifth section was also used to collect information regarding distances to slaughter facilities, markets where agricultural products were sold, feed sources, and off-farm employment.

Section 6 of the questionnaire was used to collect information regarding the distance to and use of veterinarians who worked with the species of animal on the farm. The distance to the nearest veterinarian that worked with the type of animal on the facility was identified by use of a multiple choice question with the following 6 categories: ≤ 29 miles, 30 to 99 miles, 100 to 299 miles, ≥ 300 miles, no veterinarian available, or don't know the distance to the nearest veterinarian. Producers were then asked to answer a question (yes or no) regarding whether they had used a veterinarian for their animals during the 12 months prior to the survey (eg, for treatment, consultation, or preparation of health certificates). Producers who had not used a veterinarian during that time were asked to indicate the reasons from a list provided on the questionnaire; an option to write in other reasons not included in that list was included on the survey. The following list of reasons producers had not used a veterinarian was provided on the questionnaire: too expensive, no veterinarian available in the area or veterinarian too far away, producer provides health care for animals, and no disease or other need for a veterinarian. Producers were allowed to select multiple reasons.

The seventh section of the questionnaire was used to collect information regarding biosecurity practices, use of alternative medicine, and resources that would be contacted if the producer suspected an animal had a foreign animal disease. The eighth section of the questionnaire was used to collect information regarding producer opinions about federal compensation or indemnity.

The ninth section of the questionnaire was used to collect information regarding producer demographics and farm typology (Hoppe et al., 2000). The age, race, gender, and education level of the producer were determined by use of multiple choice questions. Categories for age included < 25 years old, 25 to 44 years old, 45 to 64 years old, or ≥ 65 years old. Categories for race included White, Black or African American, American Indian or Alaska Native, Asian, and Native Hawaiian or other Pacific Islander; respondents could check all categories that applied. Categories for gender included male or female. Categories for highest level of education completed included less than a high school diploma, high school diploma or equivalent, some college (including Associate degree), or college graduate and beyond. For farm typology classification, producers were asked to select which 1 of the following 4 categories best described their farm: retirement farm (the principal operator is retired from another occupation), residential or lifestyle farm (the principal operator's primary occupation is something other than farming), farming occupation (farming is the principal operator's primary occupation), or other (respondents who selected this category were asked to specify the farm type); this classification was a simplification of the typology categories developed by the USDA-ERS (Hoppe et al., 2000).

Data collection—An introductory letter and educational materials were mailed to the 16,000 selected operations beginning April 1, 2011; questionnaires and cover letters were mailed 1 week later. One week after questionnaires were mailed, operations were contacted via an automatic dialing machine with a prerecorded message reminding respondents to complete and mail the questionnaire and thanking them if they already had done so. Nonrespondents were contacted via telephone between April 14 and May 18, 2011, and surveys were completed via telephone interview. Telephone interviews were conducted via computer-assisted telephone interview software by personnel at the NASS Arkansas Data Collection Center.

Statistical analysis—Initial entry and validation of the questionnaire data were performed by personnel at the NASS Arkansas Data Collection Center. The USDA NAHMS staff performed additional data validation to identify extreme values and data entry errors.

Responding operations were categorized by primary animal species, farm sales, and geographic region for analysis and reporting. Primary animal species (swine, dairy cattle, beef cattle, sheep or goats, poultry, or other) was determined by use of NASS list frame data and animal inventory data collected via the survey. Data for equine and other non-food animal operations were excluded from the analysis. Sheep and goat operations were combined into 1 category, and bison operations were placed in the other category because a small number of farms had sheep, goats, or bison. Although farms were selected for participation in this study on the basis of 2007, 2008, and 2009 sales data, the 2010 sales data from the questionnaire were used for analysis because that information was the most current. Operations with farm sales of $500,000 or more during 2010 were excluded from analysis. Five categories of gross annual farm sales (< $10,000, $10,000 to $49,999, $50,000 to $99,999, $100,000 to $249,999, and ≥ $250,000) were used for analysis because these were the *a priori* categories of interest. The geographic region categories were determined on the basis of USDA Economic Research Service (ERS) farm resource regions (Figure 2.1; USDA-ERS, 2000). Alaska and Hawaii were not included in farm resource regions by the ERS. After consultation with an ERS economist, operations in Alaska and Hawaii were classified in the Fruitful Rim region for this study.

Unweighted descriptive statistics were calculated to describe the sample of study respondents. Unweighted descriptive statistics were also calculated for the number of

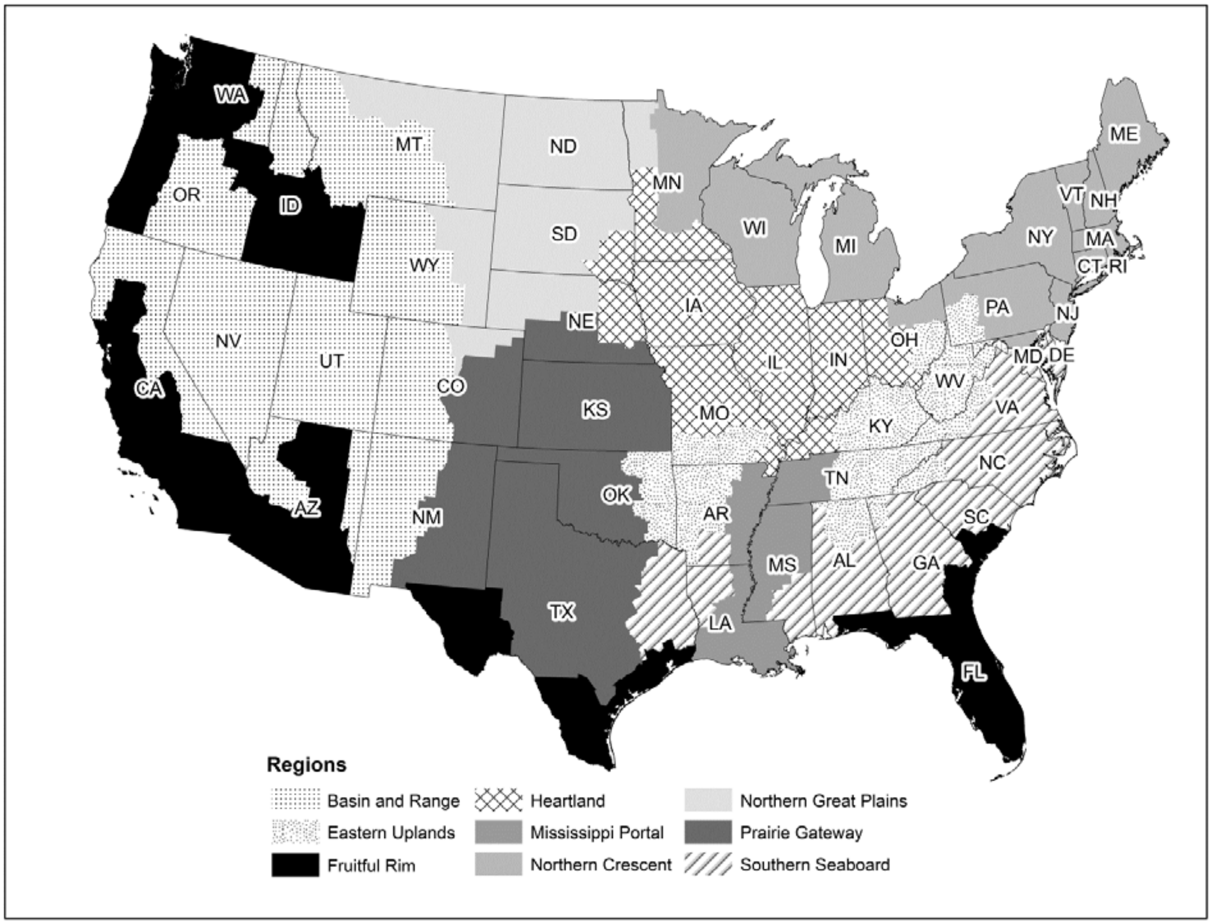

Figure 2.1—Economic Research Service Farm Resource Regions.

respondents that reported no veterinarian was available for their animals. Respondent data were weighted to create population estimates for all US small-scale food animal operations. The inverse value of the probability of selection for each operation, which varied by stratum, was the initial analysis weight. This weight was adjusted for nonresponses by dividing the sum of weights for all operations by the sum of weights for survey respondent operations (including those with no animal inventory during the 12 months prior to the survey) within each of the strata. Population estimates and 95% CIs were determined with a commercially available statistical software package[4] that accounted for the survey design and weighting. A weighted multivariable logistic regression analysis was performed to identify operation-level and producer-level factors associated with the use of veterinarians. Operations that reported no veterinarian was available for their type of animals were excluded from the multivariable model because those operations did not have an option to use a veterinarian. The respondent having used a veterinarian during the previous 12 months was used as the dependent outcome variable (dichotomous variable [yes or no response]). Independent variables were screened for inclusion in the multivariable model via bivariable logistic regression analyses, which included primary animal species on the operation as an independent variable to control for potentially confounding effects. Independent variables were evaluated for inclusion in the multivariable model if they had an association ($P \leq 0.25$) with veterinarian use after adjusting for animal species via the bivariable analyses. For the variable distance to the nearest veterinarian, the 100 to 299 miles and ≥ 300 miles categories were combined in 1 category because of small samples sizes and because a distance of ≥ 100 miles was considered to be far. Operations in the other farm typology category were combined with residential or lifestyle farms for analysis, because write-in responses indicated such farms were similar in purpose to lifestyle farms. The farm typology variable was collinear with the variables producer age and whether someone in the household earned income from an off-farm job; therefore, of these variables, only farm typology was evaluated for inclusion in the multivariable model. Farm typology was selected for inclusion in the model because that variable indicated the purpose of a farm, which may have been related to decisions regarding veterinarian use. A backward stepwise elimination procedure was used to create the final model. Survey mode (telephone vs mail) was considered as a potential confounding variable, but was not forced into the model. Interaction terms between producer

[4] PROC CROSSTAB, SUDAAN software Version 10, RTI International, Research Triangle Park, NC

education level and region, distance to a veterinarian and farm typology, distance to a veterinarian and primary animal species, distance to a veterinarian and farm sales, and distance to a veterinarian and region were evaluated. Model fit was assessed with the Hosmer-Lemeshow chi-square statistic. Logistic regression models were generated by use of a commercially available statistical software package[5] that accounted for the survey design and weighting. Values of $P \leq 0.05$ were considered significant.

2.4 RESULTS

Survey response rate, producer demographics, and operation characteristics—Of the 16,000 operations selected for participation in the NAHMS survey, 8,186 (51.2% [including operations in all 50 US states]) completed the questionnaire; 1,329 (8.3%) operations were not eligible to participate because they had not raised animals during the 12 months prior to the survey. Of the 8,186 respondents, 337 (4.1%) were excluded from the analysis because they were equine operations (n = 264), raised other non-food animal species (n=4), or had sales > $499,999 during 2010 (n=69). Therefore, 7,849 food animal operations were included in the analysis. Surveys were completed via mail for 4,206 (53.6%) operations and via telephone interview for 3,643 (46.4%) operations. A total of 6,938 respondents (88.4%) answered all of the survey questions included in the analysis of this study.

Demographic information for responding producers and characteristics of operations were summarized (Tables 2.1 and 2.2). For 6,511 (83.0%) of the operations included in the analysis, the primary type of animal on the farm was beef cattle. Operations classified as having other species had animals such as camelids, aquaculture species, bees, or captive cervids.

[5] PROC RLOGIST, SUDAAN software Version 10, RTI International, Research Triangle Park, NC

Table 2.1—Description of sample: operation characteristics for respondents to a 2011 survey of small-scale food animal operations in the US.

Operation characteristic	Number	Unweighted percentage
All respondents	7,849	100.0
Region		
Heartland	1,110	14.1
Northern Crescent	1,103	14.1
Northern Great Plains	335	4.3
Prairie Gateway	1,323	16.9
Eastern Uplands	1,781	22.7
Southern Seaboard	947	12.1
Fruitful Rim	603	7.7
Basin and Range	344	4.4
Mississippi Portal	303	3.9
Farm sales in 2010		
< $10,000	2,893	36.9
$10,000 to $49,999	2,586	32.9
$50,000 to $99,999	1,018	13.0
$100,000 to $249,999	894	11.4
≥ $250,000	223	2.8
Not reported	235	3.0
Primary animal species		
Swine	91	1.2
Dairy cattle	783	10.0
Beef cattle	6,511	83.0
Sheep or goats	160	2.0
Poultry	216	2.8
Other	88	1.1
Farm typology		
Farming occupation	2,643	33.7
Retirement farm	1,868	23.8
Residential, lifestyle, or other type	3,197	40.7
Not reported	141	1.8

Table 2.2— Description of sample: producer demographics for respondents to a 2011 survey of small-scale food animal operations in the US.

Producer* demographics	Number	Unweighted percentage
All respondents	7,849	100.0
Education level		
< High school diploma	685	8.7
High school diploma or equivalent	3,065	39.0
Some college (including Associate degree)	1,965	25.0
≥ College graduate	1,938	24.7
Not reported	196	2.5
Gender		
Male	7,086	90.3
Female	609	7.8
Not reported	154	2.0
Race		
White	7,359	93.8
Black or African American	102	1.3
American Indian or Alaska Native	95	1.2
Other or multiracial	62	0.8
Not reported	231	2.9
Age (years)		
< 25	27	0.3
25 to 44	943	12.0
45 to 64	3,976	50.7
≥ 65	2,729	34.8
Not reported	174	2.2

*A producer was defined as the primary operator for a facility.

Use of veterinarians—A total of 7,707 producers (98.2%) answered the survey question regarding use of veterinarians. Of these, 5,011 (65.0%) had used a veterinarian (for various reasons including treatment of animals, consultation, or preparation of health certificates) during the 12 months prior to the survey. On the basis of the weighted population estimate, 61.7% (95% CI, 60.6% to 62.9%) of small-scale operations had used a veterinarian during the 12 months prior to the survey (Table 2.3).

Results of multivariable logistic regression analysis were summarized (Table 2.4). Results indicated interaction terms were not significant. Compared to beef cattle operations,

Table 2.3—Results of weighted bivariable* logistic regression analysis of factors associated with use of a veterinarian by small-scale US food animal operations during the previous 12 months.

Factor		Weighted percentage of operations that used a veterinarian (95% CI)	OR	*P* value
All operations		61.7 (60.6–62.9)		
Primary animal species				<0.001
	Swine	59.4 (48.0–69.9)	0.97	0.898
	Dairy cattle	88.5 (85.5–90.9)	5.08	<0.001
	Beef cattle	60.2 (58.9–61.4)	Referent	—
	Sheep or goats	60.4 (52.0–68.3)	1.01	0.947
	Poultry	39.3 (32.4–46.6)	0.43	<0.001
	Other	59.2 (48.5–69.1)	0.96	0.855
Number of animal types†				<0.001
	1	56.0 (54.3–57.7)	Referent	—
	2	66.7 (64.6–68.7)	1.60	<0.001
	≥ 3	70.4 (67.7–73.0)	1.84	<0.001
Region				<0.001
	Heartland	72.2 (69.2–75.1)	2.41	<0.001
	Northern Crescent	73.2 (70.3–75.9)	1.70	0.001
	Northern Great Plains	79.0 (73.5–83.6)	3.60	<0.001
	Prairie Gateway	65.6 (62.7–68.3)	1.88	<0.001
	Eastern Uplands	51.9 (49.4–54.4)	1.04	0.776
	Southern Seaboard	48.3 (44.8–51.8)	0.93	0.634
	Fruitful Rim	57.6 (53.3–61.8)	1.29	0.093
	Basin and Range	80.3 (75.0–84.7)	3.99	<0.001
	Mississippi Portal	50.7 (44.7–56.6)	Referent	—
Farm sales in 2010				<0.001
	< $10,000	48.8 (46.9–50.7)	Referent	—
	$10,000 to $49,999	67.5 (65.5–69.5)	2.22	<0.001
	$50,000 to $99,999	77.9 (74.9–80.6)	3.91	<0.001
	$100,000 to $249,999	87.2 (84.7–89.3)	6.61	<0.001
	≥ $250,000	88.1 (83.1–91.7)	8.63	<0.001
Farm typology				<0.001
	Farming occupation	73.7 (71.8–75.5)	Referent	—
	Retirement farm	51.7 (49.3–54.1)	0.43	<0.001
	Residential, lifestyle, or other type	60.8 (58.9–62.6)	0.63	<0.001

*Analysis was adjusted for the primary species of animal on an operation. Each operation was assigned an analysis weight equal to the inverse of the operation's selection probability adjusted for nonresponse.
†On the survey, producers could indicate a maximum of 8 animal types (beef cattle, dairy cattle, goats, horses or other equids, poultry, sheep, swine, or other species).
— = Not applicable.

Table 2.3 (continued)—Results of weighted bivariable* logistic regression analysis of factors associated with use of a veterinarian by small-scale US food animal operations during the previous 12 months.

Factor		Weighted percentage of operations that used a veterinarian (95% CI)	OR	*P* value
Distance to nearest veterinarian (miles)				<0.001
	≤ 29	63.7 (62.4–65.0)	Referent	—
	30 to 99	60.1 (56.9–63.1)	0.88	0.072
	≥ 100 miles	68.4 (53.1–80.5)	1.27	0.501
	Unknown	10.9 (6.1–18.8)	0.07	<0.001
Someone in household earned income from off-farm job				
	Yes	64.4 (62.9–65.9)	1.42	<0.001
	No	57.5 (55.6–59.4)	Referent	—
Producer‡ education level				<0.001
	< High school diploma	52.9 (48.7–56.9)	0.72	0.001
	High school diploma or equivalent	58.3 (56.3–60.1)	Referent	—
	Some college (including Associate degree)	64.7 (62.4–67.0)	1.37	<0.001
	≥ College graduate	67.5 (65.1–69.8)	1.59	<0.001
Producer‡ expects to continue farming during the next 5 years				
	Yes	62.9 (61.7–64.1)	1.62	<0.001
	No	51.8 (48.0–55.7)	Referent	—
Producer‡ race				<0.001
	White	62.5 (61.3–63.7)	Referent	—
	Black or African American	38.2 (29.0–48.3)	0.40	<0.001
	American Indian or Alaska Native	53.6 (42.7–64.1)	0.74	0.174
	Other or multiracial	51.2 (37.9–64.3)	0.67	0.152
Producer‡ gender				
	Male	62.0 (60.8–63.2)	Referent	—
	Female	60.2 (55.9–64.3)	0.96	0.664
Producer‡ age (years)				<0.001
	< 25	77.0 (55.5–90.0)	2.25	0.119
	25 to 44	68.9 (65.5–72.1)	1.65	<0.001
	45 to 64	65.0 (63.4–66.6)	1.45	<0.001
	≥ 65	55.3 (53.3–57.3)	Referent	—

*Analysis was adjusted for the primary species of animal on an operation. Each operation was assigned an analysis weight equal to the inverse of the operation's selection probability adjusted for nonresponse.
‡A producer was defined as the primary operator for a facility.
— = Not applicable.

Table 2.4—Results of weighted* multivariable logistic regression analysis to identify factors associated with use of a veterinarian by small-scale US food animal operations identified via a 2011 survey.

Factor	OR	95% CI	*P* value
Primary animal species			<0.001
Swine	0.44	0.26–0.76	0.003
Dairy cattle	2.46	1.73–3.49	<0.001
Beef cattle	Referent	—	—
Sheep or goats	0.93	0.62–1.41	0.741
Poultry	0.31	0.21–0.46	<0.001
Other	1.27	0.69–2.35	0.440
Number of animal types†			<0.001
1	Referent	—	—
2	1.50	1.32–1.72	<0.001
≥ 3	1.71	1.45–2.03	<0.001
Region			<0.001
Heartland	2.01	1.47–2.76	<0.001
Northern Crescent	1.64	1.17–2.29	0.004
Northern Great Plains	2.05	1.32–3.17	0.001
Prairie Gateway	1.69	1.25–2.28	0.001
Eastern Uplands	1.08	0.81–1.44	0.610
Southern Seaboard	0.94	0.69–1.28	0.695
Fruitful Rim	1.19	0.85–1.65	0.309
Basin and Range	2.68	1.73–4.17	<0.001
Mississippi Portal	Referent	—	—
Farm sales in 2010			<0.001
< $10,000	Referent	—	—
$10,000 to $49,999	2.06	1.81–2.35	<0.001
$50,000 to $99,999	3.14	2.53–3.90	<0.001
$100,000 to $249,999	5.59	4.23–7.39	<0.001
≥ $250,000	7.83	4.89–12.55	<0.001
Farm typology			0.041
Farming occupation	Referent	—	—
Retirement farm	0.82	0.69–0.98	0.026
Residential, lifestyle, or other type	0.96	0.82–1.12	0.592

*Each operation was assigned an analysis weight equal to the inverse of the operation's selection probability adjusted for nonresponse.
†On the survey, producers could indicate a maximum of 8 animal types (beef cattle, dairy cattle, goats, horses or other equids, poultry, sheep, swine, or other species).
— = Not applicable.

Table 2.4 (continued)—Results of weighted* multivariable logistic regression analysis to identify factors associated with use of a veterinarian by small-scale US food animal operations identified via a 2011 survey.

Factor	OR	95% CI	*P* value
Distance to nearest veterinarian (miles)			<0.001
≤ 29	Referent	—	—
30 to 99	0.81	0.69–0.96	0.013
≥ 100	0.78	0.34–1.79	0.557
Unknown	0.09	0.04–0.19	<0.001
Producer‡ education level			<0.001
< High school diploma	0.77	0.61–0.96	0.020
High school diploma or equivalent	Referent	—	—
Some college (including Associate degree)	1.32	1.14–1.53	<0.001
≥ College graduate	1.45	1.25–1.69	<0.001
Producer‡ expects to continue farming during next 5 years			0.007
Yes	1.30	1.08–1.58	0.007
No	Referent	—	—

*Each operation was assigned an analysis weight equal to the inverse of the operation's selection probability adjusted for nonresponse.
‡A producer was defined as the primary operator for a facility.
— = Not applicable.

dairy operations were significantly ($P < 0.001$) more likely to use a veterinarian (OR, 2.46) and poultry and swine operations were significantly ($P < 0.001$ and $P = 0.003$, respectively) less likely (ORs, 0.31 and 0.44, respectively) to use a veterinarian. Operations that raised 2 animal types and operations that raised ≥ 3 animal types were significantly ($P < 0.001$) more likely (ORs, 1.50 and 1.71, respectively) to use a veterinarian, compared with operations that raised only 1 animal type. The percentage of operations that used a veterinarian increased with increasing farm sales. Of producers on retirement farms, 51.7% used a veterinarian; of producers on farming occupation operations, 73.7% used a veterinarian (Table 2.3). These results were significantly ($P = 0.026$; OR, 0.82) different in the multivariable model (Table 2.4). Operations for which the nearest veterinarian was 30 to 99 miles away were significantly ($P = 0.013$) less likely (OR, 0.81) to use a veterinarian than producers with a veterinarian ≤ 29 miles away.

Use of veterinarians by operations was significantly ($P < 0.001$) associated with producer education level (Table 2.4). Results of analysis controlled for other independent variables indicated producers who were college graduates or had some college education were more likely to use a veterinarian during the 12 months prior to the survey (ORs, 1.45 and 1.32, respectively) than producers who had graduated from high school and did not attend college.

Reasons for not using a veterinarian—Of the 2,696 producers who indicated they had not used a veterinarian during in the 12 months prior to the survey, 2,620 (97.2%) answered the survey question regarding the reason. On the basis of weighted population estimates, most producers who did not use a veterinarian (65.5%) had not used a veterinarian because animals did not have disease or there was no other need for a veterinarian, 12.5% did not use a veterinarian because it was too expensive, and 3.7% did not use a veterinarian because no veterinarian was available in their geographic area or the closest veterinarian was too far away (Table 2.5).

Distance to a veterinarian—A total of 7,666 producers (97.7%) answered the survey question regarding the distance to the nearest veterinarian that worked with the type of animal on the operation. Of these, 64 operations (0.8%) reported that no veterinarian was available and 47 (0.6%) reported that the nearest veterinarian was ≥ 100 miles away. These 111 operations were located in 40 US states and all 9 geographic regions evaluated in the study. On the basis of weighted population estimates, 82.1% (95% CI, 81.1% to 83.0%; Table 2.6) of small-scale operations had a veterinarian available ≤ 29 miles away; 1.4% (95% CI, 1.2% to 1.7%) of operations did not have a veterinarian available within 100 miles. Higher percentages of

Table 2.5—Weighted* percentage (95% CI) of operations by reasons for not using a veterinarian during the previous 12 months.

	Reason for not using a veterinarian†				
	Veterinary care too expensive	No veterinarian available or veterinarian too far away	Provide own health care for animals	No animal disease or other need for veterinarian	Other reason
All operations (n = 2,620)	12.5 (11.2–13.9)	3.7 (3.0–4.5)	44.7 (42.6–46.7)	65.5 (63.5–67.4)	1.8 (1.4–2.4)
Primary animal species					
Swine (n = 30)	11.8 (3.6–32.7)	0.0 (—)	54.1 (35.3-71.8)	59.0 (38.7–76.6)	4.0 (1.0–14.5)
Dairy cattle (n = 74)	16.5 (9.2–27.9)	6.3 (2.4–15.5)	44.2 (32.4–56.8)	69.1 (56.4–79.5)	1.7 (0.4–6.6)
Beef cattle (n = 2,301)	12.7 (11.3–14.2)	3.7 (3.0–4.6)	45.3 (43.2–47.5)	65.7 (63.7–67.7)	1.1 (0.7–1.7)
Sheep or goats (n = 57)	14.5 (6.9–27.9)	0.0 (—)	59.1 (45.1–71.7)	49.0 (35.5–62.6)	0.0 (—)
Poultry (n = 121)	3.0 (1.2–7.0)	1.5 (0.2–9.7)	16.6 (10.3–25.8)	69.3 (59.6–77.5)	20.2 (13.8–28.5)
Other (n = 37)	9.5 (3.1–25.7)	9.1 (2.2–30.8)	36.7 (22.6–53.5)	60.7 (41.9–76.7)	11.4 (3.8–29.7)

*Each operation was assigned an analysis weight equal to the inverse of the operation's selection probability adjusted for nonresponse.
†Producers were allowed to select more than one reason in the survey.
— = Not applicable.

Table 2.6—Weighted* percentage (95% CI) of operations by producer-reported distance to the nearest veterinarian, by primary animal species on the operation, and by region.

		Distance to nearest veterinarian (miles)				
	No.	≤ 29	30 to 99	≥ 100	No veterinarian available	Unknown
All operations	7,666	82.1 (81.1–83.0)	15.1 (14.3-16.0)	0.6 (0.4–0.8)	0.8 (0.6–1.1)	1.4 (1.2–1.7)
Primary animal species						
Swine	88	75.7 (65.6–83.7)	17.2 (10.3–27.2)	2.2 (0.7–6.6)	0.0 (—)	4.9 (2.3–9.8)
Dairy cattle	771	87.3 (84.5–89.6)	11.4 (9.2–14.1)	0.2 (0.0–1.3)	0.3 (0.1–1.2)	0.8 (0.3–1.9)
Beef cattle	6,373	82.5 (81.4–83.4)	15.2 (14.3–16.2)	0.5 (0.4–0.7)	0.6 (0.4–0.9)	1.2 (0.9–1.5)
Sheep or goats	151	78.9 (71.1–85.1)	17.6 (11.9–25.1)	0.9 (0.1–6.1)	1.3 (0.4–4.0)	1.3 (0.3–5.3)
Poultry	201	65.9 (58.4–72.7)	17.8 (12.7–24.4)	0.6 (0.1–4.3)	3.9 (1.6–9.2)	11.8 (7.8–17.3)
Other	82	57.8 (46.7–68.1)	19.5 (11.8–30.6)	3.8 (1.2–11.9)	15.8 (9.2–25.9)	3.1 (1.1–8.4)
Region						
Heartland	1,091	89.7 (87.6–91.5)	8.2 (6.6–10.1)	0.6 (0.3–1.4)	0.7 (0.3–1.6)	0.8 (0.3–1.7)
Northern Crescent	1,079	82.1 (79.6–84.4)	14.1 (12.0–16.4)	0.8 (0.4–1.7)	0.9 (0.4–1.9)	2.1 (1.3–3.3)
Northern Great Plains	322	67.3 (61.5–72.6)	31.8 (26.5–37.6)	0.1 (0.0–1.0)	0.5 (0.1–1.9)	0.3 (0.0–1.9)
Prairie Gateway	1,294	84.4 (82.2–86.4)	14.0 (12.1–16.1)	0.4 (0.1–0.9)	0.4 (0.2–1.0)	0.8 (0.4–1.5)
Eastern Uplands	1,745	84.1 (82.2–85.9)	13.0 (11.4–14.7)	0.2 (0.1–0.5)	0.8 (0.5–1.4)	1.9 (1.3–2.7)
Southern Seaboard	913	78.5 (75.5–81.4)	17.7 (15.1–20.6)	0.1 (0.0–0.3)	1.2 (0.6–2.1)	2.5 (1.6–3.9)
Fruitful Rim	588	76.4 (72.5–79.9)	20.4 (17.1–24.1)	0.7 (0.2–2.3)	1.4 (0.7–2.9)	1.1 (0.5–2.6)
Basin and Range	337	70.4 (64.8–75.4)	23.6 (19.0–28.9)	4.5 (2.8–7.3)	0.7 (0.2–2.8)	0.8 (0.2–3.1)
Mississippi Portal	297	82.5 (77.5–86.6)	15.4 (11.5–20.2)	0.4 (0.1–2.9)	1.1 (0.3–3.5)	0.6 (0.1–2.8)

*Each operation was assigned an analysis weight equal to the inverse of the operation's selection probability adjusted for nonresponse. Data are reported for all producers who answered the survey question (whether the producer did or did not use a veterinarian).
— = Not applicable.

operations in the Northern Great Plains and Basin and Range regions were located 30 to 99 miles from the nearest veterinarian (31.8% and 23.6% of operations, respectively), compared with operations in the Heartland, Eastern Uplands, Northern Crescent, Prairie Gateway, Mississippi and Southern Seaboard regions (8.2%, 13.0%, 14.1%, 14.0%, 15.4%, and 17.7% of operations, respectively).

2.5 DISCUSSION

In the present study, producers on small-scale food animal operations (annual sales between $10,000 and $499,999) were surveyed to collect information regarding factors related to veterinarian use. The survey questions were designed to identify potential barriers to veterinarian use and geographic and demographic factors that influence the demand for food animal veterinarians. Although the NAHMS survey included equine operations, such operations were excluded from analysis because the focus of this study was food animal operations. Horses have not been considered food animals in the United States since 2007, when all US horse slaughter facilities closed (Cowan, 2011).

Results of the present study are only applicable to small-scale food animal operations, and should not be extrapolated for large operations. Future studies could be conducted to identify factors affecting use of veterinarians by large food animal operations and equine operations. An interesting result of this study was that increasing sales was associated with increased use of veterinarians in the small-scale operations evaluated. We believe this finding justifies the study design to identify factors affecting use of veterinarians by small-scale operations, because such operations may be less likely to use veterinarians than large operations.

Although US agricultural production (and market share of sales) has been shifting toward large operation sizes for all types of commodities, 95.1% of all US farms have annual sales <

$500,000, and 40.9% of farms have sales between $10,000 and $499,999 (Hoppe et al., 2010). Small-scale operations (annual sales between $10,000 and $499,999) account for 36.6% of US agricultural production (Hoppe et al., 2010). In the US beef cow-calf industry, 90.4% of all US farms with beef cows in 2007 had fewer than 100 cows, and such farms had 45.9% of all US beef cows (NASS, 2007a). In the present study, 83.0% of the responding operations were beef cattle operations. Dairy operations with fewer than 500 cows accounted for 61% of US milk production in 2001 and 41% of US milk production in 2009 (NASS, 2010). Dairy operations were the second most common operation type in the present study (10.0% of respondents).

Operations were eligible to be selected for this study if the USDA NASS list frame indicated their gross annual farm sales were $10,000 to $499,999 between 2007 and 2009; however, 36.9% of operations reported sales of < $10,000 during 2010 on the survey questionnaire, and 69 operations were excluded from analysis because they reported sales of > $499,999 during 2010. Such findings were expected because farm sales vary among years. For many operations, recent economic conditions may have caused a decrease in animal numbers on the farm; therefore, gross sales may have declined since the time that list frame data were collected.

The percentage of operations that used a veterinarian varied with the primary animal species on an operation in this study; this finding indicated veterinarians have a larger role in production for certain food animal species than they do for others. Results indicated dairy operations were more likely to use a veterinarian compared with beef cattle operations. In 2006, 83.2% of dairy operations used veterinarians for detection of pregnancy in cows via palpation (USDA, 2009b), which was similar to the high percentage (88.5%) of dairy operations that used veterinarians in the present study. Veterinarians perform a wide variety of tasks other than detection of pregnancy via palpation for dairy and beef operations. However, results of this study indicated poultry operations were less likely to use a veterinarian compared with beef cattle operations. Survey data suggested that poultry operations were using contractor health management protocols. Because the US poultry industry is predominately structured in a vertically integrated manner, many producers raise birds under a contract with a company (MacDonald, 2008). Contractor protocols for bird health are typically established and overseen by a veterinarian. However, poultry producers typically interact with a farm manager rather than the company veterinarian, so they may have inadvertently under-reported veterinarian use.

Veterinarian use and distance to veterinarians varied with operation region in the US in this study. For example, a higher percentage of operations in the Northern Great Plains and Basin and Range regions were located 30 to 99 miles from the nearest veterinarian versus operations in other regions. This finding was not surprising considering that those regions have sparse populations and business firms for all economic sectors (defined by the USDA as a lack of urban influence); however, this finding was interesting because of the importance of pastureland and animal agriculture in those regions (Nickerson et al., 2011; NASS, 2007b). Despite the fact that veterinarians were farther away from operations in the Northern Great Plains and Basin and Range regions versus operations in other regions, operations in those regions were more likely to use veterinarians than producers in the Mississippi Portal, Southern Seaboard, and Eastern Uplands regions. Initially, regional differences in veterinarian use were thought to be related to differences in the types of animal species raised in different regions. However, when data in this study were adjusted for primary animal species and producer demographics in the multivariable model, regional differences in veterinary use were still detected. Most likely, there were unmeasured variables (e.g., cultural factors) that differed among operations in each region and were associated with high or low levels of veterinarian use. Such unmeasured variables may be important for understanding producers' decisions regarding veterinarian use and animal health decisions in general. Future research is warranted to further determine the reasons for such differences in veterinarian use among operations in various regions of the US.

Producers with a low level of education were less likely to use a veterinarian versus producers with a high level of education in this study, suggesting information regarding the importance of veterinary care for animals may not have effectively reached that group of producers, or that technical language in communications may have prevented veterinarian use by such producers. Moreover, low education levels may have been associated with low household incomes, which could have affected use of veterinarians. The inclusion of farm sales as a variable in the multivariable model partially adjusted for this potentially confounding variable. However, data regarding total household income (including income from off-farm sources) was not collected on the questionnaire in this study and may not have been strongly correlated with gross farm sales; therefore, it was difficult to completely assess the importance of education level and household income in decisions regarding veterinarian use. Because producers have a wide diversity of backgrounds, training for veterinarians regarding communication with producers of all educational levels may be warranted in continuing education conferences or veterinary school curricula (Turner and Belesky, 2010; Kleen et al., 2011).

Differences in veterinarian use between retirement farms and farming occupation farms detected in this study could have resulted from differences in producer age or economic motivations for farms or ranches operated for income versus those operated for enjoyment. In this study, 85.5% of respondents were ≥ 45 years old, and 34.8% were ≥ 65 years old. Results of other studies (NASS, 2007c; Hoppe et al., 2010) indicate that producers on small-scale operations are older than those on larger operations, and farm operators in general are older than self-employed workers in other industries. Therefore, producer age-related factors may be important regarding use of veterinary services by small-scale food animal operations.

Producer-reported distances to the nearest veterinarian were evaluated in this study to determine whether availability of veterinarians was an important factor affecting veterinarian use. Distance categories were provided on the questionnaire to improve the accuracy of the producers' responses. However, reporting bias could have occurred because producers may not have been aware of the locations of all nearby veterinarians. Most (82.1%) respondents reported the distance to the nearest veterinarian who worked with the type of animal on their operation was ≤ 29 miles.

Although only 1.4% of producers that responded to the survey of this study did not have access to a veterinarian within a 100-mile radius, such producers were broadly distributed among 40 US states. Of the estimated 341,107 small-scale food animal operations in the US, the estimated total number for which a veterinarian was ≥ 100 miles away or not available was 4,799 (95% CI, 3,833 to 5,765). Therefore, the results of this study indicated that thousands of small-scale producers have limited access to veterinarians, as suggested by authors of another report (NRC, 2012). This information may be useful in assessing potential shortages in the number of food animal veterinarians, because it provides a quantitative estimate of the number of producers who are geographically far from veterinarians who have the ability to care for their animals. However, the economic viability of veterinary practices in these potentially underserved areas could not be determined in this study; such information could be determined in future studies.

Similarly, investigators in another study (Jensen et al., 2009) identified veterinarian accessibility problems for livestock producers in Tennessee; results of that study indicated 3.0%

of producers surveyed during 2006 had a problem accessing veterinary services because no veterinarian was available with the skills to treat their animals. Tennessee is located in the Eastern Uplands and Mississippi Portal regions; results of the present study indicated 1.0% and 1.5% of producers in these regions, respectively, reported the nearest veterinarian for their type of animal was ≥ 100 miles away or not available. Therefore, results of that other study (Jensen et al., 2009) of Tennessee producers and those of the present study were similar, indicating a low percentage of producers did not have access to veterinary services in this area of the United States.

Operations located 30 to 99 miles from the nearest veterinarian were less likely to use veterinarians, compared with operations that had a veterinarian available ≤ 29 miles away in this study. This finding suggested that long distance may be an important barrier to veterinarian use. The lack of significant differences in comparisons regarding veterinarian use for operations located ≥ 100 miles from a veterinarian may have been attributable to the small sample size and resultant lack of statistical power, because only 0.6% of operations (n = 47) were ≥ 100 miles from the nearest veterinarian in this study. Also, fewer food animal operations may have stayed in business in regions with poor access to animal industry services, such as veterinarians, versus operations in other regions.

In this study, 38.3% of operations had not used a veterinarian within the 12 months prior to the survey. The most common reason for not using a veterinarian was that animals had no disease or there was no other need for a veterinarian. Animals in such herds may not have had disease. Alternatively, such producers may have perceived that animals did not have disease when, in fact, animals did have disease that the operator did not detect; if this situation were true, professional or government agencies could develop educational programs or communication strategies to instruct such producers regarding the value of routine veterinary care for animals. Educational efforts could be targeted toward producers with a low likelihood of veterinary use, such as those with old ages, only one animal type, low farm sales, or expected retirement from farming within 5 years. However, animals in such herds may not have had diseases. Producers with disease-free herds could be surveyed to determine who they would contact during unexpected animal disease outbreaks, their perceived need for veterinary services, and their frequency and reasons for veterinarian use.

The cost of veterinary care deterred only a small percentage of producers in this study from using a veterinarian. Of the 38.3% of operations that reported no use of a veterinarian during the 12 months prior to the survey, 12.5% indicated the reason was that veterinary services were too expensive. Overall, cost was a deterrent to use of veterinary services for only 4.8% of responding operations. This finding was similar to the finding of another study (Jensen et al., 2009) that only 6.1% of producers in Tennessee reported they had a problem accessing veterinary services because the cost of veterinary care was too high relative to an animal's value.

Results of this study indicated that multiple factors were associated with use of veterinarians by small-scale food animal operations, and information was determined regarding producers' perspectives about availability and use of veterinarians. The results also suggested that producers typically had adequate access to veterinarians during 2011, but there may have been localized shortages of veterinarians in some states.

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CHAPTER 3: SURVEY OF DISEASE PREVENTION PRACTICES ON UNITED STATES SMALL-SCALE FARMS AND RANCHES

3.1 SUMMARY

Objective—To describe factors affecting use of biosecurity practices on small-scale US animal operations.

Design—Cross-sectional descriptive survey.

Sample—16,000 small-scale farm or ranch operations in 50 US states.

Procedures—Data were collected using a cross-sectional mixed-mode (mail and phone) producer survey conducted by the United States Department of Agriculture's (USDA) National Animal Health Monitoring System in 2011. A stratified systematic sample of 16,000 operations in all 50 states was selected from a USDA National Agricultural Statistics Service list frame. Weighted population inferences were calculated to describe biosecurity practices.

Inference population for this chapter— Small-scale operations (gross annual agricultural sales between \$10,000 and \$499,999 during 2007-2009) in which an animal or animal product comprised the highest percentage of sales, including operations that raised horses and other non-food animal species.

Results—A total of 8,186 small-scale operations (response rate = 51.2%) completed the study questionnaire. All of these operations were eligible for analysis in this chapter. Among the estimated 43.3% (95% CI=42.2–44.5%) of operations that acquired new animals or had animals leave and return in the previous year, 40.3% (95% CI=38.6–42.1%) always quarantined the new or returning animals. The most common reason (65.3%, 95% CI=63.0–67.6%) for not quarantining was the producer trusted the source of the new animals or the place from which the

animals were returning. Over 70% of producers believed additional training in infectious disease management practices would be somewhat or very useful.

Conclusions—Biosecurity practices are important for preventing the spread of infectious animal diseases on farms and ranches. The results of this study are valuable for understanding disease transmission risk and planning educational campaigns on infectious disease control for farms and ranches.

3.2 INTRODUCTION

According to the National Association of State Departments of Agriculture:

> "Biosecurity itself is more than a buzzword; it is the vital work of strategy, efforts, and planning to protect human, animal, and environmental health against biological threats. The primary goal of biosecurity is to protect against the risk posed by disease and organisms; the primary tools of biosecurity are exclusion, eradication, and control, supported by expert system management, practical protocols, and the rapid and efficient securing and sharing of vital information. Biosecurity is therefore the sum of risk management practices in defense against biological threats (NASDA, 2001)."

Biosecurity practices on farming operations are intended to prevent the introduction of infectious disease and prevent the spread of endemic diseases on the farm (Dargatz et al., 2002). Biosecurity also has an important role in preventing the spread of a foreign animal disease (FAD) in the event of an outbreak. FAD outbreaks can have an enormous impact on individual producers and the economy, and can rapidly exhaust available resources. For example, the 2001 foot-and-mouth disease outbreak in the UK cost over 3 billion pounds (approximately 4.5 billion USD), and resulted in more than 6 million head of livestock being culled (NAO, 2002). Because trade relationships are often compromised when there are highly visible outbreaks, the economic losses can have effects beyond just infected animals. In the 2002–2003 US outbreak of exotic Newcastle disease, eradication required the euthanasia of 3.2 million birds at a cost of $160 million, and caused an estimated $121 million in trade losses (Hietala et al., 2004). Endemic diseases, such as bovine viral diarrhea and Johne's disease, also cause substantial economic losses in animal production (Hutchinson, 1996; Stott et al., 2003).

Examples of on-farm biosecurity measures include: keeping a closed herd in which animals from outside sources are not introduced; restrictions on sources for new animals; quarantine and testing of new animals; reducing contact with outside animals, such as rodents or animals from other operations; requiring disease-prevention precautions for human and vehicle traffic; not sharing farm equipment with other operations; and vaccination and herd health programs (USDA, 2009a).

Although biosecurity is important in preventing disease introduction, a low percentage of US livestock operations have adopted biosecurity practices such as standardized quarantine of new animals, and small-scale operations may be less likely to utilize biosecurity precautions (USDA, 2008; USDA, 2009a). Producer biosecurity attitudes had an association with the presence of infectious disease on a farm (Silverlas and Blanco-Penedo, 2012); however, few studies have explored the reasons for producer's biosecurity attitudes on small-scale operations. Therefore, the objectives of this study were to: 1) describe biosecurity practices on small-scale operations, 2) describe producer interest in biosecurity training and preferred channels for receiving information on biosecurity, 3) determine factors associated with consistently quarantining new or returning animals, and 4) describe producer's reasons for not using quarantine.

3.3 MATERIALS AND METHODS

Study population—The target population for this study was small-scale US agricultural operations in which an animal or animal product comprised the highest percentage of gross farm sales. Eligible operations raised beef cattle, dairy cattle, horses, swine, sheep, goats, poultry, or other farm animals for sale or home use. Operations were eligible for inclusion if the sampling list frame indicated they had gross annual farm sales from $10,000 to $499,999 during 2007 through 2009. Operations that were selected from the list frame based on these criteria were allowed to participate even if their 2010 sales fell outside of this range, since 2010 sales data were not collected until the sample was already chosen for the present study. Farms raising equids and other non-food-animal species were included in this analysis.

Study design—Data for this study were collected as part of a cross-sectional survey conducted by the US Department of Agriculture's (USDA) National Animal Health Monitoring System (NAHMS) and the National Agricultural Statistics Service (NASS) as described previously (Beam et al., 2013). Briefly, a stratified systematic sample of 16,000 operations in all 50 states was selected in January 2011 from a USDA–NASS list frame of US agricultural operations meeting the inclusion criteria for this study. The most recent NASS Census of Agriculture indicated 349,792 operations met the inclusion criteria (USDA, 2012). The four strata used for selection of operations included: 1) annual sales between $10,000 and $99,999 and one to three types of agricultural commodities produced; 2) sales between $10,000 and $99,999 and ≥four types of agricultural commodities produced; 3) annual sales between $100,000 and $249,999; and 4) annual sales between $250,000 and $499,999.

Data collection—Data collection procedures were previously described (Beam et al., 2013). To briefly summarize, a questionnaire was mailed to the 16,000 selected operations in April 2011. Nonrespondents to the mailing were contacted via telephone between April 14 and May 18, 2011, and surveys were completed via computer-assisted telephone interview software by personnel at the NASS Arkansas Data Collection Center. The survey questionnaire consisted of 35 multi-part questions in nine sections. Some sections of the questionnaire were designed to meet objectives unrelated to the present study; the full questionnaire is available (Appendix I).

This analysis focused on the following portions of the questionnaire. All respondents were asked dichotomous (yes/no) questions about the following biosecurity practices during the previous 12 months: having a fence around the entire perimeter of the livestock or poultry area that keeps out animals from other operations, animals having nose-to-nose contact with the same species of livestock from other operations along the fence, animals sharing a pasture at the same time with animals from other operations, addition of any new livestock or poultry, and having livestock or poultry that left the operation and returned. Producers who added new livestock/ poultry or had animals leave and return were asked a multiple-choice question about how often they isolated the new or returning animals (three categories—always; sometimes; or rarely or never). Respondents were provided with the following definition of isolation: "Isolate means to prevent nose-to-nose contact and to prevent the sharing of feed, drinking water, and equipment with other animals of the same species already present." Producers who sometimes or rarely/ never isolated animals selected reasons for not isolating from a list provided on the questionnaire (check all that apply), and had the option to write in other reasons.

In the ninth section of the questionnaire, data were collected on producers' interest in training in a variety of areas. Producers were asked a multiple-choice question about how useful they believed additional training in infectious disease management practices would be to themselves and their farm business—not, somewhat or very useful. The phrase "infectious disease management practices" was used instead of "biosecurity," because the term biosecurity may not be familiar to producers. Producers were also asked a question about how they would prefer to receive training or additional information (check all that apply)—through local extension office; presentation by expert; written publication; Internet; and/or livestock association/club.

Statistical analysis—Responding operations were categorized by primary animal species, geographic region, and farm sales for analysis and reporting. Primary animal species (swine, dairy cattle, beef cattle, sheep or goats, poultry, equine, or other) was determined by use of NASS list frame data and animal inventory data collected via the survey. Sheep and goat operations were combined into one category and bison operations were placed in the other category because a small number of farms had sheep, goats, or bison. The geographic region categories were determined on the basis of USDA–ERS farm resource regions (Figure 2.1). Alaska and Hawaii were not included in farm resource regions by the ERS. After consultation with an ERS economist about where those two states would best fit, operations in Alaska and Hawaii were classified in the Fruitful Rim region for this study.

Although farms were selected for participation in this study on the basis of 2007, 2008, and 2009 sales data, the 2010 sales data from the questionnaire were used for analysis because that information was the most current. Five categories of gross annual farm sales (<$10,000, $10,000 to $49,999, $50,000 to $99,999, $100,000 to $249,999, and ≥$250,000) were used for analysis because these were the *a priori* categories of interest. All producers who were selected for the study (based on having farm sales between $10,000 and $499,999 during 2007 through 2009) were allowed to participate, even if their annual farm sales at the end of 2010 were below $10,000 or above $499,999, because data were collected on biosecurity practices in the previous 12 months, at which time the operations were still classified as small-scale based on their annual 2009 sales.

Write-in comments of "other" reasons for not quarantining were subjectively categorized into six classes for reporting, including: use of all-in-all-out production; animals had health certificates, veterinary exams, tests for disease, or vaccinations; animals were returning from pasture or came from another operation under the same ownership; producer believed it wasn't necessary given the situation; never thought of it/just didn't isolate; and miscellaneous reasons.

Unweighted descriptive statistics were calculated to describe the sample of study respondents, using a commercial software program (SAS version 9.2). Respondent data were weighted to create population estimates for the target population of small-scale operations. The inverse of the probability of selection for each operation, which varied by stratum, was the initial analysis weight. This weight was adjusted for nonresponse by dividing the sum of weights for all operations by the sum of weights for respondent operations (including those with no animal inventory in the 12 months prior to the survey) within each of the strata. All weighted analyses were conducted using a commercial statistical software package which accounted for the survey design and weighting (SUDAAN software version 10, RTI International, Research Triangle Park, NC).

Weighted population estimates and 95% confidence intervals were calculated for the percentage of operations by use of biosecurity practices, producer interest in biosecurity training, and reasons for not using quarantine. Weighted chi-square analyses were conducted to evaluate for an association between producer interest in biosecurity training and region, and to evaluate for an association between producer education level and reasons for not using quarantine.

A weighted multivariable logistic regression analysis was performed to evaluate operation-level and producer-level factors associated with always quarantining new or returning animals. Respondents who "always" isolated animals were considered to have the outcome of interest, while respondents who "sometimes" or "rarely or never" isolated them were considered to lack the outcome of interest. Survey mode (telephone vs. mail) was considered as a confounder, but was not forced into the model. Other independent variables were offered for inclusion in the multivariable model if they had an association ($P \leq 0.25$) with quarantining in univariable logistic regression analyses. The farm typology variable was collinear with producer age; therefore, farm typology was initially offered for inclusion in the multivariable model. Farm typology was selected for inclusion in the model because that variable indicated the purpose of a farm, which may have been related to decisions regarding use of biosecurity practices. A backward stepwise elimination procedure was used to create the preliminary main effects model on the basis of adjusted Wald–F p-values. All variables that did not pass univariable screening ($P > 0.25$), and the producer age variable, were then offered one by one into the preliminary multivariable model, and retained in the model if statistically significant. First-order interactions between demographic variables (region, producer age, gender, race, and education level) were considered plausible and of *a priori* interest for targeting biosecurity education efforts. Therefore, these interactions were evaluated for any demographic variables that remained in the final main effects model. Interactions between other variables in the main effects model were not of *a priori* interest and were not evaluated. Variables and interactions with a P-value ≤ 0.05 were considered statistically significant. Model fit was assessed with the Hosmer-Lemeshow chi-square statistic. Logistic regression models were generated using a commercial statistical software package which accounted for the survey design and weighting (SUDAAN software version 10, RTI International, Research Triangle Park, NC).

3.4 RESULTS

A total of 8,186 small-scale operations (response "rate" = 51.2%) completed the study questionnaire. Surveys were completed via mail for 4,350 (53.1%) operations and via telephone interview for 3,836 (46.9%) operations. Unweighted descriptive statistics of study respondents are summarized in Tables 3.1 and 3.2.

Table 3.1—Description of sample: operation characteristics for respondents to a 2011 survey of small-scale operations in the US.

Operation Characteristic	Number	Percent
All respondents	8,186	100.0
Region		
Heartland	1,161	14.2
Northern Crescent	1,139	13.9
Northern Great Plains	356	4.3
Prairie Gateway	1,361	16.6
Eastern Uplands	1,839	22.5
Southern Seaboard	991	12.1
Fruitful Rim	637	7.8
Basin and Range	384	4.7
Mississippi Portal	318	3.9
Farm sales		
Less than $10,000	3,094	37.8
$10,000–$49,999	2,611	31.9
$50,000–$99,999	1,031	12.6
$100,000–$249,999	901	11.0
$250,000 or more	298	3.6
Not reported	251	3.1
Primary animal species		
Swine	99	1.2
Dairy cattle	792	9.7
Beef cattle	6,553	80.1
Sheep/goats	161	2.0
Horses/equine	264	3.2
Poultry	221	2.7
Other	96	1.2
Farm typology		
Farming occupation	2,757	33.7
Retirement farm	1,933	23.6
Residential/lifestyle or other type	3,340	40.8
Not reported	156	1.9

Table 3.2—Description of sample: producer demographics for respondents to a 2011 survey of small-scale operations in the US.

Producer* Demographics	Number	Percent
All respondents	8,186	100.0
Education level		
Less than high school diploma	702	8.6
High school diploma or GED	3,169	38.7
Some college (including Associate degree)	2,057	25.1
College graduate and beyond	2,048	25.0
Not reported	210	2.6
Gender		
Male	7,351	89.8
Female	670	8.2
Not reported	165	2.0
Race		
White	7,671	93.7
Black or African American	103	1.3
American Indian or Alaska Native	101	1.2
Other or multiracial	66	0.8
Not reported	245	3.0
Age (years)		
< 45	1,013	12.4
45 to 64	4,160	50.8
≥ 65	2,826	34.5
Not reported	187	2.3

*A producer was defined as the primary operator for a facility.

Biosecurity practices—Biosecurity practices of small-scale operations are summarized in Table 3.3. Open operations added new livestock or poultry in the 12 months before the survey, and/or had livestock or poultry leave and return in the 12 months before the survey. The estimated percentage of open operations varied by species and ranged from 39.3% of equine operations to over 60% of swine, sheep/goat, and poultry operations (Table 3.3). Across all small-scale operations, 43.3% were open operations. Among these, an estimated 40.3% (95% CI = 38.6–42.1%) always quarantined new or returning animals (Table 3.4), 11.7% (95% CI = 10.5–12.9%) sometimes quarantined them, and 48.0% (95% CI = 46.2–49.8%) rarely or never quarantined.

Table 3.3—Estimated percentage (using weights) of small-scale operations by biosecurity practices during the previous 12 months, by primary animal species on the operation.

	Primary animal species							
	Swine	Dairy cattle	Beef cattle	Sheep/goats	Horses/ equine	Poultry	Other	All
	Percent operations (95% confidence interval)							
Added new livestock/ poultry	61.3 (50.3-71.2)	38.6 (35.1-42.2)	38.2 (37.0-39.5)	57.4 (49.1-65.4)	33.8 (27.8-40.3)	67.9 (60.6-74.4)	40.7 (30.8-51.4)	39.3 (38.2-40.4)
Had livestock/poultry leave and return	17.4 (10.1-28.4)	16.9 (14.2-20.0)	12.8 (12.0-13.7)	28.1 (21.1-36.4)	23.8 (18.5-30.0)	10.3 (7.0-14.9)	20.8 (13.3-30.9)	13.9 (13.1-14.8)
Open operation*	63.3 (52.4-73.0)	45.8 (42.2-49.5)	41.9 (40.6-43.2)	63.3 (55.0-71.0)	39.3 (33.1-45.9)	68.9 (61.6-75.4)	46.7 (36.4-57.3)	43.3 (42.2-44.5)
Livestock/poultry shared a pasture at the same time with livestock/ poultry from other operations	4.7 (1.7-12.1)	6.7 (4.9-9.0)	8.7 (8.0-9.5)	12.6 (8.0-19.4)	8.0 (5.1-12.3)	1.4 (0.4-4.2)	7.4 (3.4-15.5)	8.4 (7.8-9.1)
Fencing biosecurity level†								
Perimeter fence with no fence-line contact	62.5 (52.0-72.0)	63.6 (59.9-67.1)	49.3 (48.0-50.5)	66.3 (57.8-73.9)	66.9 (60.4-72.8)	62.4 (55.3-69.1)	63.2 (52.4-72.9)	51.8 (50.7-52.9)
Perimeter fence with fence-line contact	7.3 (3.3-15.2)	21.1 (18.1-24.4)	46.2 (45.0-47.5)	24.6 (17.9-32.9)	24.4 (19.2-30.4)	15.4 (11.0-21.0)	11.5 (6.3-19.9)	41.9 (40.8-43.0)
No perimeter fence	30.2 (21.8-40.3)	15.3 (12.9-18.2)	4.5 (4.0-5.1)	9.1 (5.2-15.4)	8.7 (5.6-13.3)	22.2 (16.9-28.6)	25.3 (17.3-35.4)	6.3 (5.8-6.9)
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Added new livestock/poultry, or had livestock/poultry leave and return in past 12 months.
†**Perimeter fence with no fence-line contact** = Operation had a fence around the entire perimeter of the livestock or poultry area that keeps out animals from other operations, and there was NOT nose-to-nose contact with the same species of livestock from other operations anywhere along the fence. **Perimeter fence with fence-line contact** = Operation had a fence around the entire perimeter of the livestock or poultry area that keeps out animals from other operations, but there was nose-to-nose contact with the same species of livestock from other operations somewhere along the fence. **No perimeter fence** = Operation did not have a fence around the entire perimeter of the livestock or poultry area that keeps out animals from other operations.

Table 3.3 (continued)—Estimated percentage (using weights) of small-scale operations by biosecurity practices during the previous 12 months, by primary animal species on the operation.

	Primary animal species							
	Swine	Dairy cattle	Beef cattle	Sheep/goats	Horses/ equine	Poultry	Other	All
Animal types kept on operation	Percent operations (95% confidence interval)							
Swine	100.0 (-)	5.9 (4.4- 7.9)	3.9 (3.5- 4.4)	13.4 (8.7-20.1)	2.1 (0.9- 4.5)	6.0 (3.3-10.7)	2.1 (0.5- 9.1)	5.1 (4.7- 5.6)
Dairy cattle	3.8 (1.4- 9.6)	100.0 (-)	1.8 (1.5- 2.1)	5.2 (2.4-10.6)	0.7 (0.2- 2.2)	4.9 (2.6- 8.8)	0.0 (-)	8.5 (8.1- 9.0)
Beef cattle	31.6 (22.9-41.7)	26.2 (23.0-29.6)	100.0 (-)	26.1 (19.7-33.7)	8.2 (5.2-12.7)	42.9 (36.1-49.9)	9.4 (4.9-17.3)	87.2 (86.5-87.9)
Sheep/goats	8.2 (3.8-16.6)	9.2 (7.4-11.5)	8.3 (7.7- 9.0)	100.0 (-)	9.6 (6.7-13.6)	8.5 (5.1-13.9)	8.1 (3.8-16.3)	10.3 (9.7-11.0)
Horses/equine	22.1 (14.6-32.0)	27.8 (24.7-31.1)	36.4 (35.2-37.7)	40.6 (32.9-48.8)	100.0 (-)	24.2 (18.7-30.8)	23.5 (15.8-33.3)	37.8 (36.7-38.9)
Poultry	8.0 (3.9-15.5)	23.3 (20.4-26.6)	14.0 (13.2-14.9)	40.4 (32.8-48.6)	16.7 (12.6-21.8)	100.0 (-)	13.2 (7.5-22.2)	16.9 (16.1-17.8)
Other species	0.0 (-)	1.1 (0.6- 2.3)	1.9 (1.6- 2.3)	6.4 (3.4-11.6)	2.6 (1.2- 5.7)	3.1 (1.2- 8.2)	100.0 (-)	3.1 (2.8- 3.6)
Number of animal types§								
1	53.2 (42.5-63.5)	46.9 (43.3-50.5)	53.2 (51.9-54.5)	27.0 (20.2-35.2)	72.1 (66.1-77.5)	46.3 (39.3-53.5)	62.5 (51.9-72.1)	52.9 (51.8-54.1)
2	27.3 (18.9-37.6)	27.4 (24.3-30.8)	32.8 (31.6-34.0)	35.1 (27.7-43.4)	18.9 (14.3-24.5)	30.2 (24.4-36.6)	24.4 (16.3-34.9)	31.8 (30.7-32.9)
≥ 3	19.6 (12.8-28.8)	25.7 (22.6-29.0)	14.0 (13.2-14.8)	37.8 (30.4-45.9)	9.0 (6.1-12.9)	23.5 (17.9-30.3)	13.0 (7.5-21.6)	15.3 (14.5-16.1)
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

§Maximum of seven animal types: swine, dairy cattle, beef cattle, sheep/goats, horses/equine, poultry, other species.

Table 3.4—Estimated percentage (using weights) of open operations that always quarantined new or returning animals, and univariable analysis of **operation-level** factors associated with always quarantining.

Factor	n	Percent operations that always quarantined	95% confidence interval	*P* value
All open operations	3,535	40.3	38.6-42.1	
Primary animal species				<0.001†
Swine	60	63.1	49.6-74.9	
Dairy cattle	345	22.4	18.1-27.4	
Beef cattle	2,758	41.5	39.6-43.5	
Sheep/goats	94	46.1	35.7-56.7	
Horses/equine	95	33.8	24.5-44.6	
Poultry	139	41.2	32.6-50.4	
Other	44	43.2	28.6-59.2	
Number of animal types*				0.008†
1	1,487	37.4	34.7-40.1	
2	1,229	41.6	38.7-44.6	
≥ 3	819	44.2	40.5-47.9	
Region				0.002†
Heartland	553	42.0	37.6-46.5	
Northern Crescent	522	39.6	35.2-44.2	
Northern Great Plains	175	31.4	24.6-39.2	
Prairie Gateway	600	41.6	37.4-45.9	
Eastern Uplands	716	42.8	38.9-46.8	
Southern Seaboard	386	41.7	36.4-47.1	
Fruitful Rim	267	38.5	32.4-44.9	
Basin and Range	191	26.3	20.3-33.4	
Mississippi Portal	125	47.2	38.0-56.6	
Farm sales				0.078†
Less than $10,000	1,054	36.7	33.8-39.8	
$10,000–$49,999	1,160	42.2	39.1-45.3	
$50,000–$99,999	570	41.4	37.1-45.9	
$100,000–$249,999	486	42.7	38.2-47.4	
$250,000 or more	204	43.0	36.2-50.1	
Farm typology				0.240†
Farming occupation	1,340	41.1	38.3-44.0	
Retirement farm	609	37.2	33.2-41.4	
Residential/lifestyle or other type	1,541	41.2	38.6-43.8	
Used a veterinarian in last 12 months				0.459
Yes	2,600	40.8	38.8-42.9	
No	898	39.3	35.9-42.8	
Anyone in household earns income from an off-farm job				0.187†
Yes	2,358	41.1	39.0-43.3	
No	1,122	38.6	35.5-41.7	
Survey mode				<0.001†
Mail	1,879	36.7	34.3-39.1	
Phone	1,656	44.7	42.1-47.3	

*Maximum of seven animal types: swine, dairy cattle, beef cattle, sheep/goats, horses/equine, poultry, other species.
†Variables offered for inclusion in the multivariable model.

Across all operations in the population, therefore, an estimated 25.9% were open operations *and* sometimes, rarely or never quarantined new or returning animals.

Several other biosecurity practices are described in Table 3.3. For instance, less than 15% of operations across all animal species allowed their animals to share a pasture at the same time with animals from other operations (Table 3.3). Overall, an estimated 52.9% of operations raised only one animal type. But, again, there were differences across types of animal operations. For operations where small ruminants (sheep/goats) were the primary animal species, an estimated 37.8% raised at least two additional animal types in the 12 months prior to the survey (Table 3.3).

Producer interest in training on biosecurity—Producer interest in biosecurity training is summarized in Table 3.5 for all small-scale operations, and for the subset of operations that were open operations *and* sometimes, rarely, or never quarantined new or returning animals. Among this subset of operations, an estimated 76.1% of producers believed that additional training on infectious disease management (biosecurity) practices would be somewhat (48.7%) or very (27.4%) useful to themselves and their farm business (Table 3.5), and no significant differences were detected for producer interest in biosecurity training by region (chi-square = 0.574, df = 8, P value = 0.80). For all small-scale operations, 73.9% of producers believed that additional training on biosecurity would be somewhat (44.7%) or very (29.2%) useful to themselves and their farm business.

Of the 8,186 survey respondents, 7,554 (92.3%) answered the survey question about their preferred channels for receiving training or additional information. For about half of operations, the local extension office (56.1%) or written publications (49.4%) were preferred channels for receiving training or additional information (Table 3.6). Across types of operations, the highest percentage of beef cattle operations (57.0%) preferred to receive information from the local extension office. Over 40% of sheep/goat operations (45.2%), equine operations (46.3%), and operations raising other animal species (56.9%) indicated the Internet was a preferred channel for receiving training and additional information, compared to less than 30% of cattle and poultry operations (Table 3.6).

Table 3.5—Estimated percentage (using weights) of operations in which the producer believed that additional training in infectious disease management practices would be somewhat or very useful, by region, and by quarantine practices.

	Operations that did not quarantine animals*	Operations that were closed or quarantined animals†	All operations
n	2,041	5,658	7,905‡
	Percent operations (95% confidence interval)		
All regions	76.1 (74.1-78.1)	73.6 (72.3-74.8)	73.9 (72.8-74.9)
Region			
Heartland	74.8 (69.4-79.5)	71.4 (67.9-74.7)	71.9 (69.0-74.6)
Northern Crescent	75.2 (69.9-79.8)	71.5 (67.8-74.8)	72.0 (69.0-74.8)
Northern Great Plains	76.9 (67.7-84.2)	80.4 (74.4-85.3)	78.3 (73.4-82.5)
Prairie Gateway	77.3 (72.0-81.9)	75.3 (72.2-78.1)	75.4 (72.8-77.8)
Eastern Uplands	74.7 (69.7-79.1)	73.8 (71.2-76.3)	73.8 (71.5-76.0)
Southern Seaboard	79.1 (72.4-84.5)	71.8 (68.0-75.4)	73.1 (69.8-76.1)
Fruitful Rim	80.4 (72.6-86.3)	74.3 (69.6-78.4)	75.4 (71.5-78.9)
Basin and Range	71.7 (62.7-79.3)	75.1 (68.3-80.9)	74.2 (69.0-78.8)
Mississippi Portal	74.7 (61.6-84.4)	73.9 (67.5-79.5)	74.0 (68.4-78.9)

*The subset of operations that were open operations *and* sometimes, rarely or never quarantined new or returning animals in the 12 months prior to the survey.
†The subset of operations that were either closed operations, or were open operations that always quarantined new and returning animals in the 12 months prior to the survey.
‡ Includes 206 operations that could not be classified with regard to use of quarantine because of missing data on questionnaire. There were 281 operations with missing data on producer interest in biosecurity training.

Table 3.6—Estimated percentage (using weights) of operations by preferred channels for receiving training or additional information, by primary animal species on the operation.

	Primary animal species							
	Swine	Dairy cattle	Beef cattle	Sheep/ goats	Horses/ equine	Poultry	Other	All operations
Channel	Percent operations (95% confidence interval)							
Local extension office	51.5 (40.6-62.2)	52.2 (48.4-56.1)	57.0 (55.7-58.4)	50.1 (41.5-58.7)	47.5 (40.6-54.5)	59.7 (52.2-66.8)	42.1 (30.8-54.2)	56.1 (54.9-57.3)
Presentation by expert	34.8 (25.2-45.9)	27.3 (24.0-30.9)	24.3 (23.2-25.5)	30.9 (23.5-39.3)	24.6 (19.0-31.2)	25.3 (19.3-32.3)	38.9 (28.5-50.5)	24.9 (23.9-26.0)
Written publication	50.3 (39.5-61.1)	52.1 (48.3-56.0)	49.5 (48.1-50.8)	51.1 (42.4-59.6)	45.1 (38.1-52.2)	44.7 (37.4-52.3)	49.1 (37.3-61.0)	49.4 (48.2-50.7)
Internet	39.5 (29.1-50.9)	24.2 (21.1-27.7)	28.8 (27.6-30.0)	45.2 (36.8-53.9)	46.3 (39.4-53.4)	29.7 (23.0-37.3)	56.9 (44.8-68.3)	29.8 (28.7-31.0)
Livestock association/club	17.9 (10.9-27.9)	14.7 (12.2-17.7)	22.5 (21.4-23.7)	25.9 (19.0-34.4)	21.0 (15.7-27.5)	16.0 (11.6-21.8)	26.0 (17.0-37.6)	21.9 (20.9-22.9)

Factors affecting utilization of quarantine—Results of univariable analysis on factors associated with always quarantining new or returning animals are summarized in Tables 3.4 and 3.7. When evaluating multiple factors affecting use of quarantine, seven variables were associated with always isolating new or returning animals (Table 3.8). Compared with beef cattle operations, dairy cattle operations were less likely to quarantine new or returning animals (OR = 0.29; $P < 0.001$), and swine operations were more likely to quarantine them (OR = 1.86; $P = 0.046$; Table 3.8). Operations in the Northern Great Plains (OR = 0.42, $P = 0.002$) and Basin and Range (OR = 0.36, $P < 0.001$) regions were less likely to always quarantine animals, compared with operations in the Mississippi Portal region. Producer gender was borderline significant ($P = 0.052$); female producers were more likely to use quarantine than male producers (OR = 1.32). Producers who preferred to receive training or information from a presentation by an expert were more likely to always isolate new or returning animals than producers who did not prefer this channel for receiving information or training (OR = 1.34, $P = 0.001$). Producers who completed telephone surveys were more likely to report the use of quarantine than producers who completed mail surveys. The Hosmer-Lemeshow chi-square statistic did not indicate a significant lack of fit for the model ($P = 0.65$). The interaction of region with gender was evaluated and was not statistically significant.

Reasons for not using quarantine—Among the 2,041 operations that were open operations and sometimes, rarely, or never quarantined new or returning animals, 1,937 (94.9%) answered the survey question about reasons for not quarantining animals. Reasons for not quarantining animals are summarized in Table 3.9. Among the subset of operations that were open operations and sometimes, rarely, or never quarantined new or returning animals, an

Table 3.7—Estimated percentage (using weights) of open operations that always quarantined new or returning animals, and univariable analysis of **producer-level*** factors associated with always quarantining.

Factor	n	Percent operations that always quarantined	95% confidence interval	*P* value
All open operations	3,535	40.3	38.6-42.1	
Gender				0.118†
Male	3,195	39.8	38.0-41.7	
Female	296	44.8	38.9-51.0	
Age				0.218†
< 45	588	41.0	36.7-45.4	
45 to 64	1,973	41.6	39.3-44.0	
≥ 65	920	37.9	34.6-41.4	
Race				0.422
White	3,371	40.2	38.5-42.0	
Other	91	44.7	34.2-55.8	
Education level				0.149†
Less than high school diploma	265	34.2	28.1-40.8	
High school diploma or GED	1,283	39.6	36.7-42.5	
Some college (including Associate degree)	944	40.8	37.5-44.2	
College graduate and beyond	988	42.5	39.2-45.9	
Producer expects to continue farming over the next 5 years				0.099†
Yes	3,239	40.6	38.8-42.5	
No	211	34.5	28.0-41.6	
Prefer to receive training via presentation by expert				<0.001†
Yes	997	46.4	43.0-49.8	
No	2,366	38.7	36.6-40.8	
Prefer to receive training through local extension office				0.119†
Yes	1,865	42.2	39.8-44.6	
No	1,498	39.3	36.7-42.0	
Prefer to receive training via written publication				0.219†
Yes	1,708	42.0	39.5-44.6	
No	1,655	39.8	37.2-42.3	
Prefer to receive training via Internet				0.410
Yes	1,079	42.0	38.8-45.2	
No	2,284	40.4	38.2-42.6	
Prefer to receive training via a livestock association or club				0.029†
Yes	832	44.4	40.8-48.1	
No	2,531	39.7	37.7-41.8	

*A producer was defined as the primary operator for a facility.
† Variables offered for inclusion in the multivariable model.

Table 3.8—Multivariable analysis (using weights) of factors associated with always quarantining new or returning animals in the previous 12 months (n = 3,300 small-scale operations).

Factor	Odds ratio	OR 95% CI	*P* value
Primary animal species			<0.001
Swine	1.86	1.01-3.41	0.046
Dairy cattle	0.29	0.20-0.41	<0.001
Beef cattle	Referent		
Sheep/goats	1.16	0.73-1.83	0.540
Horses/equine	0.72	0.43-1.20	0.209
Poultry	0.80	0.51-1.24	0.314
Other	1.14	0.60-2.19	0.689
Number of animal types*			0.007
1	Referent		
2	1.24	1.03-1.48	0.022
≥ 3	1.36	1.11-1.67	0.003
Region			<0.001
Heartland	0.86	0.55-1.35	0.514
Northern Crescent	1.05	0.65-1.67	0.851
Northern Great Plains	0.42	0.24-0.72	0.002
Prairie Gateway	0.84	0.54-1.30	0.430
Eastern Uplands	0.96	0.62-1.48	0.852
Southern Seaboard	0.90	0.57-1.44	0.672
Fruitful Rim	0.69	0.42-1.13	0.138
Basin and Range	0.36	0.21-0.62	<0.001
Mississippi Portal	Referent		
Farm sales			0.001
Less than $10,000	Referent		
$10,000–$49,999	1.26	1.04-1.53	0.019
$50,000–$99,999	1.45	1.13-1.86	0.003
$100,000–$249,999	1.70	1.31-2.21	<0.001
$250,000 or more	1.42	0.99-2.04	0.058
Producer† gender			0.052
Male	Referent		
Female	1.32	1.00-1.74	
Prefer to receive training via presentation by expert			0.001
Yes	1.34	1.13-1.59	
No	Referent		
Survey mode			<0.001
Mail	Referent		
Phone	1.43	1.22-1.67	

*Maximum of seven animal types: swine, dairy cattle, beef cattle, sheep/goats, horses/equine, poultry, other species.
†A producer was defined as the primary operator for a facility.
CI = confidence interval.

Table 3.9—Estimated percentage (using weights) of operations by reason(s)* for **not** quarantining new or returning animals, by primary animal species on the operation.

	Primary animal species							
	Swine	Dairy cattle	Beef cattle	Sheep/ goats	Horses/ equine	Poultry	Other	All
Reason*	Percent operations (95% confidence interval) †							
Do not have a separate enclosure or extra equipment	34.8 (17.2-57.8)	48.2 (41.6-54.8)	26.9 (24.5-29.5)	20.6 (10.8-35.5)	16.1 (8.1-29.4)	15.1 (9.0-24.2)	27.2 (12.3-49.8)	28.1 (26.0-30.3)
Trust the source of the new animals, or the place from which they are returning	40.2 (22.2-61.3)	55.9 (49.2-62.4)	67.9 (65.2-70.5)	63.7 (47.9-77.0)	65.8 (50.9-78.2)	39.6 (29.6-50.5)	54.5 (33.8-73.8)	65.3 (63.0-67.6)
Inadequate labor or time	8.5 (2.1-28.9)	12.8 (9.0-17.9)	10.8 (9.2-12.7)	15.9 (7.5-30.7)	4.8 (1.5-14.8)	2.0 (0.5- 7.6)	7.9 (1.8-28.8)	10.6 (9.2-12.2)
Don't believe isolation is beneficial or prevents disease	4.7 (0.7-26.5)	8.5 (5.4-12.9)	4.9 (3.9- 6.2)	8.5 (3.4-19.4)	2.2 (0.3-14.1)	5.3 (2.3-12.1)	16.4 (5.9-38.2)	5.4 (4.5- 6.6)
Other reasons	30.2 (15.4-50.5)	10.7 (7.0-16.1)	8.0 (6.6- 9.6)	11.6 (4.5-26.9)	22.4 (12.1-37.8)	43.7 (33.4-54.6)	32.7 (16.4-54.6)	10.4 (9.0-12.0)

*Producers could select more than one reason.

†Table includes only operations that were open operations *and* sometimes, rarely or never isolated/quarantined new or returning animals in the 12 months prior to the survey.

estimated 65.3% of producers indicated they did not quarantine because they trust the source of the new animals, or the place from which the animals are returning. For operations that primarily raised swine, poultry, or "other" species, over 30% of operations in this subset wrote in other reasons for not quarantining (Table 3.9). For swine and poultry operations, the most common write-in reason for not quarantining was use of all-in-all-out production (Table 3.10). Across all operation types, 5.4% of non-users of quarantine indicated they did not believe isolation was beneficial or prevented disease (Table 3.9). Producers who did not complete high school were more likely (chi-square = 9.32, df = 1, *P* value = 0.002) to cite lack of belief in the benefit of isolation (13.8%, 95% CI = 9.1–20.5%) than producers who completed high school or higher education (4.6%, 95% CI = 3.7–5.8%).

Table 3.10—Summary of "other" reasons for not quarantining written in by producers, by primary animal species on the operation.

	Primary animal species			
"Other" reason	Dairy cattle	Beef cattle	Swine or poultry	All other species
	Number mentioning this other reason			
Use of all-in-all-out production	1	16	36	0
Animals had health certificates/ veterinary exams / tests for disease / vaccinations	3	16	1	3
Returning from pasture or came from another operation under the same ownership	2	17	0	0
Producer believed it wasn't necessary given the situation	7	9	4	7
Never thought about it / just didn't isolate	4	4	1	0
Miscellaneous reasons	6	52	2	12
Total number written comments	23	114	44	22

3.5 DISCUSSION

Biosecurity practices are an important tool for protecting animal health on farms and ranches. Addition of new animals and direct contact with outside animals at events are common sources for potential disease introduction (Sanderson et al., 2000; Wells, 2000; Casal, 2007; Dunowska et al., 2007; Villarroel et al., 2007). In this study, less than half (43.3%) of small-scale operations had either of these types of exposures during the 12 months prior to the survey. This is consistent with previous literature in which smaller operations were less likely to add new animals than larger operations (USDA, 2009b, 2011; Traub-Dargatz et al., 2012).

In this study, producers were not asked to specify the type of animal species that was added or left and returned. Many small-scale operations (47.1%) raised more than one animal type. Therefore, operations in which beef cattle were the primary animal species may have added sheep, poultry, horses, or a different species. Previous studies have focused specifically on movement of one animal type (USDA, 2007, 2009a). For example, in a study of cow-calf operations, only 5.4% of operations had any cattle leave the operation and return in 2007 (USDA, 2009a). In the present study, 12.8% of beef cattle operations had animals leave and return in the 12 months prior to the survey. Results from this study are useful for measuring the overall risk for introduction of diseases that are transmissible between species, since it includes movements for all farm animal species. For instance, adding a goat with Johne's disease or foot and mouth disease to a beef cattle operation could also affect the cattle on the operation. However, the disease risk may be overestimated in this study since addition of a given species of animal may not have plausible disease implications for other species.

Contact with outside animals along fence lines or in shared pastures can also spread infectious diseases. In the present study, approximately half of small-scale operations lacked fencing around the entire perimeter of their livestock/poultry area, or had fencing but reported fence-line contact with outside animals. A relatively high percentage of swine operations (30.2%), poultry operations (22.2%) and operations raising "other" species (25.3%) lacked a perimeter fence around the animal area in this study. However, poultry and swine are typically raised in barns which prevent exposure to wildlife and domestic animals from other farms. Fencing is not as important for preventing disease spread on operations where animals are raised in barns (USDA, 2012). Fencing is also less applicable to operations that raise certain "other" species, such as aquaculture in ponds.

Results of this study were based on biosecurity practices reported by producers on a survey, rather than observation of actual producer biosecurity behavior. One limitation of these data was the possibility of reporting bias, since producers may have over reported use of practices, especially if they believed they should be using them or felt guilty about not using them. For instance, Nespeca et al. (1997) found disagreement when comparing producer responses on a questionnaire about biosecurity practices to actual biosecurity behavior on poultry farms; disagreement was 28–37% per farm.

In this study, we found that survey mode had a significant association with use of quarantine in the multivariable model. Producers who responded by mail were less likely to report use of quarantine, which suggested telephone respondents may have felt social pressure to give the "right" answer or to answer in a way that would please the interviewer in our study. In other research, respondents sometimes gave more positive responses on telephone surveys than on mail surveys (McHorney et al., 1994; Powers et al., 2005; Feveile et al., 2007); however, Feveile et al. (2007) found agreement in responses across telephone and mail surveys for questions about health-related behavior. In this study, we kept the survey mode variable in the final multivariable model to control for confounding.

Among small-scale operations that acquired new animals or had animals leave and return in this study, less than half (40.3%) always quarantined the new or returning animals to reduce the risk of disease introduction. Producers who always quarantined were more diversified (raised multiple animal types), had higher annual farm sales, and had a preference to receive training or information for their farming business via a presentation by an expert. This suggests in-person training may be an effective method for convincing producers to adopt biosecurity measures because it allows one-on-one interaction. In a study on compliance with health recommendations by human patients, social factors had a greater role in compliance than factual information (Clark et al., 2012). Alternatively, there could have been a confounding variable that was not included in our analysis. For instance, producers who prefer presentations by experts may have been more risk averse or may have possessed another personality trait that was associated with use of quarantine. The increased use of quarantine with higher farm sales in this study was consistent with previous studies in which larger operations were more likely to use biosecurity practices (USDA, 2008, 2009a). The reason for the association between diversification (raising multiple animal types) and use of quarantine in this study was less clear.

In this study, dairy operations were less likely to quarantine new or returning animals than beef cattle operations. Quarantine may have been more difficult for dairy operations because of the necessity to use shared milking facilities. In 2006, the cattle classes most commonly acquired by small-scale dairy operations were lactating cows and dairy bulls (USDA, 2007). In the present study, about half of dairy operations that did not quarantine reported that a lack of separate facilities was a reason for not quarantining.

Female producers were more likely (44.8%) to use quarantine than male producers (39.8%) in our study, though the association was only borderline significant in the multivariable model ($P = 0.052$). In one study, use of biosecurity practices was higher among people who were risk averse in general (Valeeva et al., 2011), and women may be more risk averse than men (Rosen et al., 2003). Rosen et al. (2003) also found higher risk aversion by race and education level, but these two factors were not significantly associated with use of quarantine in this study.

Based on our findings, producers in the Northern Great Plains and Basin and Range regions were less likely to use quarantine (31.4 and 26.3% of operations, respectively, always isolated new or returning animals), compared with the other regions (where 38.5 to 47.2% of operations always quarantined). Therefore, educational outreach may be needed, especially in these two regions. Among producers who did not quarantine, over 70% believed that additional training in infectious disease management practices would be somewhat or very useful to themselves and their farm business. This suggested that producers are open to learning more about biosecurity. The question about usefulness of training was placed in the ninth section of the questionnaire, after producers had answered a number of other questions about biosecurity and animal health. Therefore, the results of this question may have been biased because producers' perception of the usefulness of training on infectious disease management might have been lower if this question had been asked in isolation. Nonetheless, the high percentage who believed training would be useful suggested that most producers are interested in the topic, once they are thinking about it.

This study provided valuable information on channels for delivering information to producers. The local extension office or written publications were preferred channels for about half of producers. Other studies have suggested that education on biosecurity needs to come from a source that the producer trusts and that government documents may be ineffective (Heffernan et al., 2008; Palmer et al., 2009). Producers were not asked if they would prefer to receive training from their private veterinarian in this study, but veterinarians can be integral in prompting producers to implement biosecurity practices (Ellis-Iversen et al., 2010; Marvin et al., 2010; Young et al., 2010). Interestingly, use of a veterinarian in the previous 12 months was not associated with use of quarantine in this study. This suggested that either veterinarians did not routinely discuss or recommend quarantine or that producers did not take their veterinarian's advice on quarantining. Veterinarians in Great Britain were skeptical about their clients' willingness to adopt biosecurity practices and felt that more evidence was needed to demonstrate the economic advantages of the practices (Gunn et al., 2008). Veterinarians may be in the best position to educate producers on biosecurity, so future research is needed to determine if US veterinarians are educating producers on the topic, and if not, why not.

This study also described producer's reasons for not using quarantine. Educational campaigns targeting nonadopters of quarantine should be based upon producers' reasons for not using the practice. The most common reason was the producer trusted the source of the animals or the place from which the animals were returning. Very few of the nonusers of quarantine reported they lacked belief in the benefit or effectiveness of quarantine. Therefore, educational campaigns emphasizing the scientific merit of quarantine may be ineffective, since our results indicated most nonadopters already believed it is beneficial. Education on which types of animal sources are and are not "trustworthy" may be more useful in changing producer behavior with regard to quarantine of new animals.

In summary, biosecurity practices are critical for preventing the spread of endemic and foreign animal infectious diseases. This study provided nationally representative data on biosecurity practices used by small-scale operations across a variety of animal species; these data are useful for planning and preparing for FAD outbreaks and for evaluating the need for producer education on infectious disease control. Temporary quarantine is a key biosecurity practice for new herd additions and animals returning from events, because new or returning animals are common sources for potential spread of infectious diseases. Despite the importance of quarantine, less than half of small-scale operations that had new or returning animals isolated them. This study identified several factors associated with use of quarantine, which can be used to target education and understand high-risk demographics for disease transmission in the event of an FAD or emerging infectious disease. Data on producers' reasons for not using quarantine and preferred training channels can be used for designing more effective educational campaigns and to guide future targeted studies exploring producers' decisions about infectious disease prevention practices.

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CHAPTER 4: DISTANCE TO SLAUGHTER FACILITIES, MARKETS, AND FEED SOURCES USED BY SMALL-SCALE US FOOD ANIMAL OPERATIONS

4.1 SUMMARY

Objective—To describe the spatial distribution of small-scale US food animal operations across geographic regions and the rural-urban continuum, and describe movement distances for animals, products, and feed.

Design—Cross-sectional descriptive survey.

Sample—16,000 small-scale farm or ranch operations in 50 US states.

Procedures—Data were collected using a cross-sectional mixed-mode (mail and phone) producer survey conducted by the United States Department of Agriculture's (USDA) National Animal Health Monitoring System in 2011. A stratified systematic sample of 16,000 operations in all 50 states was selected from a USDA National Agricultural Statistics Service list frame. Producers were asked about the farthest one-way distance (in miles) to slaughter facilities, destinations where they sold animals or products, and feed sources. Descriptive statistics were calculated to describe movement distances, and weighted population estimates were generated to describe the spatial distribution of operations and animals across geographic regions and the rural-urban continuum.

Inference population for this chapter— Small-scale operations (gross annual agricultural sales between \$10,000 and \$499,999 during 2007-2009) that had at least one head of a major food animal species (beef cattle, dairy cattle, swine, poultry, sheep or goats).

Results—A total of 8,186 small-scale operations (response rate = 51.2%) completed the study questionnaire. Of these, 7,925 operations had at least one head of a major food animal species, and thus were eligible for analysis in this chapter. About half of eligible operations (51.0%,

n=4,044) were mixed operations that raised more than one animal type, and 42.0% of respondents (n=3,329) raised only beef cattle. The remaining operations raised dairy cattle, swine, poultry or small ruminants. The median value for the farthest distance for movements of animals, products, and feed was ≤ 35 miles, but some movements were over long distances (2,500 miles). Across all small-scale operations, 75% of operations reported the farthest distance animals or products were transported for sale was 60 miles or less, and 95% of operations reported 150 miles or less. For distance to slaughter facilities, 75% of operations reported the farthest distance was 40 miles or less, and 95% of operations reported 90 miles or less.

Conclusions— For most animal species, estimated geographic distribution was consistent with the distribution of commodity production across all operation sizes in the US. However, small-scale dairy operations were primarily located in the Northern Crescent region, even though the majority of US milk is produced in California. Operations were distributed across the entire rural-urban continuum, from highly rural to highly urban counties. The results of this study are an important tool for better understanding disease spread dynamics for this segment of the industry, and for informing disease spread models.

4.2 INTRODUCTION

Although there has been a shift toward larger farm sizes in the US, the majority of US farms have gross annual sales <\$500,000 (Hoppe, 2010). Therefore, these operations should not be overlooked when planning and preparing for animal disease outbreaks. In addition, operations with sales <\$50,000 located near urban centers produce most of the locally-marketed food in the United States (Martinez et al., 2010). Local food systems are a growing phenomenon and are gaining support from Federal, State and local governments (Martinez et al., 2010; Lewis and Peters, 2012). Because of consumer and government interest in small-scale operations, and their potential role in livestock disease spread, this study was conducted to characterize spatial aspects of small-scale US food animal operations.

Stochastic models have become an important tool in epidemiologic and economic modeling of disease outbreaks (e.g., Schoenbaum and Disney, 2003; Karsten et al., 2005; Patyk et al., 2013). Parameterization of the models requires data on geographic locations of farms. The United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) publishes the spatial distribution of operations and animals by commodity for all operation sizes (USDA-NASS, 2007). However, regional distribution may differ between large-scale and small-scale operations. For example, in 2006 the majority of US milk was produced in California by large-scale dairy operations; while most small-scale dairy operations were located in the Northeastern US (MacDonald, 2007). Understanding the geographic distribution of small-scale operations is important in planning for animal disease outbreaks, informing disease spread models, and selecting areas to focus foreign animal disease (FAD) educational campaigns targeted at these producers. Urban proximity for livestock operations may also play a role in FAD spread, since commerce and trade are more concentrated in urban areas. For example, the metropolitan areas of New York City and Baltimore were considered high risk areas for introduction of Rift Valley Fever because of their port locations for international trade, as well as climate and other factors (Konrad and Miller, 2012).

Parameterization of disease spread models also requires data on frequency and distance for contacts between premises. Ideally, these data would describe movements for a variety of animal species and for different regions of the US. Several reports have been published on distances animals were shipped from one operation to another for breeding or feeding (Forde et al., 1998; Shields and Mathews, 2003; Wayne, 2011; Lindstrom et al., 2013). Other types of movements, such as movement of animals to markets or slaughter facilities and movement of animal feed, have not been as well documented in the US (Lindstrom et al., 2013). These types of movements could be important in disease spread. For instance, contaminated feed has been linked to outbreaks of bacterial (Moreno-Lopez, 2002; Wagner et al., 2005; Osterberg et al., 2006; Torres et al., 2011; Fasanella et al., 2013; Koyuncu et al., 2013), parasitic (Jenkins et al., 2013) and prion diseases (Windl and Dawson, 2012). Feed delivery trucks were identified as a likely mechanism for spread of avian influenza between poultry operations (Dorea et al., 2010). In the 2001 outbreak of foot and mouth disease (FMD) in the UK, sheep movements through livestock markets were implicated in causing the widespread dissemination of the disease (NAO, 2002). Long-distance transport to markets increases the risk of wide geographic spread of an epidemic disease (Ferguson et al., 2001; Shields and Mathews, 2003).

Thus, this study aims to describe spatial dimensions of movements on small-scale US food animal operations. This study had three specific objectives: 1) to describe distances to animal feed sources and locations where animals or products were sold, 2) to describe distances to slaughter facilities, and 3) to estimate the spatial distribution of small-scale operations and animals on these operations across geographic regions and the rural-urban continuum. This information is needed to better understand disease dynamics for this segment of the industry, to parameterize disease spread models, and to understand the proximity of small-scale operations to common destinations utilized in agricultural production and marketing.

4.3 MATERIALS AND METHODS

Data sources—The data analyzed in the present study were collected as part of a larger cross-sectional survey conducted by the USDA's National Animal Health Monitoring System (NAHMS) and NASS as described previously (Beam et al., 2013). Farms were eligible to be included in the NAHMS survey if they met the following inclusion criteria: 1) farms had gross annual sales from $10,000 to $499,999 during 2007 through 2009, and 2) an animal or animal product comprised the highest percentage of their gross annual farm sales.

Study design and data collection—Study design and data collection procedures were described previously (Beam et al., 2013). Briefly, a stratified systematic sample of 16,000 operations in all 50 states was selected in January of 2011 from a USDA NASS list frame of US agricultural operations meeting the inclusion criteria for the NAHMS survey. The most recent NASS Census of Agriculture indicated 349,792 operations met these inclusion criteria (USDA, 2012). A questionnaire was mailed to the 16,000 selected operations in April of 2011. Non-respondents to the mailing were contacted via telephone between April 14 and May 18, 2011, and surveys were completed via computer-assisted telephone interview software by personnel at the NASS Arkansas Data Collection Center.

Inclusion criteria for this study—The target population for the present study was a subset of the population targeted in the NAHMS survey. Specifically, this study focused on operations that had at least one head of a major food animal species (beef cattle, dairy cattle, swine, poultry, sheep or goats). Operations that exclusively raised other farm animal species, such as horses, were not part of the objectives of this study and were excluded from analysis.

Survey instrument—The full survey questionnaire consisted of 35 multi-part questions in 9 sections (Appendix I). The questionnaire included a question about the total dollar value of agricultural products sold from the operation in 2010 (gross sales—the total of all sales before subtracting expenses or payment of taxes). Information on animal inventory during the 12 months prior to the survey was also collected on the questionnaire. Producers were asked questions to determine if they used a slaughter facility, transported animals or products to sell them (e.g., to auction, other farms, fair, farmer's market), obtained feed that was transported/ shipped by a supplier, or obtained feed that was transported to the operation by the producer. Producers were also asked to report the farthest one-way distance (in miles) to slaughter facilities, destinations where they sold animals or products, and feed sources (separately for feed shipped by a supplier and feed transported to the operation by the producer).

Statistical analysis—Operations were categorized based on animal type, farm sales, geographic region and rural-urban continuum (RUC) code for analysis and reporting. In order to describe movement distances separately for each animal type, operations that raised only one animal type were classified into one of five categories: beef cattle, dairy cattle, swine, poultry, and sheep/goats. Sheep and goats were considered one animal type. All operations that raised more than one animal type were classified into a single animal type category called "mixed operations." Operations that exclusively raised other animal species (e.g., horses, bison) were excluded from analysis (see inclusion criteria). The questionnaire collected data on farm sales in 2010 as an outcome variable. Farms were classified into five farm sales categories based on 2010 sales (less than $10,000, $10,000 to $49,999, $50,000 to $99,999, $100,000 to $249,999, and $250,000 or more). The geographic region categories were based on USDA ERS Farm Resource Regions (Figure 2.1). RUC codes (Table 4.1) were assigned to each operation using the farm's county location (from the sampling list frame) and RUC datasets available from the USDA Economic Research Service (ERS).[6] RUC codes were published in 2003 based on 2000 census data; codes from the 2010 census were not available at the time of analysis.

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[6] RUC datasets available at: http://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx

Table 4.1—Rural-urban continuum (RUC) codes, 2003.

Code	Description
	Metro Counties:
1	Counties in metro areas of 1 million population or more
2	Counties in metro areas of 250,000 to 1 million population
3	Counties in metro areas of fewer than 250,000 population
	Nonmetro Counties:
4	Urban population of 20,000 or more, adjacent to a metro area
5	Urban population of 20,000 or more, not adjacent to a metro area
6	Urban population of 2,500 to 19,999, adjacent to a metro area
7	Urban population of 2,500 to 19,999, not adjacent to a metro area
8	Completely rural or less than 2,500 urban population, adjacent to a metro area
9	Completely rural or less than 2,500 urban population, not adjacent to a metro area

a. Descriptive statistics

Unweighted descriptive statistics were calculated to describe the sample of study respondents by survey response mode (phone vs. mail), animal type, farm sales, geographic region and RUC code. Descriptive statistics were also calculated for the following continuous variables: herd or flock size, and distance (miles) for movements of animals, products and feed. Descriptive statistics and box and whisker plots were generated using a commercial statistical software package (SAS Version 9.2, RTI International, Research Triangle Park, NC).

b. Population inferences

Respondent data were weighted to create population estimates for the distribution of operations across geographic regions and RUC codes. The inverse of the probability of selection for each operation was the initial analysis weight. This weight was adjusted by the sum of weights for all operations divided by the sum of weights for respondent operations (including those with no animal inventory in the 12 months prior to the survey), within each of the strata. To describe the number and percentage of animals by geographical region and RUC code, animal-level weights for each animal type were created by multiplying the operation weight by the respective animal inventory (number of head) from the questionnaire. Population estimates and 95% confidence intervals were generated using a commercial statistical software package that accounts for the survey design and weighting (SUDAAN software Version 10, RTI International, Research Triangle Park, NC).

4.4 RESULTS

Survey respondents—A total of 8,186 small-scale operations (response "rate" = 51.2%) completed the NAHMS survey questionnaire. Of these, 261 were excluded from this analysis because they had no inventory of cattle, swine, poultry, sheep or goats (these operations exclusively raised other species, such as horses). Therefore, 7,925 operations were used for this analysis. Surveys were completed via mail for 4,229 (53.4%) operations and via telephone interview for 3,696 (46.6%) operations. Descriptive statistics of study respondents are shown in Tables 4.2, 4.3 and 4.4. Among mixed operations, the most common species combination was beef cattle and horses (Table 4.3). Herd size distributions were right skewed (Table 4.4) as expected given the USDA ERS report on farm sector structure.

Distances of movements of animals, products and feed—Descriptive statistics for the farthest distance travelled for movements of animals, products and feed are summarized in Table 4.5. Some small-scale operations did not engage in the various movement types. For example, 96.1% (7,616/7,925) of operations answered the survey question asking if they transported animals or products to sell them, and 81.1% of respondents (6,176/7,616) reported having this type of movement. Similarly, when excluding missing questionnaire responses, 43.0% of operations (3,322/7,722) reported they received feed that was shipped by a feed supplier, 68.1%

Table 4.2— Description of sample: operation characteristics for respondents to a 2011 survey of small-scale food animal operations in the US.

	Number	Percent
All operations	7,925	100.0
Region		
Heartland	1,131	14.3
Northern Crescent	1,102	13.9
Northern Great Plains	340	4.3
Prairie Gateway	1,332	16.8
Eastern Uplands	1,795	22.6
Southern Seaboard	959	12.1
Fruitful Rim	607	7.7
Basin and Range	353	4.5
Mississippi Portal	306	3.9
RUC code of operation's county		
1	986	12.4
2	922	11.6
3	1,030	13.0
4	667	8.4
5	273	3.4
6	1,877	23.7
7	1,019	12.9
8	476	6.0
9	675	8.5
Farm sales		
Less than $10,000	2,932	37.0
$10,000-$49,999	2,580	32.6
$50,000-99,999	1,014	12.8
$100,000-249,999	883	11.1
$250,000 or more	282	3.6
Not reported	234	3.0
Animal type*		
Swine	49	0.6
Beef cattle	3,329	42.0
Dairy cattle	365	4.6
Sheep/goats	40	0.5
Poultry	98	1.2
Mixed	4,044	51.0

* Operations with only one animal type were classified into 5 categories: swine, beef cattle, dairy cattle, sheep/goats, and poultry. Sheep and goats were considered to be one animal type. Operations with more than one animal type were classified into a category called mixed operations.

Table 4.3—Summary of common animal combinations on mixed small-scale US food animal operations.

Beef cattle	Dairy cattle	Sheep/ goats	Poultry	Horses/ equids	Number operations
X				X	1,668
X			X		335
X			X	X	329
X		X		X	174
X		X			140
X	X				134
				Total	2,780*

*1,264 mixed operations had other combinations of animals.

Table 4.4—Distribution for herd or flock size of small-scale US food animal operations, by animal type on the operation.

	Animal type				
	Swine	Beef cattle	Dairy cattle	Sheep/goats	Poultry
Percentiles			Number head		
5th	15	10	22	3	10
25th	400	25	55	14.5	2,000
Median	1,570	50	80	60	24,500
75th	2,900	102	120	135	45,000
95th	4,500	300	180	325	192,000

Table 4.5—Descriptive statistics for the farthest distance (miles) to destinations for selling animals or products, feed sources, and slaughter facilities for small-scale US food animal operations.

			Distance percentiles (miles)					
Movement type	Animal type	n*	5th	25th	Median	75th	95th	Max.
Operation transported animals or products to sell them	All operations	6029	7	20	35	60	150	2500
	Swine	15	3	30	60	300	500	500
	Beef cattle	2644	7	20	30	50	103	1200
	Dairy cattle	191	6	15	23	40	80	500
	Sheep/goats	27	10	18	40	100	200	250
	Poultry	9	8	20	25	35	125	125
	Mixed	3143	7	20	40	65	190	2500
Feed shipped/ transported by the supplier	All operations	3220	4	12	25	50	200	5000
	Swine	32	5	12.5	27.5	45	200	600
	Beef cattle	1143	4	10	20	50	150	2000
	Dairy cattle	249	4	10	20	50	200	2000
	Sheep/goats	9	10	15	30	50	400	400
	Poultry	65	5	15	30	40	100	300
	Mixed	1722	5	13	26.5	60	250	5000
Feed transported to operation by producer	All operations	5096	2	9	15	30	75	700
	Swine	11	2	8	20	25	120	120
	Beef cattle	2136	2	8	15	25	60	400
	Dairy cattle	139	1	4	10	15	60	150
	Sheep/goats	25	8	10	20	30	50	80
	Poultry	22	2	5	12	17	30	35
	Mixed	2763	3	10	16	30	90	700
Live animals transported to a slaughter facility	All operations	3169	5	15	25	40	90	2000
	Swine	18	5	25	55	180	300	300
	Beef cattle	1120	5	15	25	40	75	500
	Dairy cattle	157	5	10	20	30	60	200
	Sheep/goats	13	15	30	35	70	100	100
	Poultry	14	2	12	19	60	250	250
	Mixed	1847	5	15	28	45	100	2000

*Of the 6,176 operations that reported transporting animals or products to sell them, 6,029 answered the survey question about distance, and 147 questionnaires had missing responses for distance. Similarly, there were 102, 99 and 101 questionnaires with missing responses for distance for feed shipped by supplier, distance feed was transported by producer, and distance to slaughter facility, respectively.

(5,195/7,625) reported the producer transported feed to the operation, and 42.1% (3,270/7,763) reported live animals were transported to a slaughter facility.

Among operations that transported animals or products to sell them; 75% reported the farthest distance was 60 miles or less, and 95% of operations reported 150 miles or less (Table 4.5). Among beef cattle operations, 95% of operations reported the farthest distance to locations for selling animals or products was 103 miles or less, but the maximum reported distance was 1,200 miles for beef cattle operations (Table 4.5). The 95th percentile for distance increased as farm sales increased for all movement types (Figures 4.1-4.4).

The medians for the farthest distance travelled for feed shipped by a supplier ranged from 20 to 30 miles for the various animal types (Table 4.5). The maximum reported distances for feed shipped by a supplier varied by animal type, ranging from 300 miles for poultry operations to 5000 miles for mixed operations.

Among operations that had animals transported to a slaughter facility, 75% of operations reported the farthest distance to the slaughter facility was 40 miles or less, and 95% of operations reported 90 miles or less (Table 4.5). However, 25% of swine operations (n=18) transported pigs 180 or more miles to slaughter facilities, 5% of small ruminant or mixed operations transported animals 100 or more miles, and 5% of poultry operations (n=14) transported animals 250 or more miles (Table 4.5). Movement distances by region for cattle operations are summarized in Table 4.6.

Population inferences for spatial distribution of operations and animals—There were an estimated 352,133 operations (95% CI = 339,726-364,539) in the US that met the inclusion

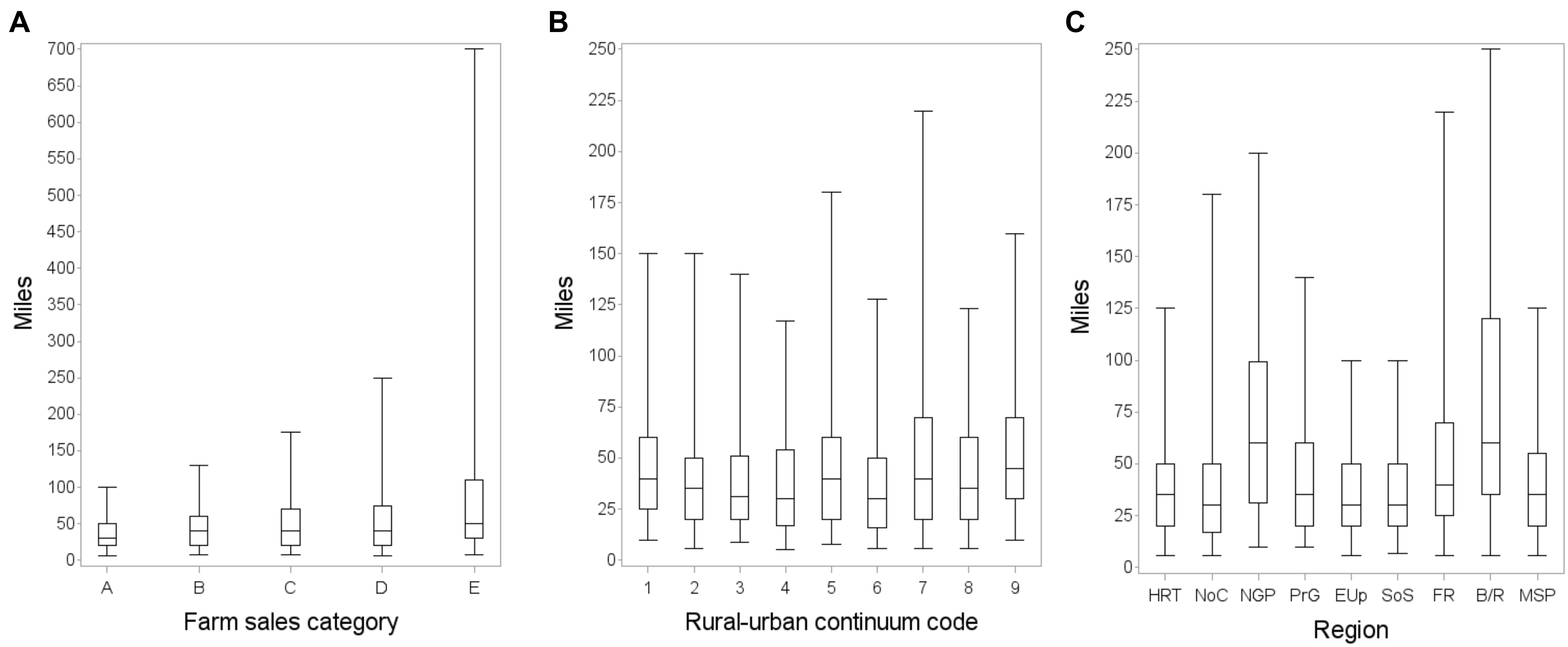

Figure 4.1—Farthest distance (miles) animals or products were transported to sell them, by farm sales category, rural-urban continuum code and region. Boxes show the median and quartiles, whiskers show the 5th and 95th percentiles.

(A) Farm sales categories: A=gross annual sales <$10,000 (n=2,206), B=$10,000 to 49,999 (n=2,123), C=$50,000 to 99,999 (n=775), D=$100,000 to 249,999 (n=589), E=$250,000 or more (n=190). 146 operations excluded from graph A due to missing sales data.

(B) Rural-urban continuum code (See Table 4.1 for description of codes): 1 (n=767), 2 (n=677), 3 (n=784), 4 (n=461), 5 (n=202), 6 (n=1,447), 7 (n=779), 8 (n=357), 9 (n=555) .

(C) Region: HRT=Heartland (n=855), NoC=Northern Crescent (n=618), NGP=Northern Great Plains (n=272), PrG=Prairie Gateway (n=1,108), EUp =Eastern Uplands (n=1,440), SoS=Southern Seaboard (n=744), FR=Fruitful Rim (n=475), B/R=Basin and Range (n=266), MSP=Mississippi Portal (n=251).

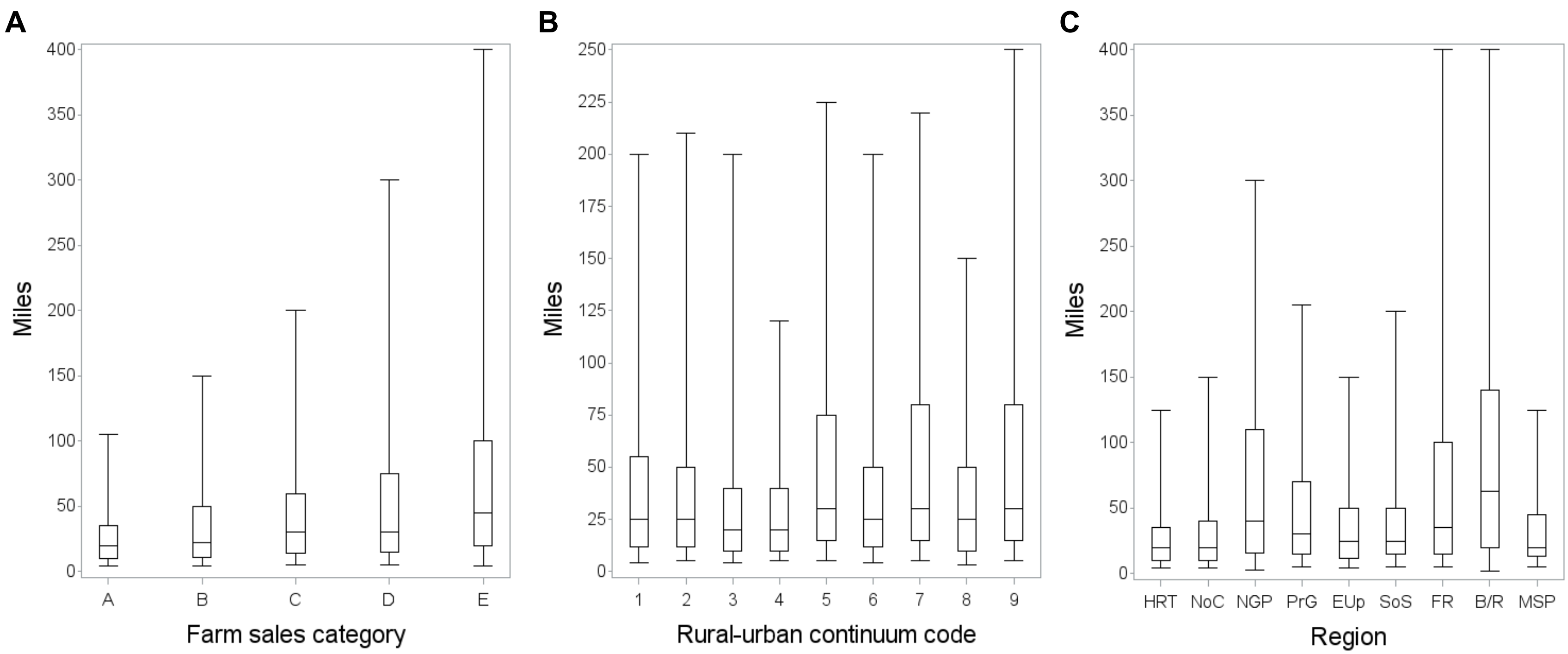

Figure 4.2—Farthest distance (miles) feed was shipped/transported by the supplier, by farm sales category, rural-urban continuum code and region. Boxes show the median and quartiles, whiskers show the 5th and 95th percentiles.

(A) Farm sales categories: A=gross annual sales <$10,000 (n=789), B=$10,000 to 49,999 (n=986), C=$50,000 to 99,999 (n=569), D=$100,000 to 249,999 (n=596), E=$250,000 or more (n=217). 63 operations excluded from graph A due to missing sales data.

(B) Rural-urban continuum code (See Table 4.1 for description of codes): 1 (n=355), 2 (n=397), 3 (n=409), 4 (n=297), 5 (n=106), 6 (n=730), 7 (n=413), 8 (n=206), 9 (n=307) .

(C) Region: HRT=Heartland (n=552), NoC=Northern Crescent (n=595), NGP=Northern Great Plains (n=151), PrG=Prairie Gateway (n=476), EUp =Eastern Uplands (n=656), SoS=Southern Seaboard (n=334), FR=Fruitful Rim (n=230), B/R=Basin and Range (n=136), MSP=Mississippi Portal (n=90).

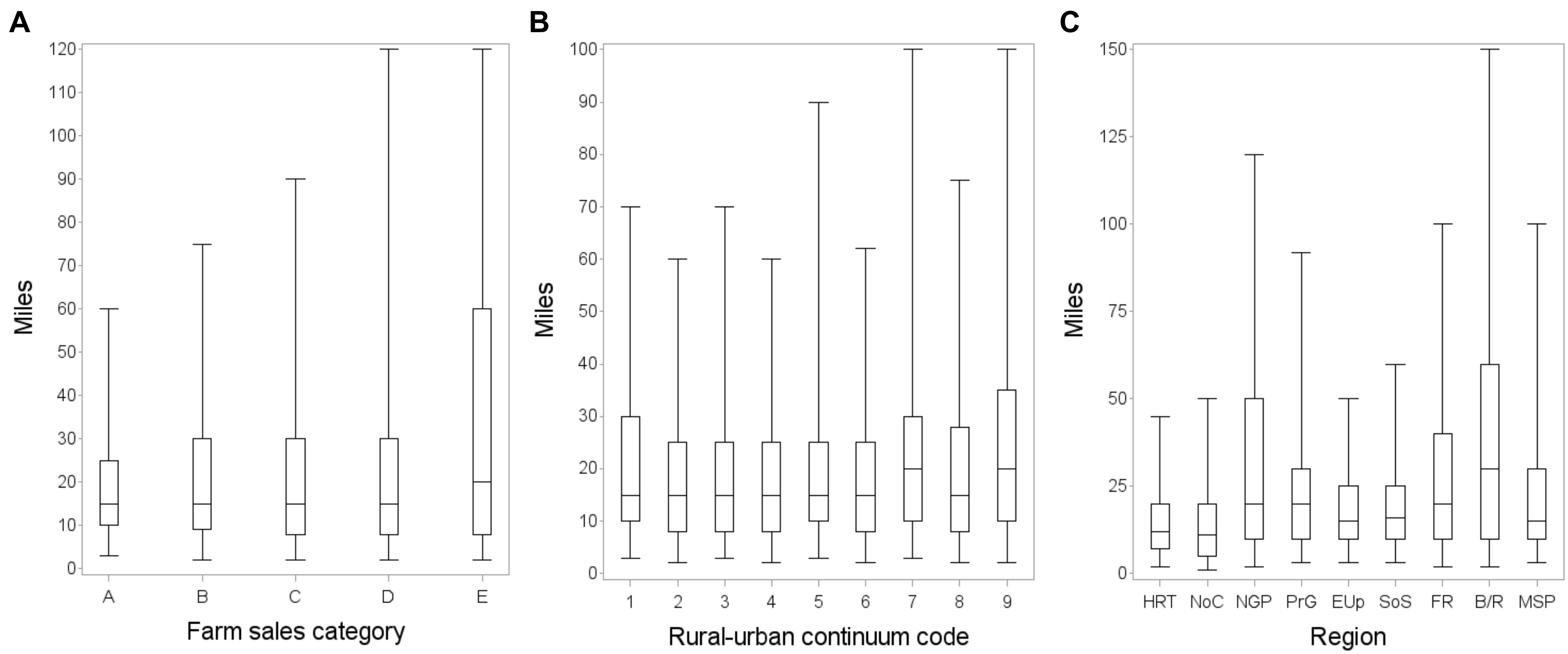

Figure 4.3—Farthest distance (miles) feed was transported to the operation by the producer, by farm sales category, rural-urban continuum code and region. Boxes show the median and quartiles, whiskers show the 5th and 95th percentiles.

(A) Farm sales categories: A=gross annual sales <$10,000 (n=2,147), B=$10,000 to 49,999 (n=1,734), C=$50,000 to 99,999 (n=573), D=$100,000 to 249,999 (n=391), E=$250,000 or more (n=125). 126 operations excluded from graph A due to missing sales data.

(B) Rural-urban continuum code (See Table 4.1 for description of codes): 1 (n=664), 2 (n=553), 3 (n=655), 4 (n=412), 5 (n=181), 6 (n=1,256), 7 (n=649), 8 (n=290), 9 (n=436) .

(C) Region: HRT=Heartland (n=667), NoC=Northern Crescent (n=519), NGP=Northern Great Plains (n=217), PrG=Prairie Gateway (n=995), EUp =Eastern Uplands (n=1,193), SoS=Southern Seaboard (n=641), FR=Fruitful Rim (n=405), B/R=Basin and Range (n=225), MSP=Mississippi Portal (n=234).

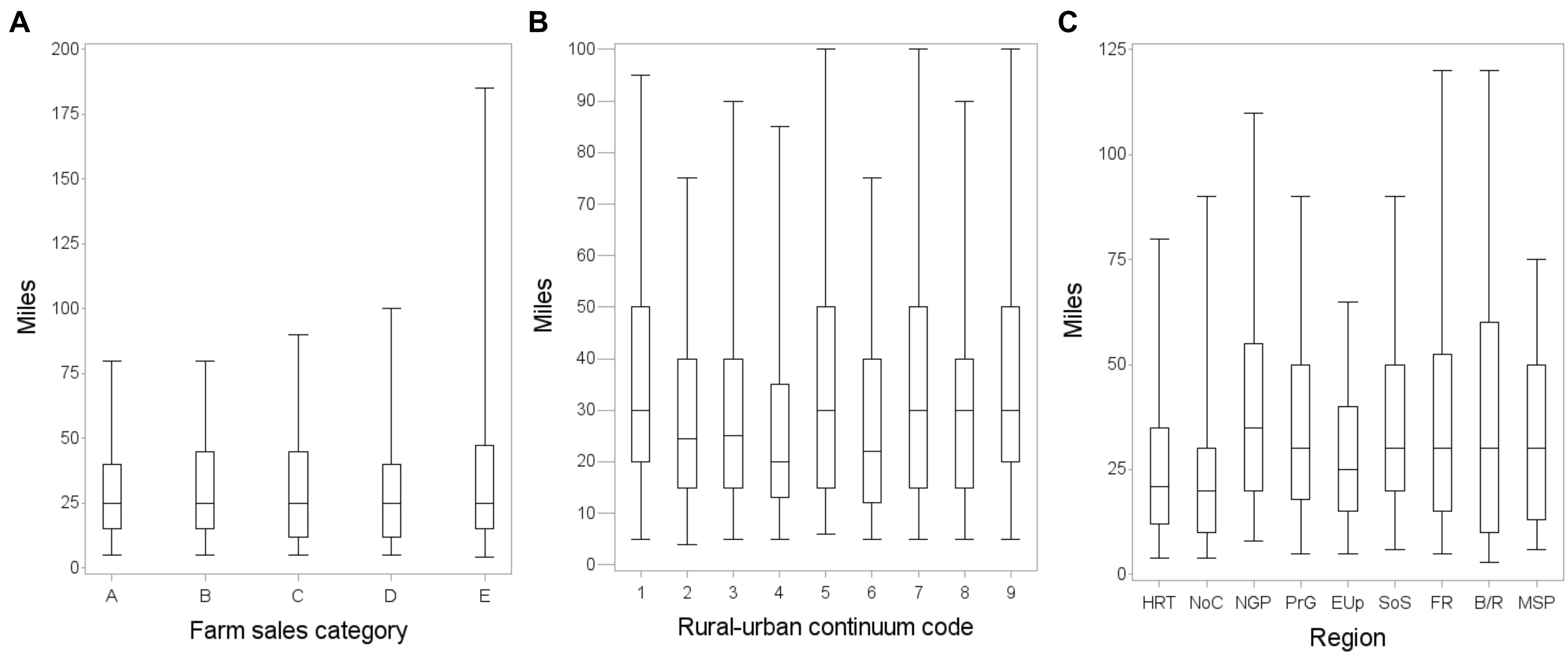

Figure 4.4—Farthest distance (miles) animals were transported to a slaughter facility, by farm sales category, rural-urban continuum code and region. Boxes show the median and quartiles, whiskers show the 5th and 95th percentiles.

(A) Farm sales categories: A=gross annual sales <$10,000 (n=1,015), B=$10,000 to 49,999 (n=1,035), C=$50,000 to 99,999 (n=469), D=$100,000 to 249,999 (n=428), E=$250,000 or more (n=148). 74 operations excluded from graph A due to missing sales data.

(B) Rural-urban continuum code (See Table 4.1 for description of codes): 1 (n=356), 2 (n=380), 3 (n=438), 4 (n=266), 5 (n=112), 6 (n=723), 7 (n=412), 8 (n=189), 9 (n=293) .

(C) Region: HRT=Heartland (n=530), NoC=Northern Crescent (n=568), NGP=Northern Great Plains (n=178), PrG=Prairie Gateway (n=484), EUp (n=705), SoS=Southern Seaboard (n=258), FR=Fruitful Rim (n=176), B/R=Basin and Range (n=179), MSP=Mississippi Portal (n=91).

Table 4.6—Regional* descriptive statistics for the farthest distance (miles) to destinations for selling animals or products, feed sources and slaughter facilities for small-scale cattle operations.

			Distance percentiles (miles)				
Movement type	Animal type and region	n	5th	25th	Median	75th	95th
Operation transported animals or products to sell them	Beef cattle						
	Heartland	406	6	20	31	50	100
	Northern Crescent	130	5	20	30	60	250
	Northern Great Plains	102	10	30	60	75	140
	Prairie Gateway	534	8	20	34.5	50	105
	Eastern Uplands	756	7	18	30	50	100
	Southern Seaboard	376	6	20	30	50	85
	Fruitful Rim	171	7	25	40	60	120
	Basin and Range	51	5	35	60	90	150
	Mississippi Portal	118	4	15	31	50	120
	Dairy cattle						
	Heartland	29	7	20	35	50	300
	Northern Crescent	136	6	14	20	35	60
Feed shipped/ transported by the supplier	Beef cattle						
	Heartland	228	4	10	17.5	30	100
	Northern Crescent	74	3	7	19.5	40	80
	Northern Great Plains	42	2	10	30	60	200
	Prairie Gateway	225	5	10	20	50	200
	Eastern Uplands	302	4	12	25	50	150
	Southern Seaboard	138	6	12	25	60	250
	Fruitful Rim	69	3	10	25	80	200
	Basin and Range	22	2	15	70	150	400
	Mississippi Portal	43	5	12	20	50	100
	Dairy cattle						
	Heartland	28	5	8.5	20	35	200
	Northern Crescent	186	4	10	20	45	180
Feed transported to operation by producer	Beef cattle						
	Heartland	319	2	6	14	20	40
	Northern Crescent	107	1	5	12	25	45
	Northern Great Plains	78	1	8	20	45	120
	Prairie Gateway	453	3	10	16	30	70
	Eastern Uplands	603	3	9	15	25	50
	Southern Seaboard	302	2	10	16	25	60
	Fruitful Rim	135	1	10	20	32	100
	Basin and Range	33	2	10	26	100	150
	Mississippi Portal	106	2	8	15	23	100
	Dairy cattle						
	Heartland	22	2	3	10	20	70
	Northern Crescent	98	1	3	10	15	50

*Some regions are excluded due to small sample size.

Table 4.6 (continued)—Regional* descriptive statistics for the farthest distance (miles) to destinations for selling animals or products, feed sources and slaughter facilities for small-scale cattle operations.

			Distance percentiles (miles)				
Movement type	Animal type and region	n	5th	25th	Median	75th	95th
Live animals transported to a slaughter facility	Beef cattle						
	Heartland	228	4	12	20	30	50
	Northern Crescent	125	5	10	20	30	80
	Northern Great Plains	55	8	20	40	50	80
	Prairie Gateway	184	5	15	25	45	80
	Eastern Uplands	308	5	15	25	40	60
	Southern Seaboard	109	6	18	30	50	80
	Fruitful Rim	42	8	15	30	60	100
	Basin and Range	31	3	10	30	70	100
	Mississippi Portal	38	6	12	27.5	50	75
	Dairy cattle						
	Heartland	15	2	20	25	35	200
	Northern Crescent	125	5	10	15	25	50

*Some regions are excluded due to small sample size.

criteria for this study. Of these, an estimated 171,279 were mixed-species operations (Table 4.7). An estimated 162,018 small-scale operations in the US raised only beef cattle (Table 4.7). We estimated that there were 18,688 small-scale operations in the US with at least one pig (of which 1,847 raised exclusively swine), accounting for 5.867 million total pigs on small-scale operations (Table 4.7). An estimated 43.8% of swine-only operations were located in the Heartland region (Table 4.8), and 57.4% of all pigs on small-scale operations were located in the Heartland region (Table 4.9). We estimated that the majority of small-scale dairy operations (72.2%) were located in the Northern Crescent region (Table 4.8). An estimated 41.6% of poultry-only operations (and 50.8% of all poultry on small-scale operations) were located in the Southern Seaboard region (Tables 4.8 and 4.9). Of operations that raised exclusively beef cattle,

Table 4.7—Estimated total number of operations (95% CI) and estimated number of animals (95% CI) on small-scale US food animal operations (using weights), by animal type.

	Animal type					
	Swine	Beef cattle	Dairy cattle	Sheep/goats	Poultry	Mixed
# single-species operations	1,847 (1,285-2,409)	162,018 (154,935-169,101)	11,619 (10,474-12,763)	2,012 (1,344-2,679)	3,358 (2,635-4,082)	171,279 (164,048-178,511)
# operations with at least one head of the respective species	18,688 (16,818-20,557)	318,635 (307,120-330,150)	31,149 (29,154-33,144)	37,649 (34,923-40,375)	61,848 (58,207-65,488)	NA
# animals (1,000 head)*	5,867 (4,609-7,124)	23,533 (22,292-24,774)	2,099 (1,877-2,321)	1,979 (1,674-2,284)	287,771 (217,119-358,423)	NA

*Includes animals on mixed operations.

Table 4.8—Estimated percentage (using weights) of swine, beef cattle, dairy cattle, sheep/goat, poultry and mixed operations in each geographical region and rural-urban continuum (RUC) code.

	Animal type					
	Swine	Beef cattle	Dairy cattle	Sheep/goats	Poultry	Mixed
Region	Weighted percent operations (95% confidence interval)					
Heartland	43.8	14.6	12.6	26.8	8.2	12.0
	(30.1-58.6)	(13.6-15.7)	(9.6-16.4)	(15.0-43.2)	(4.0-16.0)	(11.1-12.9)
Northern Crescent	20.8	6.0	72.2	9.2	12.4	11.8
	(10.7-36.7)	(5.3-6.7)	(67.1-76.7)	(3.3-23.2)	(7.1-20.6)	(11.0-12.5)
Northern Great Plains	0.0	3.2	2.2	4.2	0.0	4.4
	(--)	(2.7-3.7)	(1.1-4.3)	(0.6-23.9)	(--)	(3.8-5.0)
Prairie Gateway	16.2	19.9	0.0	30.6	11.9	18.1
	(6.9-33.5)	(18.7-21.2)	(--)	(17.7-47.6)	(5.9-22.5)	(17.0-19.3)
Eastern Uplands	1.5	27.9	6.3	6.1	17.7	20.2
	(0.2-9.6)	(26.5-29.4)	(4.2-9.5)	(1.8-18.8)	(11.4-26.5)	(19.0-21.4)
Southern Seaboard	12.7	14.9	2.0	10.5	41.6	11.7
	(6.0-25.0)	(13.7-16.1)	(0.9-4.4)	(4.1-24.5)	(31.6-52.4)	(10.7-12.8)
Fruitful Rim	3.2	7.2	4.0	5.2	7.6	10.3
	(0.5-19.0)	(6.4-8.2)	(1.9-8.2)	(1.3-18.5)	(3.2-17.2)	(9.5-11.3)
Basin and Range	0.0	1.9	0.0	4.1	0.0	7.1
	(--)	(1.5-2.5)	(--)	(0.6-24.0)	(--)	(6.4-7.9)
Mississippi Portal	1.8	4.4	0.7	3.3	0.6	4.4
	(0.3-11.2)	(3.8-5.2)	(0.2-3.2)	(0.5-19.6)	(0.1-4.1)	(3.8-5.1)
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.8 (continued)—Estimated percentage (using weights) of swine, beef cattle, dairy cattle, sheep/goat, poultry and mixed operations in each geographical region and rural-urban continuum (RUC) code.

	Animal type					
	Swine	Beef cattle	Dairy cattle	Sheep/ goats	Poultry	Mixed
RUC code of operation's county	Weighted percent operations (95% confidence interval)					
1	3.8 (0.5-21.8)	14.7 (13.4-16.0)	4.1 (2.4-7.0)	11.4 (4.6-25.4)	9.8 (4.9-18.7)	13.9 (12.8-15.1)
2	7.7 (2.8-19.8)	10.6 (9.6-11.8)	21.2 (17.0-26.1)	14.3 (5.9-30.9)	18.7 (11.7-28.7)	11.7 (10.7-12.8)
3	18.2 (8.8-33.9)	13.0 (11.8-14.3)	14.7 (11.4-18.8)	9.3 (2.9-26.0)	13.5 (7.3-23.7)	13.9 (12.8-15.1)
4	16.9 (7.8-33.0)	7.4 (6.5-8.5)	15.8 (12.4-20.0)	13.5 (5.2-30.7)	12.1 (7.2-19.6)	8.5 (7.6-9.5)
5	3.1 (0.7-11.7)	3.5 (2.9-4.2)	2.5 (1.2-4.9)	2.9 (0.7-10.9)	2.5 (0.8-7.7)	3.3 (2.8-4.0)
6	27.1 (15.6-42.8)	25.2 (23.6-26.8)	24.2 (19.9-29.1)	22.0 (11.5-37.8)	24.0 (16.3-33.8)	22.2 (20.9-23.6)
7	14.1 (7.3-25.5)	11.5 (10.5-12.7)	6.9 (4.4-10.5)	12.4 (4.9-28.1)	8.5 (4.3-16.1)	13.1 (12.1-14.2)
8	6.6 (2.0-19.8)	5.5 (4.7-6.4)	7.3 (5.1-10.4)	1.2 (0.2-7.8)	10.2 (4.4-21.8)	5.9 (5.1-6.7)
9	2.5 (0.6-9.3)	8.6 (7.7-9.6)	3.3 (1.9-5.8)	13.0 (5.3-28.6)	0.7 (0.1-4.7)	7.5 (6.7-8.4)
Total	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.9—Estimated percentage (using weights) of animals* on small-scale US food animal operations in each geographical region and rural-urban continuum (RUC) code.

	Animal type				
	Swine	Beef cattle	Dairy cattle	Sheep/goats	Poultry
	Weighted percent animals (95% confidence interval)				
Region					
Heartland	57.4 (46.6-67.6)	12.8 (11.8-13.9)	15.4 (12.7-18.6)	13.9 (10.1-18.7)	8.0 (2.8-20.6)
Northern Crescent	25.5 (16.5-37.4)	4.9 (4.4-5.5)	66.5 (62.2-70.5)	11.0 (7.2-16.6)	5.7 (2.8-10.9)
Northern Great Plains	0.6 (0.1-3.3)	8.9 (7.9-10.1)	2.1 (1.1-4.1)	7.6 (4.4-12.6)	0.3 (0.1-2.0)
Prairie Gateway	3.5 (1.7-7.1)	22.0 (19.8-24.3)	0.7 (0.3-1.7)	23.7 (18.3-30.1)	1.0 (0.2-4.5)
Eastern Uplands	1.5 (0.3-6.0)	19.7 (18.5-20.9)	6.8 (5.2-8.8)	12.5 (9.4-16.5)	29.2 (19.7-41.0)
Southern Seaboard	10.4 (6.3-16.6)	10.8 (9.9-11.7)	2.7 (1.6-4.8)	6.3 (4.4-9.1)	50.8 (37.7-63.7)
Fruitful Rim	0.6 (0.3-1.0)	10.4 (9.1-11.9)	5.0 (2.1-11.0)	10.6 (6.0-18.1)	2.0 (1.2-3.2)
Basin and Range	0.3 (0.1-0.8)	6.8 (5.9-7.9)	0.5 (0.2-1.6)	13.0 (7.5-21.7)	0.9 (0.2-4.0)
Mississippi Portal	0.2 (0.1-0.8)	3.7 (3.2-4.2)	0.3 (0.1-0.6)	1.4 (0.7-3.0)	2.1 (0.5-8.5)
Total	100.0	100.0	100.0	100.0	100.0
RUC code of operation's county					
1	8.9 (2.8-24.9)	10.6 (9.4-11.9)	6.5 (4.3-9.7)	11.1 (6.7-17.8)	6.7 (2.5-16.3)
2	6.2 (2.2-16.6)	10.1 (9.0-11.2)	15.4 (12.8-18.5)	11.8 (8.2-16.6)	15.2 (6.3-32.3)
3	14.0 (7.4-25.0)	12.3 (10.4-14.5)	14.7 (11.9-17.9)	13.0 (8.6-19.3)	10.9 (5.7-19.9)
4	9.9 (4.7-19.7)	6.1 (5.3-7.0)	14.6 (11.9-17.9)	7.0 (4.4-10.9)	7.4 (3.8-14.0)
5	2.6 (0.4-14.3)	3.9 (3.1-5.0)	1.2 (0.7-2.3)	6.4 (2.2-17.1)	4.6 (1.1-17.6)
6	19.6 (11.6-31.1)	21.2 (19.6-22.8)	29.1 (24.3-34.3)	18.0 (12.9-24.6)	29.2 (19.0-42.0)
7	29.6 (18.9-43.1)	15.8 (14.4-17.4)	7.4 (5.3-10.2)	13.2 (9.2-18.5)	12.8 (5.7-26.3)
8	5.5 (2.1-13.7)	6.2 (5.4-7.1)	7.6 (5.7-10.0)	6.4 (3.0-12.9)	12.5 (6.2-23.7)
9	3.7 (1.7-7.7)	13.8 (12.2-15.5)	3.5 (2.1-5.8)	13.1 (8.9-18.9)	0.7 (0.2-2.5)
Total	100.0	100.0	100.0	100.0	100.0

*Includes animals on mixed operations.

an estimated 14.7% (Table 4.8) were located in counties with metropolitan areas of 1 million or more people (RUC =1), and 10.6% of all beef cattle on small-scale operations were in highly urban counties (RUC=1; Table 4.9).

4.5 DISCUSSION

Small-scale food animal operations are an important component of US agricultural production. In fact, farms with annual sales between $10,000 and $499,999 account for 36.6% of the total value of US agricultural production and comprise 40.9% of all US farms (Hoppe, 2010). Therefore, it is important to consider the unique spatial features of these farms when planning and preparing for animal disease outbreaks and modeling disease spread. This study focused on operations with at least one head of cattle, swine, poultry, sheep or goats, because we considered these to be the core livestock species of interest for disease spread modeling. Future studies could explore movement practices for other species of farmed animals.

It has been described that movements of animals, products and feed on food animal operations can spread diseases of significance to animal and human health (Kao et al., 2007; Halvorson, 2009). In the UK FMD outbreak in 2001, livestock markets were implicated in causing widespread disease dissemination (NAO, 2002). Movement of animal products is also an avenue for disease spread (e.g., Hartnett et al., 2007; Cobb, 2011; Wijnker et al., 2012). Feed movements may allow indirect dissemination of disease via feed trucks (Dorea et al., 2010) or contaminated feed (Moreno-Lopez, 2002; Wagner et al., 2005; Osterberg et al., 2006; Windl and Dawson, 2012; Jenkins et al., 2013). Similarly, movement of animals to slaughter facilities can be a route for indirect disease spread between farms, since trucks and equipment used to transport animals to slaughter may be reused for other purposes. Thus, it is crucial that information on distances for these movements are available to inform disease spread models and understand disease spread dynamics. Although previous studies have described movements of animals between operations (Shields and Mathews, 2003; Dominguez, 2007; USDA, 2009; Lindstrom et al., 2013), limited literature was available describing movements of feed and movements of animals to livestock markets or slaughter facilities in the United States. In our study, we focused on these lesser-explored movements.

Most small-scale operations reported that movement distances for feed, animals and products were <40 miles, while a small percentage of operations reported very long-distance movements (2,500 miles). A right-skewed distribution for distance was also seen in animal movement data from the UK (Vernon, 2011) and Sweden (Lindstrom et al., 2009). In the present study, the 95th percentile for movement distance increased as farm sales increased for all movement types. For example, 5% of farms with sales over $250,000 transported animals or products 700 miles or more to sell them in the present study. Area markets for commodities (e.g., feed) and products (e.g., milk) may not have been able to accommodate these larger producers. In addition, economies of scale may have allowed these producers to use markets and feed sources that were farther from the farm. This information could be incorporated into stochastic disease spread models to account for differing movement practices between farms of different sizes.

In some parts of the US, access to slaughter facilities may be a challenge for small-scale operations that wish to directly market their meat products to consumers (Goodsell et al., 2010; Lewis and Peters, 2012). In addition, some commodities (e.g., swine and poultry) are predominantly produced in a vertically-integrated industry structure, which may affect availability of slaughter facilities for independent producers. Therefore, we theorized that animals from small-scale operations might be transported long distances to slaughter facilities.

Long-distance transport to slaughter facilities affects animal welfare, meat quality, and food safety (Grandin, 2000; Perez et al., 2002; Gosalvez et al., 2006; Dewell et al., 2008; Yalcin and Guler, 2012; Torrey et al., 2013). For example, broiler chickens that travelled 102.5 miles (165 km) to slaughter had higher stress and lower meat quality than broilers transported 40.4 miles (65 km) or 71.5 miles (115km; Yalcin and Guler, 2012). Longer transport distance reduced carcass yield and increased live weight losses and mortality in pigs in Spain (Gosalvez et al., 2006). Cattle hides were more likely to culture positive for *E. coli* 0157 when the cattle were transported more than 100 miles (160.9 km) to slaughter (Dewell et al., 2008).

Despite these concerns about long distance-transport, few peer-reviewed studies previously described slaughter transport distances in the US (Dominguez, 2007; Marshall et al., 2009). Thus, data from the present study provided context for relationships of distance with animal welfare and meat quality. For instance, 95% of operations in the present study reported a maximum distance of 90 miles or less to the slaughter facility, which suggested there were minimal animal welfare and meat quality concerns related to transport distance for the processing phase of the supply chain in this population overall. However, in this study, results suggested a shortage of slaughter facilities may exist for small-scale operations that raised swine or poultry, as well as operations located in the Northern Great Plains, Fruitful Rim and Basin and Range regions, because the 95th percentile for transport distance exceeded 100 miles for these operation types. Overly sparse supply chain infrastructure, such as these stated distances to slaughter, could increase the risk of widespread disease dissemination

This study had several limitations. Selection criteria were based on having gross annual farm sales between $10,000 and $499,999 during 2007-2009. Sales data for 2010 were collected on the survey questionnaire. We found that 37.0% (n=2,932) of responding operations had sales less than $10,000 in 2010, and 66 operations (0.8%) had sales of $500,000 or more. We opted to include these operations in our analysis based on our *a priori* inclusion criteria. Therefore, the actual distribution of farm sales in our respondent population should be considered when interpreting our results. More than half of respondents (51.0%) raised more than one animal type. Because the study questionnaire did not ask which type of animal or product was moved, results were reported separately for operations that raised only one animal type. For mixed operations, it was not possible to determine which species of animal was being moved. Some operations reported they did not engage in movement of animals to slaughter, or movement of animals and products for sale. It is possible that the operations did not move animals to these destinations; on the other hand, it is also possible that producers did not report movements of animals or products because someone else was responsible for their transportation or sale.

In this study, we also estimated the regional and rural-urban distribution of small-scale operations. Because we sampled from a comprehensive list frame of US operations, we were able to make inference to the entire US population of small-scale food animal operations using survey weights. Based on these population inferences, regional trends were identified in the locations of small-scale operations. For instance, our estimates indicated that swine were concentrated in the Heartland region, poultry were concentrated in the Southern Seaboard, and dairy cattle were concentrated in the Northern Crescent. We estimated that beef cattle, small ruminant and mixed operations were less regionally concentrated. For most animal species, these findings were consistent with the distribution of commodity production across all operation sizes in the US (USDA-NASS, 2007). However, dairy operations had different regional distributions for large and small-scale operations. Our findings were consistent with Macdonald et al. (2007); we estimated most small-scale dairy operations were located in the Northern

Crescent region. Because exact geospatial coordinates for farms are not readily available in the US for disease spread modeling, modelers often estimate geospatial information on farm locations and farm types (e.g., Patyk et al., 2013). Results of this study can be compared to such estimated population files to verify that small-scale operations are properly represented by region for modeling purposes.

Rural-urban continuum (RUC) codes[7] described the degree of urban influence at the county level. Counties with RUC code 1 contained portions of a metropolitan area that collectively had 1 million or more people. However, these counties sometimes had areas that were quite rural, particularly in the Western US where county sizes were large. RUC codes were also based on proximity to a neighboring county that contained a metro area. In 2000, 82.6% of the human population lived in metro counties (RUC code=1, 2 or 3; US Census). In comparison, we estimated in the present study that only 33.0% of beef cattle on small-scale operations were in metro counties. The most rural counties (RUC=7, 8 or 9) contained an estimated 35.8% of beef cattle on small-scale operations, but only 4.9% of the US human population (US Census, 2000).

In this study, small-scale operations were distributed across all nine RUC codes. Similarly, Thomas and Howell (2003) demonstrated that livestock and poultry production are not restricted to highly rural areas, despite perceptions to the contrary. In fact, metropolitan fringe counties were the second-highest contributor to total livestock and poultry sales from 1978 to 1997 (Thomas and Howell, 2003). Urban influence had both positive and negative implications for agricultural operations. Although urban proximity increased access to markets for selling products directly to consumers, it also increased the cost of agricultural production (Nehring et

[7] For more information on RUC codes see: http://www.ers.usda.gov/data-products/rural-urban-continuum-codes/documentation.aspx

al., 2006). In this study, at least 5% of operations that were located in counties with RUC code 5, 7 or 9 had transported products ≥160 miles to sell them. The 95th percentile for distance to markets was lower for operations located in all other RUC codes. Counties with RUC codes 5, 7 and 9 had small urban populations and were not adjacent to a metropolitan area, which might explain why some operations in these counties travelled long distances to markets and supply chain services. It appears from this study that adjacency to a metropolitan area was important in reducing distance to markets for producers in rural counties.

In this study, the percentage of operations that were located in metropolitan counties (RUC code of 1, 2 or 3) ranged from 29.7% of swine operations to 42.0% of poultry operations. In recent years, a number of cities have passed ordinances that allow small production animals to be raised in urban areas. For example, Denver, Colorado; Columbia, Missouri; and Ann Arbor, Michigan have recently passed laws that allow backyard chickens within city limits (Bartling, 2010). This trend is important from a public health standpoint, since it will likely increase interactions between humans and farm animals in highly populated areas. Urban backyard livestock populations could also create new disease concerns for small-scale operations in urban and peri-urban areas. In fact, small-scale operations that are located in metropolitan counties may want to consider the growing trend of backyard livestock when making decisions about disease control and prevention practices.

In summary, this study estimated the spatial distribution of small-scale food animal operations across geographic regions and the rural-urban continuum, and described movement distances. The results of this study are an important tool for better understanding disease dynamics for this segment of the industry, and for informing disease spread models.

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CHAPTER 5: CONCLUSION

This thesis described the use of veterinarians, use of biosecurity practices and movement practices for small-scale farm and ranch operations in the US. This is a population for which limited information was previously available on these three factors which are essential for disease control and prevention. One of the strengths of the research conducted in this thesis was the large sample size and the inclusion of operations raising a variety of animal species in all 50 US states, which allowed comparisons between different industry segments and regions. Furthermore, a nationally representative sample was selected from a comprehensive list frame of US farms, which allowed inferences to the population of all small-scale operations in the US. This thesis fills critical information gaps about disease prevention and control strategies on small-scale operations, and the results are useful to many agricultural stakeholders, including government analysts for disease spread modeling and disease risk assessments.

Based on the analysis in Chapter 2, only a small percentage of food animal producers (1.4%) lacked access to a veterinarian within 100 miles of the operation, but these producers were located in 40 different states. Veterinary medical organizations and colleges, state animal health officials, and the USDA Veterinary Medicine Loan Repayment Program can use this information on veterinarian availability to define shortages of food animal veterinarians and plan mitigation strategies for veterinary shortages. We also described reasons for not using veterinarians and found that producers with lower education levels and producers in certain geographic regions were less likely to use veterinarians. Private practice veterinarians can use this information to understand disease risks in their geographical region, design outreach and marketing plans to attract new clients and raise awareness for preventive animal husbandry practices, and provide relevant biosecurity educational materials to their clients.

Temporarily quarantining new animals is an important disease prevention practice for agricultural operations. In Chapter 3, we identified operation characteristics and producer demographics associated with the use of quarantine for new animals, and described producers' reasons for not quarantining animals. This information is useful for designing educational campaigns that aim to change producer biosecurity behavior. The results of Chapter 4 are useful to disease spread modelers, since little information was previously available on the movement distances we described, especially with the degree of specificity on types of operations.

In this thesis, differences were seen in veterinarian use, biosecurity practices, and movement distances across different animal species. These variations are likely related to production and marketing differences for the various species. For example, cattle have a long production lifecycle compared to broiler chickens, while other species (e.g., poultry and swine) are predominantly produced in a vertically-integrated industry structure. Furthermore, some commodities are marketed on a daily basis (e.g., milk on a dairy operation) while others are marketed once annually (e.g., calf crop on a cow-calf operation). These production and marketing differences may explain some of the managerial differences that would alter perceptions about veterinarian use, biosecurity practices, and movement distances between species, and may play an important role in producers' decisions about disease prevention practices. This study elucidated these important differences, which are critical for understanding disease spread risks in the United States. In conclusion, the results of this study made a substantial contribution to the understanding of disease control and prevention practices on small-scale farms and ranches in the United States.

APPENDIX I: STUDY QUESTIONNAIRE

-

USDA

Animal and Plant Health Inspection Service

Veterinary Services

LIVESTOCK OPERATIONS REPORT

National Animal Health Monitoring System

2150 Centre Ave., Bldg. B
Fort Collins, CO 80526-8117

Form Approved
O.M.B. Number 0579-0368
Approval Expires 02/28/2013
NAHMS 260
Project Code 954

Please help us by completing this questionnaire and mailing it in the accompanying business reply envelope. Information requested in the survey is used to prepare estimates of selected agricultural commodities. Under Title 7 of the U.S. Code and CIPSEA (Public Law 107-347), facts about your operation are kept **confidential** and used only for statistical purposes in combination with similar reports from other producers. Response is **voluntary**.

Please make corrections to name, address and zip code, if necessary.

Section A – Livestock Inventory

Important: In this survey, the word "*livestock*" is meant to include cattle, poultry, goats, sheep, swine, horses, other equine, aquaculture and other farm animals raised for sale or home use.

1. What was the peak number of the following livestock or poultry on your operation during the last 12 months?

	None	Peak number on this operation at any one time in the last 12 months
a. Beef cattle.	☐	0001
b. Dairy cattle.	☐	0002
c. Swine.	☐	0003
d. Sheep.	☐	0004
e. Goats.	☐	0005
f. Chickens and other poultry.	☐	0006
g. Horses and other equine.	☐	0007
h. Bison.	☐	0008
i. Other livestock species (specify:____________________)	☐	0009

If no livestock or poultry on this operation in the last 12 months, go to Section J, Conclusion.

NAHMS-260
NOV 2010

-

2. During the last 12 months, were any **new** livestock or poultry brought onto your operation?. . . 0010 ₁☐Yes ₃☐No

3. During the last 12 months, were any livestock or poultry moved off and **returned** to your operation (e.g., taken to fair, bred elsewhere, etc.)?. .. . . 0011 ₁☐Yes ₃☐No

If you answered "No" to both items 2 and 3, go to Section B.

For the next two questions, "isolate" means to prevent nose-to-nose contact and to prevent the sharing of feed, drinking water, and equipment with other animals of the same species already present.

4. During the last 12 months, did you rarely, sometimes, or always isolate the new or returning animals for a period of time?

0012 ☐ Always. On average, how many days did you isolate new or returning animals? . . . .**days** [0175] (Skip to Section B)

☐ Sometimes. On average, how many days did you isolate new or returning animals? . . . . **days** [0176] (continue to next question)

☐ Rarely, or never (continue to next question)

5. Which of the following are reasons you sometimes or rarely isolate new or returning animals? (Check all that apply.)

0013 ☐ I do not have a separate enclosure or extra equipment for isolating animals

0139 ☐ I trust the source of the new animals, or the place from which the animals are returning

0140 ☐ I have inadequate labor or time to implement isolation

0141 ☐ I don't believe isolation is beneficial or prevents disease

0142 ☐ Other reasons (specify: ________________________)

Section B – Crop Inventory

1. Were any of the following crops grown on your operation during the last 12 months?

a.	Hay.	0014	₁☐Yes	₃☐No
b.	Wheat.	0015	₁☐Yes	₃☐No
c.	Corn, barley, oats, or rye.	0016	₁☐Yes	₃☐No
d.	Soybeans and other oil-bearing crops and/or oilseeds.	0017	₁☐Yes	₃☐No
e.	Tobacco.	0018	₁☐Yes	₃☐No
f.	Cotton and/or cotton seed.	0019	₁☐Yes	₃☐No
g.	Vegetables and/or melons.	0020	₁☐Yes	₃☐No
h.	Fruits, berries, and/or tree nuts.	0021	₁☐Yes	₃☐No
i.	Other crops? (specify:________________________).	0022	₁☐Yes	₃☐No

-

Section C – Marketing

1. Which of the following best describes the total dollar value of agricultural products sold from this operation in 2010? (Check one only. Please report **gross sales**, the total of all sales before subtracting operating expenses, payment of taxes, or other expenses.)

0023
- 1☐ None
- 2☐ Less than $10,000
- 3☐ $10,000 to 49,999
- 4☐ $50,000 to $99,999
- 5☐ $100,000 to $249,999
- 6☐ $250,000 to $499,999
- 7☐ $500,000 or more

2. Do you **market** or **advertise** any of your agricultural products as:

a.	Naturally raised livestock?	0024	1☐Yes	3☐No
b.	No animal by-products fed?	0025	1☐Yes	3☐No
c.	USDA certified organic?	0026	1☐Yes	3☐No
d.	Grass-fed livestock (finished on grass not feedlot)?	0027	1☐Yes	3☐No
e.	Pasture-raised livestock (access to pastures)?	0028	1☐Yes	3☐No
f.	Cage-free egg layers?	0029	1☐Yes	3☐No
g.	Certified humane by American Humane Association, Humane Farm Animal Care Program, or Animal Welfare Institute?	0030	1☐Yes	3☐No
h.	Promoting conservation (e.g., land preservation, Predator Friendly Certification, eco-friendly, etc.)?	0031	1☐Yes	3☐No

3. In the last 12 months, what percentage of this operation's animals or animal products were marketed through the following channels?

		Percent
a.	Auction or sales barn	0032
b.	Broker/wholesaler/distributor	0033
c.	Direct to **individual** or **consumer** (e.g., farmer's market, Community Supported Agriculture (CSA), private sales, etc.)	0034
d.	Direct to health food/specialty food stores (e.g., Whole Foods, etc.)	0035
e.	Direct to restaurants/institutions (farm to school)	0036
f.	As a member of a **cooperative wholesale** distribution channel (farmer-owned)	0037
g.	Other (specify:____________________)	0038
h.	Total (add items a-g, must equal 100%)	**100%**

4. Do you use the internet to market any of your agricultural products?

0039 3☐ No – (Skip to Section D)

1☐ Yes – Which of the following do you use? (Check all that apply.)

- 0040 ☐ Website for farm business
- 0143 ☐ E-mail messages
- 0144 ☐ On-line farm directory (a list of local farms on a website)
- 0145 ☐ Facebook
- 0146 ☐ On-line message board (e.g., Craigslist, etc.)
- 0147 ☐ Other (specify:____________________)

-

Section D – Future Plans

1. Do you expect to continue farming over the next 5 years?

0042 1☐ **Yes, complete this column** ↓ 3☐ **No, complete this column** ↓

How necessary are the following factors to your decision to **continue** farming?

			How Necessary?		
			Not	Somewhat	Very
a.	Stable cost of farm expenses	0044	1☐	2☐	3☐
b.	Improved prices you get for your products	0045	1☐	2☐	3☐
c.	Greater stability of prices for your products	0046	1☐	2☐	3☐
d.	Interest rates on debt remain low	0047	1☐	2☐	3☐
e.	Access to operating loans	0048	1☐	2☐	3☐
f.	Ability to find off-farm employment to supplement income	0049	1☐	2☐	3☐
g.	Other factors (specify: ____________)	0050	1☐	2☐	3☐

How important are the following factors to your decision to **leave** farming in the next 5 years?

			How Important?		
			Not	Somewhat	Very
a.	Cost of farm expenses	0051	1☐	2☐	3☐
b.	Prices you get for your products	0052	1☐	2☐	3☐
c.	Instability of prices you get for your products	0053	1☐	2☐	3☐
d.	Access to markets	0054	1☐	2☐	3☐
e.	Interest rates on debt	0055	1☐	2☐	3☐
f.	Access to operating loans	0056	1☐	2☐	3☐
g.	Difficulty finding off-farm employment to supplement income	0057	1☐	2☐	3☐
h.	Lack of interest from future generations (no farm successor)	0058	1☐	2☐	3☐
i.	Opportunity to sell land for non-farm purpose (e.g., urban development, preservation project, etc.)	0059	1☐	2☐	3☐
j.	Burden of Government regulations	0060	1☐	2☐	3☐
k.	Other factors (specify: ____________)	0061	1☐	2☐	3☐

Which of the following best describes your plans after leaving farming? (**Check one only**)

0062
1☐ Retirement
2☐ Change to a different job/career
3☐ Other (specify: ____________)

-

Section E – Resources

1. Do you use any of the following for slaughtering livestock or poultry (for home use or sale)?
   a. Mobile slaughter service that comes to your operation? . . . . 0065 ₁☐ Yes ₃☐ No
   b. Live animals transported to the slaughter facility? . . . . 0066 ₁☐ Yes ₃☐ No

      If yes, what is the farthest one-way distance to the slaughter facility? . . . . **miles** [0067 ____]

2. Do you transport your animals or products to sell them? (e.g., to auction, other farms, fair, farmer's market, etc.). . . . . 0068 ₁☐ Yes ₃☐ No

   If yes, what is the farthest one-way distance you travel? . . . . **miles** [0069 ____]

3. Do you use any of the following to obtain feed for your livestock or poultry?
   a. Home grown feed? . . . . 0070 ₁☐ Yes ₃☐ No
   b. Feed transported/shipped by supplier? . . . . 0071 ₁☐ Yes ₃☐ No

      If yes, what is the farthest one-way distance feed is transported? . . . . **miles** [0072 ____]

   c. Transport feed to operation myself. . . . . 0073 ₁☐ Yes ₃☐ No

      If yes, what is the farthest one-way distance you travel? . . . . **miles** [0074 ____]

4. Does anyone in your household, including yourself, earn income from an off-farm job?

   0075 ₃☐ No - (Skip to Section F)
   ₁☐ Yes - (Continue to next question)

5. What industry(s) do they or you work in? (Check all that apply.)

   0077 ☐ Agriculture, forestry, fishing, hunting, or mining
   0164 ☐ Construction
   0165 ☐ Manufacturing
   0166 ☐ Education services
   0167 ☐ Healthcare services
   0168 ☐ Other government services
   0169 ☐ Wholesale trade, warehousing, utilities or transportation
   0170 ☐ Finance, insurance, real estate, and other professional services
   0171 ☐ Recreation or tourism including eating and lodging
   0172 ☐ Retail trade or personal services
   0173 ☐ Other (specify:______________________)

6. What is the farthest one-way distance anyone in your household travels to their off-farm job? . . . . **miles** [0078 ____]

Section F – Use of Veterinarians

1. How many miles away is the nearest veterinarian that works with your type(s) of livestock or poultry (**Check one only**)?

   0079 ₁☐ 29 miles or less
   ₂☐ 30 - 99 miles
   ₃☐ 100 - 299 miles
   ₄☐ 300 miles or more
   ₅☐ No veterinarian available for my type of animals
   ₆☐ Don't know

2. In the last 12 months, did you use a veterinarian for your livestock or poultry? (e.g., treatment, consultation, health certificates, etc.)

   0080 ₁☐ Yes - (Go to Section G)
   ₃☐ No - (Continue to next question)

3. What were the reasons for **not** using a veterinarian? (Check all that apply.)

   0081 ☐ Too expensive
   0160 ☐ No veterinarian available in my area or veterinarian too far away
   0161 ☐ I provide my own health care for my animals
   0162 ☐ No disease or other need for veterinarian
   0163 ☐ Other reasons (specify:______________________________)

-

Section G – General Management

1. In the last 12 months, have you used natural or alternative medicine such as holistic, herbal or homeopathic treatments for your livestock or poultry?(e.g., garlic for parasites, echinacea, chiropractic, acupuncture, etc.)

   0083 ₃☐ No
   ₁☐ Yes - (specify:________________________)

2. In the last 12 months, did your livestock or poultry ever share a pasture at the same time with livestock or poultry from other operations? . . . . 0084 ₁☐ Yes ₃☐ No

3. Do you have a fence around the entire perimeter of your livestock or poultry area that keeps out animals from other operations?

   0085 ₃☐No (Go to Item 5)
   ₁☐Yes (Continue to next question)

4. Is there anywhere along this perimeter that your livestock or poultry has nose-to-nose contact with the same-species of livestock from other operations? . . . . 0087 ₁☐Yes ₃☐No

5. If you had livestock or poultry on your operation you suspected of having a foreign animal disease (a disease not known to be present in the United States, such as foot-and-mouth disease or exotic Newcastle disease, etc.) how likely are you to directly contact the following resources?

		Not Likely	Somewhat Likely	Very Likely
a. Extension agent/university.	0088	₁☐	₂☐	₃☐
b. State Veterinarian's office.	0089	₁☐	₂☐	₃☐
c. U.S. Department of Agriculture.	0090	₁☐	₂☐	₃☐
d. Private veterinarian.	0091	₁☐	₂☐	₃☐
e. Other (specify:____________)	0092	₁☐	₂☐	₃☐

Section H – Federal Livestock and Poultry Compensation

Both USDA and State Veterinarians are responsible for controlling a specific set of regulated diseases, such as tuberculosis, brucellosis, pseudorabies, exotic Newcastle disease, etc. If it is determined that a herd or flock is infected and must be removed and euthanized to prevent disease spread of these regulated diseases, Federal law provides compensation (indemnity) to the producer based upon "fair-market value" of the animals lost.

1. Have you previously heard of Federal compensation (indemnity) as described above?. . . . . 0094 ₁☐ Yes ₃☐ No

   The next questions in this section ask for **your opinion** about how the Federal government should compensate farmers for animals removed or euthanized to prevent disease spread.

2. In your opinion, which of the following should be used to determine the fair-market value for a production animal removed or euthanized to prevent the spread of a regulated disease? (Check one only.)

   0095 ₁☐ The market price of healthy young breeding replacement stock
   ₂☐ The market price of healthy animals of similar age, weight, and purpose on a similar farm
   ₃☐ The current market price of a cull animal

-

For the next question, "*infectious disease management*" is defined as: Management practices that reduce the chance that infectious disease will be carried onto the farm by animals or people.

3. Which of the following statements do you agree with more? (Check one only.)

0096 1☐ The government should take into account a livestock owner's infectious disease management practices when determining compensation.
2☐ The government should pay full compensation regardless of a livestock owner's infectious disease management practices

Section I – Your Operation

1. Please rate the importance to you of the following reasons for farming:

		How Important?		
a. Family tradition/heritage.	0138	1☐ Not	2☐Somewhat	3☐Very
b. Maintain farm for future generations.	0101	1☐ Not	2☐Somewhat	3☐Very
c. Source of income	0102	1☐ Not	2☐Somewhat	3☐Very
d. Tax benefits.	0103	1☐ Not	2☐Somewhat	3☐Very
e. Products for personal consumption.	0104	1☐ Not	2☐Somewhat	3☐Very
f. Lifestyle.	0105	1☐ Not	2☐Somewhat	3☐Very
g. Other reasons for farming (specify: ______________)	0106	1☐ Not	2☐Somewhat	3☐Very

2. How useful would additional training be to you and your farm business in the following areas?

		How Useful?		
a. Infectious disease management practices.	0107	1☐ Not	2☐Somewhat	3☐Very
b. Marketing of products.	0108	1☐ Not	2☐Somewhat	3☐Very
c. Managing the business.	0109	1☐ Not	2☐Somewhat	3☐Very
d. Hiring and managing labor.	0110	1☐ Not	2☐Somewhat	3☐Very
e. Tax-related issues.	0111	1☐ Not	2☐Somewhat	3☐Very
f. Animal health/diseases.	0112	1☐ Not	2☐Somewhat	3☐Very
g. Government programs and regulations.	0113	1☐ Not	2☐Somewhat	3☐Very
h. Rules governing interstate or international movement of animals or products.	0114	1☐ Not	2☐Somewhat	3☐Very
i. How to transfer the farm to the next generation.	0115	1☐ Not	2☐Somewhat	3☐Very
j. Other areas (specify:____________________).	0116	1☐ Not	2☐Somewhat	3☐Very

3. How would you prefer to receive training or additional information? (Check all that apply.)

0117 ☐ Through local extension office
0148 ☐ Presentation by expert
0149 ☐ Written publication
0150 ☐ Internet
0151 ☐ Livestock association/club

4. How many hours per month do you spend completing paperwork related to local, state, or Federal health and environmental regulations?. . . . . **hours** [0122 ______]

5. Which of the following best describes this farm? (Check one only.)

0123 1☐ Retirement farm (the principal operator is retired from another occupation)
2☐ Residential/lifestyle farm (the principal operator's primary occupation is something OTHER than farming)
3☐ Farming occupation (farming is the principal operator's primary occupation)
4☐ Other (specify: ____________________________)

-

6. An operator is an individual who is involved in the day-to-day decisions for this operation. Please fill in the following table for up to 2 operators of this operation.

			Primary Operator		Secondary Operator (leave blank if not applicable)
a.	Is the operator of Spanish, Hispanic or Latino origin or background, such as Mexican, Cuban, or Puerto Rican, regardless of race?	0127	1☐ Yes 3☐ No	0128	1☐ Yes 3☐ No
b.	What is the operator's race?		Mark one or more.		Mark one or more.
		0129	☐ White	0130	☐ White
		0152	☐ Black or African American	0156	☐ Black or African American
		0153	☐ American Indian or Alaska Native	0157	☐ American Indian or Alaska Native
		0154	☐ Asian	0158	☐ Asian
		0155	☐ Native Hawaiian or other Pacific Islander	0159	☐ Native Hawaiian or other Pacific Islander
c.	Sex of operator	0131	1☐ Male 2☐Female	0132	1☐ Male 2☐Female
d.	What is the operator's age?	0133	1☐ Less than 25 years old 2☐ 25 to 44 years 3☐ 45 to 64 years 4☐ 65 years old or more	0134	1☐ Less than 25 years old 2☐ 25 to 44 years 3☐ 45 to 64 years 4☐ 65 years old or more
e.	What is the highest level of formal education the operator has completed?	0135	1☐ Less than high school diploma 2☐ High school diploma or equivalency (GED) 3☐ Some college (include Associate degree) 4☐ College graduate and beyond		

7. Who completed this survey?

0137 1☐ Primary operator

2☐ Secondary operator

3☐ Other(specify:________________________________)

Section J – Conclusion

Thank you for your time. Please return this questionnaire in the enclosed envelope.

Comments:

9910	MM	DD	YY
Date:	__	__	__

For office use only

Response			Respondent		Mode			Enum.	Eval.	R. Unit
1-Comp 2-R 3-Inac 4-Office Hold	5-R – Est 6-Inac – Est 7-Off Hold – Est 8-Known Zero	9901	1-Op/Mgr 2-Sp 3-Acct/Bkpr 4-Partner 9-Oth	9902	1-Mail 2-Tel 3-Face-to-Face 4-CATI 5-Web	6-e-mail 7-Fax 8-CAPI 19-Other	9903	098	100	921