Brucella suis and farm biosecurity: assessing risk in pigs raised outdoors in New York State

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OBJECTIVE
To evaluate the Brucella suis exposure status of pigs raised with outdoor access on farms in New York State and assess biosecurity and management practices of those farms.

ANIMALS
250 pigs that were raised for commercial purposes, had access to the outdoors, and were > 4 months of age on 24 farms in New York State.

PROCEDURES
Farms were randomly selected from a sampling frame generated for the study and contacted to recruit them to participate. Participating farms were provided a questionnaire to complete. Up to 30 pigs per farm were tested for serum anti-Brucella antibodies.

RESULTS
Farm were classified as seasonal and year round. Seasonal farms raised pigs for slaughter, and year-round farms bred pigs, raised them for slaughter, and sold live pigs to others to raise. None of the 250 pigs had antibodies to Brucella spp. Nevertheless, the biosecurity assessment revealed a need for enhanced practices in procurement and management of swine in a wide range of areas.

CLINICAL RELEVANCE
There was no evidence for ongoing B suis infection on these swine farms in New York State, but biosecurity and preventive practices at these facilities could be improved to prevent the introduction and spread of B suis and other pathogens.

Brucella is a genus of zoonotic, gram-negative intracellular pathogens that affect cattle (Brucella abortus), small ruminants (Brucella melitensis), canines (Brucella canis), and swine (Brucella suis, which has also been reported in cattle). Numerous other species, including humans, can be infected, and there are a variety of nonzoonotic species of Brucella. In the United States, state-federal cooperative programs eradicated brucellosis from commercial swine in all 50 states in 2011 but the pathogen continues to circulate in feral swine in the United States, presenting an ongoing exposure risk to domestic swine herds raised in transitional operations. The USDA defines commercial swine herds as those raised in a manner that prevents contact with feral swine and that are in continuous operation. Transitional farms are those that are composed of captive feral swine or housed swine that can be exposed to feral swine because of management practices. Furthermore, the census definition of a farm is a location that produces ≥ $1,000 in product in any given year.

In 2016, infection with B suis biotype 1a was diagnosed in a New York State farmer who raised pigs with outdoor access. This farmer’s sow also tested positive for B suis biotype 1. Tracebacks revealed that the source farm for the index farm’s animals reported a feral boar mating with its sows in 2004. There was no comment on illness in the 2 pigs kept from the feral swine mating, but the boar lived until 2014 and the sow farrowed multiple times. A total of 50 farms and 13 states were involved in the outbreak investigation. Nine B suis–positive herds were identified, and all positive animals were confirmed as infected with B suis biotype 1. Of note, all 9 of the positive herds had operations with outdoor access. The positive farms were depopulated with indemnity.
Brucellosis in animals can result in various clinical signs, including abortion, decreased milk yield, fertility challenges, and hygromas. Infected animals are often culled to prevent disease spread. *Brucella melitensis* and *B. abortus* have vaccines available for the livestock, but *B. suis* does not. Control is via testing and culling of infected herds and implementation of sound biosecurity practices to limit disease introduction from other farms and wildlife reservoirs.

Humans with brucellosis often develop a fever and malaise and can develop a variety of other symptoms, making brucellosis hard to diagnose. Chronic disease associated with granuloma formation can occur anywhere in the body. Acute disease can be treated with antibiotics if the condition is properly diagnosed. Some risk factors for humans contracting *B. suis* infection include hunting and field dressing of feral swine, working in a packing plant, and, for farmers and veterinarians, assisting with farrowing.

Most (> 66%) housing setups on farms in the United States that raise < 100 pigs include outdoor access. The number of small-scale swine farm operations in New York State grew between 2012 and 2017. These systems differ in biosecurity from farms where pigs are raised indoors with strict biosecurity measures, no contact with other domestic livestock, and limited contact with wildlife. The growth of small-scale swine farming systems with differing biosecurity has important potential implications for infectious disease risk to both commercial and non-commercial swine herds in the United States. The purposes of the study reported here were to evaluate the exposure status to *B. suis* for pigs on farms in New York State that raise pigs with outdoor access and to better understand the biosecurity and management practices of these farms.

### Materials and Methods

The Cornell University Institutional Animal Care and Use Committee approved the animal sampling protocol for this study (protocol number 2018-0068). The Cornell University Institutional Review Board provided an exemption for the questionnaire used. Participating farms were required to sign a consent form under New York State law. All participating animal owners were informed verbally and in writing that study participation included animal sampling and completion of a questionnaire and that a positive test result would result in a response from state and federal veterinarians.

#### Farm sampling and sample size

Any farm in New York State that raised pigs with continual outdoor access for a commercial purpose was eligible to be enrolled in the study. Commercial purpose was defined as selling pigs or pig products for income; this included selling pigs as pets or for exhibition, selling pigs as live animals for any purpose, and selling pork or any other commodity that came from raising pigs. Outdoor access was defined as animals spending part of the day outside of an enclosed, roofed building. Individual pigs > 5 months of age or of reasonable size at 4 months of age were eligible for sampling and up to 30 pigs could be sampled at each participating farm. These age considerations were instituted to allow for safe sampling of pigs after maternal antibodies were no longer detectable. The USDA compiled a list of New York farms that had pigs with outdoor access during the 2016 swine brucellosis case response, and this list was used as the initial study sampling frame. Additional farms were added to the list via review of publicly available websites, including Facebook, meatsuite.com, and localharvest.com, and through Google searches. Farms were randomly selected from the sampling frame and contacted via telephone, email, or both for recruitment by Cornell faculty members. Recruiters reviewed the study and consent documentation with the farm owner, and the owner then agreed or declined to participate. If a farm did not have current contact information available or if recruiters did not receive a response after multiple attempts at contacting a farm, the farm was dropped from the selection without replacement.

Reported *B. suis* prevalence data on this pig population were limited. Therefore, individuals working for the USDA and the New York State Department of Agriculture and Markets (NYSDAM) were contacted for expert opinion on brucellosis in New York State. They estimated the prevalence to be < 1%. Diagnostic testing followed the Swine Brucellosis Program Uniform Methods and Regulations guidelines, with a screening buffered antigen plate agglutination test and a confirmatory fluorescence polarization assay. The buffered antigen plate agglutination test had a 77% sensitivity and 96% specificity, and the confirmatory fluorescence polarization assay had a specificity of 99%. The calculated in-series specificity was 99%. To determine prevalence up to 5% with a 5% error at 95% confidence, we calculated that a sample size of 122 pigs was needed prior to accounting for clustering. According to the 2017 New York Agricultural Census, 92% of small swine enterprises (defined as < 100 head of swine; n = 1,560) had < 24 animals, 6% had 25 to 50 animals, and 2% had 51 to 99 animals. Assuming we sampled a mean of 15 animals/farm and that the intraclass correlation was approximately 0.2, the adjusted sample size was calculated to be 464.

### Questionnaire development

The biosecurity questionnaire for the study was developed by the Cornell research team with the assistance of veterinarians from the USDA and NYSDAM. The questionnaire used mostly close-ended questions with a few open-ended questions when it was necessary to capture greater detail on a specific topic. The questionnaire topics included farm demographics, animal sourcing, types of production (meat, breeding, and exhibition), animal movements, animal and animal product sales, slaughter facilities used, animal health and feeding practices, and farm biosecurity practices. Once a final draft of the questionnaire was completed, it was distributed to additional veterinarians from the...
same organizations to receive feedback on its clarity, flow, and content. The finalized questionnaire was provided to participating farmers in both a hardcopy and an online format, allowing participants to select a preferred submission method.

**Sample collection and diagnostic testing**

After recruitment, farm names and contact information were sent to the USDA to facilitate brucellosis testing sample collection in collaboration with field veterinarians from the NYS DAM. State and federal veterinarians then coordinated sampling with participating farm owners. These veterinarians went to the farms and performed jugular or anterior vena cava venipuncture and ear-tagged pigs from which samples were collected. They also, when possible, collected basic information on number of animals, breed, age, and sex and crude data on animal use. This information was recorded on the laboratory sample submission form. Animal sampling for the study occurred from April 2019 through February 2021. The USDA and NYS DAM veterinarians created unique identification numbers for each farm and individual animal. This allowed Cornell researchers to remain blinded to both the farm questionnaire and animal diagnostic test results. Farm owners recorded the unique identification number on the questionnaire prior to submission. Cornell researchers had access to the individual questionnaires and could link the questionnaires to the brucellosis test results on the basis of this unique identification number. The USDA and NYS DAM were provided aggregate questionnaire data; the regulatory agencies were not given access to farm-level questionnaire data to provide owner anonymity and encourage accurate and complete responses. Early in sampling, 10 blood samples were lost due to hemolysis; therefore, centrifugation of all blood samples prior to shipping became required practice and was effective in preventing further sample hemolysis. Serum samples were sent to the Kentucky Eastern Regional Federal Brucellosis Laboratory for B suis screening via the buffered antigen plate agglutination test and, if positive, for confirmatory testing with a fluorescence polarization assay that incorporated a B abortus antigen. Confirmation of positive test results was performed at the USDA National Veterinary Service Laboratory in Ames, Iowa.

**Biosecurity scoring**

To quantify farm biosecurity practices and the animal care practices that contributed to biosecurity, the University of Ghent BioCheck biosecurity assessment model was adapted for use in this target pig population and integrated into the study questionnaire.22 Our adaptation of the BioCheck scoring system allowed for both estimation of the risk of disease introduction and identification of focus areas for risk reduction. The scoring process for this study had 2 steps. First, each specific question related to biosecurity in the study questionnaire was given a point value defined by the BioCheck model that reflected the topic’s contribution to biosecurity. The Cornell veterinarians aligned each study question to its corresponding subcategory and question in the BioCheck scoring table22 to determine the appropriate score for each question. Second, a weight was given to each of the possible answers that a respondent could choose for each study question. The assigned weights for each answer reflected the differing biosecurity risks represented by the answers. To determine the biosecurity risk of each answer, 7 veterinarians from the USDA, National Pork Board, Cornell University, and NYS DAM were asked to rank each question’s associated answers on a scale from 0 to 1, in increments of 0.25. In this scale, 1 represented the most biosecure practices and 0 the least biosecure practices. Points awarded for each question were determined by the product of question score and the selected answer weight. The resulting individual scores for each question were summed and scaled to 100 and used to determine a biosecurity score. We considered biosecurity scores > 90 as excellent, > 80 to 90 as good, > 70 to 80 as fair, and ≤ 70 as poor. In addition to the biosecurity score, a subset of questions pertaining to preventive veterinary care and veterinary use were used to calculate a separate animal care score. Scoring was done in the same manner as described for biosecurity scoring, except that scores were scaled to 10 points rather than 100. All scores were calculated with standard software (Excel, version 2016 and 365; Microsoft Corp).

**Statistical analysis**

Data collected from the questionnaires and the laboratory sample submission forms were compiled to provide a full summary of the pigs and farms sampled. Data were categorized, and frequencies and percentages were calculated to summarize descriptive findings for all farms, seasonal farms, and year-round farms. In some instances, answers to multiple questions were compiled to provide the most accurate summary of the data. Biosecurity scores were evaluated for normality with Q-Q plots, and the Shapiro-Wilk normality test, and medians and ranges were calculated for all farms, seasonal farms, and year-round farms. The Wilcoxon rank sum test was used to compare nonparametric data between seasonal and year-round farms. All statistical analyses were performed with standard software (Stata, version 16.1 IC; StataCorp). Values of P ≤ 0.05 were considered significant.

**Results**

A total of 218 randomly selected farms were contacted between March 2019 and December 2020, with 24 (11%) agreeing to participate in the study. Of those 24 farms, 20 (83%) returned completed questionnaires. Participating farms were located across New York State. Animal sampling occurred year round between April 2019 and March 2021. In total, 260 animals across the 24 farms were sampled, but samples for 10 pigs were discarded because of hemolysis. The remaining 250 samples were tested.
with the buffered antigen plate agglutination test. None of these pigs were positive for antibodies against *B. suis*.

The median number of pigs sampled on each farm was 9.5 (range, 1 to 30). Only 1 farm had 30 pigs sampled. The median age of pigs sampled was 6 months (range, 4 to 48 months). Of the 260 pigs sampled, 173 (66.5%) were females, and 83 (31.9%) were males (sex of the remaining 4 [1.5%] animals was not specified).

The 20 farms that completed the questionnaire raised pigs for a variety of commercial reasons, with 11 (55%) reporting raising pigs for > 1 source of revenue. Eighteen (90%) farms sold pigs for meat, 13 (60%) sold live pigs to others to raise for meat or slaughter, 7 (35%) sold breeding stock, 1 (5%) sold semen, and 1 (5%) sold pigs for other uses. Of the 20 farms, 10 (50%) raised purebred animals, and 11 (55%) raised crossbred animals, with some farms raising both purebred and crossbred animals; breeds of pigs raised on 3 (15%) farms were not reported. Heritage breeds predominated among the breed types represented; there were 14 farms that reported raising pure heritage breeds or heritage-only crosses and 5 farms that reported raising heritage–nonheritage crosses. The most common purebred heritage breeds reported were the American Guinea (n = 2 farms) and the Tamworth (2).

To assess biosecurity and veterinary use practices, the 20 farms that submitted questionnaires were classified as seasonal (n = 5) or year-round (15) farms. Seasonal farms raised only nonbreeding pigs, mostly from May to September, and at the time of sampling had a median of 10 animals (range, 10 to 19). Year-round farms raised pigs for both breeding and nonbreeding purposes. At the time of sampling, year-round farms had a median of 2 sows (range, 0 to 11) and a median of 0 (range, 0 to 42) nonbreeding pigs.

For 19 of the 20 farms, the primary use of the pigs was for meat and live sale. One year-round farm only raised and sold pigs as pets. Four seasonal farms responded to questions on the sale of their pigs (Table 1). Seasonal farms sold meat off their property, primarily at farmer’s markets and to individuals, and sent a median of 20 pigs to slaughterhouses each year. One seasonal farm sold pigs to Massachusetts. Four seasonal farms completed the section of the questionnaire about purchase of pigs; all reported purchasing their pigs from private vendors and other farmers, with 2 of these farms purchasing pigs from heritage breeders. One seasonal farm reported importing pigs from Pennsylvania.

Year-round farms were more diversified in their sources of commercial income (Table 1). Nine of 14 sold live pigs to others, 8 of 14 sold meat off their property, 7 of 14 sold meat on their property, and 1 of 14 categorized all their pigs as pets. Only 1 other farm kept some pigs as pets. Year-round farms sold pigs at livestock markets (3/14), at slaughterhouses (4/14), to private vendors and farmers (12/14), and to heritage breeders (5/14); 1 farm reported they used their pigs for self-consumption. Thirteen of 14 responding year-round farms sold pork to individuals, and 1 used them for self-consumption. Only 1 of 10 year-round farms that responded to location of pork sales sold meat at farmers’ markets. Year-round farms sold a median of 10 pigs/y to slaughterhouses, kept a median of 2.5 pigs/y for on-farm slaughter, and kept a median of 4 pigs/y for breeding purposes. These farms did not have nonbreeding animals on their farm all year, as evidenced by some farms not having nonbreeding pigs at the time of the survey even though they reported selling pigs every year. The year-round farms often bred their own replacement pigs (8/15) or purchased pigs (6/15). Of those that purchased pigs, 5 purchased pigs from private vendors and other farmers, and 1 purchased pigs from heritage breeders. One year-round farmer exported nonbreeding pigs to Massachusetts.

Year-round farms were the only farms that raised pigs for breeding purposes. Seven of the 15 year-round farms sold breeding stock, including 1 that also sold semen. Customers for breeding stock and semen included private vendors and heritage breeders (Table 2). These farms sourced their pigs almost equally through on-farm breeding, breeding and purchase of pigs, and purchase of pigs only. Purchase of breeding stock was from private vendors and heritage breeders. Sales of breeding pigs occurred throughout the year. Six of these 7 year-round farms were involved in interstate movement of their breeding pigs. They imported breeding pigs from California, Illinois, Indiana, Montana, Ohio, Oklahoma, Pennsylvania, Washington, and Wisconsin. Five year-round farms exported pigs for breeding purposes to Connecticut, Kansas, Massachusetts, North Carolina, Pennsylvania, Vermont, and Virginia.

Median farm biosecurity score across all farms was 61.24 (range, 40.49 to 90.66; scored on a scale from 0 to 100), and biosecurity scores did not differ significantly (P = 0.76) between the year-round (median score, 61.24; range, 40.49 to 90.66) and seasonal (median score, 61.23; range, 46.62 to 77.37) farms. No farms reported feral swine sightings. Of 18 responding farms, 16 isolated new animals for 7 to 30 days, with 7 of those 16 farms isolating animals for 30 days. Almost all farms bought commercial feed, but 7 of the 20 responding farms fed plate waste from the home. One reported specifically that they fed meat scraps and did not cook the garbage, while only 1 farm reported cooking the garbage to 350 °F. Most dead stock were composted (n = 10) or buried (9), but a few farms reported putting dead animals in the garbage (2) or dumping them off the farm (1). Most farms received poor biosecurity scores owing to a lack of closed herds, with all farms bringing animals in and almost all purchasing from farms without knowing the animal brucellosis and pseudorabies disease status. One year-round farm reported purchasing breeding stock from brucellosis- and pseudorabies-free farms, and one seasonal farm purchased stock from pseudorabies-free farms. Four farms had animals leave the farm, and 1 of these farms did not isolate those animals on their return. All farms that responded reported that other animals...
were present, with cattle being the most commonly reported. Six of the farms reported that their pigs had contact with other domestic animals; 5 reported contacts with cattle and 1 with poultry. Farms did report health requirements for animal purchase (5 that purchased breeding animals and 8 that purchased nonbreeding animals) and rodent control programs (11 farms). When further described, the prepurchase health requirements included visual appearance (4 nonbreeding farms), vaccination or deworming (1 breeding farm and 4 nonbreeding farms), use of state guidelines (1 breeding farm), and breed standards (1 breeding farm); 1 breeding farm purchased from a closed herd that also provided health records. Rodent control most commonly was through a contracted company (4 farm), a cat (4 farms), or use of bait (7 farms) or a combination thereof.

Median animal care score across all farms, which evaluated preventive veterinary care and veterinary

Table 1—Use, sale, and source of pigs during 2019 through 2021 for 20 farms in New York State that raised nonbreeding pigs with outdoor access; farms were classified as seasonal (n = 5; farms that raised pigs only for slaughter) or year-round (15; farms that bred pigs, raised them for slaughter, and sold live pigs to others to raise).

| Variable                                                      | Seasonal farms | Year-round farms |
|---------------------------------------------------------------|----------------|------------------|
| Use of pigs                                                   |                |                  |
| Meat for sale on property                                    | Yes 3, No 1   | Yes 7, No 7      |
| Meat for sale off propertya                                   | No 4, No 1    | Yes 8, No 7      |
| Exhibition (eg, 4H and shows)                                 | No 0, No 4    | No 14, No 1      |
| Live sale to others                                          | No 1, No 3    | No 5, No 5       |
| Other                                                         | No 0, No 4    | No 13, No 1      |
| Sale of nonbreeding pigs                                      |                |                  |
| Livestock markets                                            | No 0, No 5    | No 3, No 11      |
| Direct to slaughterhousea                                     | No 5, No 0    | No 4, No 8       |
| Private vendors, farms, or individuals                        | No 0, No 5    | No 12, No 2      |
| Heritage breed breeders                                      | No 0, No 5    | No 5, No 9       |
| Other                                                         | No 0, No 5    | No 13, No 1      |
| Site of slaughter                                            |                |                  |
| Slaughterhouse                                               | No 5, No 0    | No 12, No 0      |
| On farm                                                      | No 0, No 5    | No 4, No 4       |
| Custom exempt or customer slaughter                           | NA, NA, NA    | No 2, No 3       |
| Slaughter for self-consumption                                | NA, NA, NA    | No 1, No 4       |
| Professionally slaughtered on farm                           | NA, NA, NA    | No 1, No 4       |
| Sale of pork from pigs slaughtered at a slaughterhouseb       |                |                  |
| NY State farmers’ market                                     | No 3, No 1    | No 1, No 9       |
| Restaurant in NY State                                       | No 1, No 3    | No 2, No 8       |
| Individuals in NY State                                      | No 3, No 1    | No 10, No 5      |
| Individuals outside NY State                                 | No 1, No 3    | No 3, No 7       |
| Grocery store in NY State                                    | No 1, No 3    | No 1, No 10      |
| Other                                                        | No 0, No 4    | No 0, No 9       |
| Source of pigs                                               |                |                  |
| Breeding                                                     | No 0, No 4    | No 8, No 7       |
| Purchase                                                     | No 4, No 0    | No 6, No 9       |
| Livestock market                                             | No 0, No 4    | No 0, No 6       |
| Private vendor or farm                                       | No 4, No 0    | No 5, No 1       |
| Heritage breed breeder                                       | No 2, No 2    | No 2, No 4       |
| Import pigs into NY State                                    |                |                  |
| Nonbreeding pigs                                             | No 1, No 3    | No 0, No 15      |
| Breeding pigs                                                | NA, NA, NA    | No 6, No 1       |
| Source of breeding pigs                                       |                |                  |
| Breeding                                                     | No 3, No 1    | No 4, No 2       |
| Purchase                                                     | No 4, No 3    | No 4, No 0       |
| Livestock market                                             | No 0, No 6    | No 1, No 1       |
| Private vendor or farm                                       | No 4, No 2    | No 1, No 1       |
| Heritage breed breeder                                       | No 5, No 1    | No 1, No 1       |

aIncludes contract slaughter.

bFor respondents that raised pigs as pets, this section of the questionnaire did not apply and was recorded as a nonresponse. NY = New York.

Table 2—Sale and source of pigs during 2019 through 2021 for 7 farms in New York State that raised nonbreeding pigs with outdoor access.

| Variable                                                      | Yes | No | No response |
|---------------------------------------------------------------|-----|----|-------------|
| Sale of breeding pigs                                         |     |    |             |
| Livestock market                                              | 0   | 7  | 0           |
| Private vendor                                                | 6   | 1  | 0           |
| Heritage breed breeder                                        | 6   | 1  | 0           |
| Other                                                         | 1   | 6  | 0           |
| Source of breeding pigs                                       |     |    |             |
| Breed new pigs                                                | 3   | 4  | 0           |
| Breed new pigs and purchase                                   | 4   | 3  | 0           |
| Purchase pigs                                                 | 3   | 4  | 0           |
| Livestock market                                              | 0   | 6  | 1           |
| Private vendor or farm                                        | 4   | 2  | 1           |
| Heritage breed breeder                                        | 5   | 1  | 1           |

Farms sold a median of 4 pigs/y (range, 1–10 pigs/y) for breeding purposes.
use, was 5.41 (range, 0.59 to 8.51; scored on a scale from 0 to 10). Again, animal care scores did not differ significantly ($P = 0.759$) between year-round (median score, 5.52; range, 0.59 to 8.51) and seasonal (median score, 5.30; range, 3.82 to 6.18) farms. Four of the 20 farms did not use veterinarians at all, including 1 that reported an absence of veterinarians that treat swine in the region. Thirteen of the farms used a veterinarian for sick animal care only, and 3 farms used veterinarians for general health purposes. Preventive medicine programs such as vaccination and parasite management were limited.

**Discussion**

Despite eradication of brucellosis from the United States' commercial swine herd, the disease remains an issue in feral swine and was reported in a New York State farmer and the farmer's swine herd in 2016.\(^5\) Thus, this zoonotic disease remains an important threat in the United States even though it has been eradicated from commercial herds.\(^5\) The goal of the present study was to evaluate the brucellosis status of swine farms that raised pigs outdoors in New York State and to understand this unique and growing segment of the swine industry and its biosecurity practices.

Recruitment of farms for enrollment in the study was a challenge, with a low (24/218 [11%]) participation rate. The most common reasons for refusal to participate were a lack of response and distrust in engaging with government authorities; less common reasons that were mentioned included biosecurity concerns (i.e., letting others enter the farm for sampling) and logistical issues around capturing the animals for sampling. Unfortunately, data on nonparticipation were not consistently captured and cannot be quantified. We were not able to meet our target sample size because COVID-19 pandemic restrictions prevented sampling of some farms prior to sale of their animals. Yet, this sample size gave us enough power to detect a true prevalence of 3% with 95% confidence and 5% error, even with an assay that had a sensitivity of 77% and specificity of 99%. None of the pigs tested had positive buffered antigen plate agglutination test results. This test detects antibodies, with positive results indicating recent exposure to *Brucella* spp and negative results indicating that recent exposure was unlikely in these animals. It is possible that some of these results were false-negative results given the test's limited sensitivity. Yet, the findings suggest that the risk of brucellosis in domestic commercial swine in New York is likely quite low.

In our study, we identified 2 distinct farm types in New York State that raised swine outdoors: seasonal farms and year-round farms. Both participated in selling pigs for nonbreeding purposes, either selling pigs for slaughter or selling pigs to be raised for slaughter, but year-round farms bred pigs and sold live animals to other farms, such as seasonal farms. There was an overlap in the time when year-round farms sold live pigs to others and when seasonal farms purchased pigs. This occurred primarily in April and May. Year-round farms bred the animals that they sold. Breeding facilities are at a greater risk of brucellosis maintenance, because offspring are infected as neonates or in utero. In addition, year-round farms sold pigs to be raised for slaughter throughout the state and sold breeding pigs to other states. They also imported pigs from other states more often than seasonal farms did. This resulted in a high potential for import and export of animals with disease concerns because there was also limited veterinary preventive medicine on these sites. Our findings suggest that year-round farms would be the best population to target for brucellosis education, in that they move the most pigs in and out of state, are involved in higher-risk breeding activities, and are a major supplier of pigs to seasonal farms.

Overall, biosecurity on all farms was poor. Biosecurity refers to the means used to keep pathogens off a farm, and it includes evaluation of animals for purchase, rodent control, preventive veterinary care, feeding practices (including garbage feeding), quarantine of animals, disposal of deceased animals, farrowing practices, farm visitor management, and farm design, among other areas. The median biosecurity score was 61.2 (on a scale from 0 to 100) for farms in this study. The animal care score was a subset of the biosecurity score and measured veterinary use, vaccine protocols, and parasite control practices. Again, the median score was poor at 5.4 (on a scale from 0 to 10). Both scores indicate a need to enhance farm biosecurity.

Of note, the overall poor biosecurity and animal care scores in this study suggested that farms are at risk for entry of a variety of infectious pathogens, not just *Brucella* spp. Most farmers had minimal health requirements when purchasing pigs and did not purchase from brucellosis- and pseudorabies-free farms. Many farms used cats for rodent control, which is consistent with findings from the 2012 Swine Report from the USDA.\(^18\)

Access to veterinarians compounds the challenges of biosecurity. Most farms in the present study typically used a veterinarian only when an animal was sick, and there was reported limited access to veterinarians able to treat commercial swine in New York State, especially for small-scale farmers. Given the export and import needs of these farms, this need may lead to a lack of oversight of animals coming into the state. Furthermore, the most common other livestock species that had access to these pigs were cattle, and cattle can be infected with *B. abortus* and *B. suis* cannot be differentiated serologically.\(^17\) The National Pork Board Pork Quality Assurance program provides a template to assist farmers in enhancing their biosecurity practices, and this may be a useful platform to engage this niche of farms to enhance their biosecurity and animal care practices.

Our findings did suggest that the 2016 brucellosis incident was contained and indicated that brucellosis is not currently present on New York State swine.
farms with outdoor access. Yet, given the findings on movement of animals into and out of the state and the current biosecurity and animal care protocols in place, combined with the potentially nonspecific clinical signs of brucellosis in pigs, there is a threat that a reintroduction of brucellosis could occur and go unnoticed.

USDA Wildlife Services report the removal and elimination of feral swine from New York State since 2014, but we believe the participating farms maintain some degree of risk given our biosecurity findings. Although no feral swine sightings were reported by farmers in our study, feral swine have historically created breeding colonies in New York State. Pigs with outdoor access are at higher risk for contact with feral swine and contracting brucellosis. Targeting pigs raised outdoors in ongoing brucellosis surveillance programs is needed to maintain vigilance for this zoonotic pathogen. Working with this growing transitional segment of the swine industry to enhance their farm biosecurity in New York State and across the nation provides an opportunity to reduce disease risks on these farms and in the United States swine industry more broadly. Broader swine medicine training opportunities for veterinarians, to include small and mixed animal practitioners, particularly in states that do not have a robust formal industry, could provide needed resources to further protect New York State farms, farmers, and swine. Furthermore, outreach to these farms is needed to build knowledge of swine management and trust in regulatory veterinary care and oversight.

Our study had several limitations. First, our sample size of tested pigs was limited, and we could not detect disease freedom to a 1% prevalence, only to a 3% prevalence. Given the low participation rate, our findings may not be representative and generalizable to other farms raising pigs outdoors in New York State. Farms willing to participate in the study could have had different biosecurity and management practices from the group that declined to participate. It is expected that enrolled farms had greater interest in improvement or awareness of biosecurity needs.

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