Project Title and NPB project identification number: Participatory regional surveillance to establish regional FAD status within the U.S. and improve swine movement decisions (NPB #22-028).

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Industry Summary: The extensive movement of animals, personnel, and materials facilitates the spread of infectious agents within and between countries, e.g., PEDV, ASFV, and others. Thus, an effective national surveillance system is crucial to the early detection, control, and elimination of notifiable pathogens. Previously, we showed that "active participatory regional surveillance," i.e., surveillance based on targeted sampling/testing of 10 poor-doing pigs per production site could detect a transboundary pathogen at 0.01% site-level prevalence (Trevisan et al., 2024). In this study, we expanded this concept to address surveillance of a notifiable pathogen in the contiguous 48 states.

Using the 2017 USDA Census of Agriculture, we created a dataset consisting of of 66,637 farms (71,555,218 pigs) in the lower 48 states (8,080,470 km2). Each farm was identified by geolocation (latitude, longitude), production type (breeder, feeder, breeder/feeder), and inventory. Using the USDA's Animal Disease Spread Model software, the spread of a "generic" pathogen was simulated for 180 days over a range of parameters for spread variables, i.e., direct contact (movement of infected animals), indirect contact (movement of people, vehicles, etc.), and local area spread (probability of infecting a farm at ≥1 km). Each spread simulation was initiated in an index herd randomly selected from one of 4 “pig density" categories, i.e., < 1 pig, 1 to 10 pigs, 10 to 100 pigs, and >100 pigs per km2. Each of the 6,075 scenarios was replicated 1,000 times to account for the stochastic nature of the ADSM software. The ADSM output for each scenario provided the infection status of each farm by day post-outbreak (DPO). Using these data, an R function was used to calculate the probability (P) of detecting ≥ 1 positive farm by DPO as a function of the percentage (%) of herds participating in the surveillance program, site-level detection sensitivity, and herd-level prevalence. The effect of sampling interval on detection was evaluated by comparing P for a specific DPO vs the aggregate P (Pa) based on sampling every 14 days using the complementary probability formula.

The results showed that detection was largely a function of producer participation. Even with low site-level detection sensitivity, a high probability of detection was achieved. For example, 60% producer participation and a 50% site-level sensitivity achieved a >90% probability of detecting at least one site if there were 6 positive sites among 66,637. In addition, sampling at two-week intervals led to earlier and higher detection probabilities. For example, with 40% participation and 10% site-level sensitivity, a two-week sampling interval (DPOs 14, 28, and 42) provided a 91% probability of detecting a positive herd, compared to a 70% probability of detection for a single sampling at DPO 42. Notably, the sampling protocol evaluated in this study was similar to that proposed in the US Swine Health Improvement Plan (US SHIP).

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Key Findings:

- Active producer participation in surveillance, i.e., collection and submission of samples from poor-doing pigs, is key to detection at low prevalence.
- Periodic sampling (e.g., every two weeks) increased the probability of detecting at low prevalence compared to a single sampling event.
- Testing a few targeted samples from many farms offers a highly sensitive method for disease detection in an active surveillance program.

Keywords: Foreign animal diseases, notifiable pathogens, transboundary diseases, active participatory surveillance, disease spread simulations, early detection, sampling and testing.

Scientific Abstract: Implementing an effective, sustainable, and affordable surveillance system capable of early detection of transboundary pathogens is crucial for enabling a rapid and effective response. Previously, it was shown that an active participatory design based on collecting and testing a few targeted samples from many participating farms, could achieve detection at a low prevalence and sustainable cost (Trevisan et al., 2024). In this study, we expanded the concept to the 48 contiguous states.

Using the 2017 USDA Census of Agriculture, we created a dataset of 66,637 farms in the contiguous 48 U.S. states (8,080,470 km2). Each farm was identified by geolocation, production type, and inventory. The spread of a "generic" pathogen within this region was simulated for 180 days over a range of spread parameter values (6,075 scenarios) using the Animal Disease Spread Model (ADSM) software (v3.5.10.0). The output dataset for each scenario reported the infection status of each farm by day post-outbreak (DPO). Using this dataset, an R function was used to calculate the probability (*P*) of detecting ≥ 1 positive farm by DPO as a function of the percentage (%) of herds participating in the surveillance program, site-level detection sensitivity, and disease prevalence. The effect of sampling interval was evaluated by comparing *P* for a specific DPO vs the aggregate P (*Pa*) based on sampling every 14 days (Equation 1).

(Equation 1) $Pa = [1 - (1 - P_{14}) \times (1 - P_{28}) \times \ldots (1 - P_{DPO})]$

Detection simulations revealed that the probability of detection increased with both higher producer participation and site-level detection sensitivity. However, even with low site-level sensitivity, high detection probabilities at a low prevalence were achieved as producer participation increased. Further, the results showed that sampling at 2-week intervals significantly improved detection at a low prevalence versus a single sampling at a specific DPO. For example, given 40% producer participation (26,654 participating herds) and 10% site-level detection sensitivity, a single sampling event on DPO 42 (0.04% prevalence/29 infected herds) provided a 70% probability of detecting at least one positive herd. In contrast, sampling at 2-week intervals (DPOs 14, 28, and 42) provided a 91% probability of detection at DPO 42.

Thus, a surveillance design based on testing a few samples from poor-doing pigs in each of many herds can provide low-cost, highly sensitive detection. It should be noted that this surveillance sampling design is similar to that proposed for the U.S. SHIP program.

Introduction: As the global movement of livestock, people, and materials continues to grow, so does the risk of spreading infectious diseases across borders, e.g., porcine epidemic diarrhea virus (PEDV), African swine fever virus (ASFV), and others. Thus, implementing an effective, sustainable, and affordable surveillance system capable of early detection is crucial, if we are to respond quickly and efficiently to the inevitable introduction of a transboundary pathogen into the country. In a pilot project, we showed that an active participatory design for the regional surveillance of notifiable swine pathogens could achieve detection at a low prevalence and sustainable cost (Trevisan et al., 2024). Herein, we expanded this concept to the contiguous 48 states.

Objectives: The objective of this project is to establish the effect of sample size, sampling frequency, and producer participation (%) on the performance of a FAD participatory surveillance system. Achieving this objective will make it possible for US Swine Health Improvement Program stockholders to select and implement the FAD surveillance design they consider most suitable.

Participatory surveillance has never been used in swine surveillance; hence some background is useful. Participatory surveillance is based on the concept that the population at risk, i.e., swine producers in this case, participate directly in the surveillance process. Participatory surveillance evolved in the 1990's with computer networks and social media. ProMed (1994) is a well-known example of participatory surveillance, i.e., ProMed subscribers observe and report disease events in real-time. In this project, participatory surveillance means that producers outside of USDA Control Areas collect samples from poor-doing pigs and send them to NAHLN laboratories for testing (ASFV, CSFV, etc).

The rationale for this approach is as follows:

1. Sample collection is the largest cost of surveillance. Further, sampling by persons not part of the production system presents a meaningful biosecurity risk because it requires samplers, vehicles, and sampling materials to move between production sites. Thus, sample collection by producers who have undergone Certified Swine Sample Collector (CSSC) training both reduces sampling costs and preserves site biosecurity.
2. Targeted sampling of poor-doing pigs provides clear selection guidelines for CSSC samplers. Targeted sampling accounts for the heterogenous distribution ("clustering") that follows the introduction of a pathogen, ASFV in particular (Busch et al., 2021). Targeted sampling is also a recommended approach for both ASFV and CSFV detection, as per recent publications by the European Food Safety Authority expert committees (Nielsen et al., 2021a,b).
3. Diagnostic testing in approved laboratories provides accurate real-time assessment and produces electronic data ready for real-time analysis and rapid communication to animal health authorities. In fact, this is exactly the purpose for which the NAHLN system was established by the U.S. Congress after the events of September 11, 2001.
4. The elements needed to implement participatory surveillance are already in place. Specifically, CSSC training is in the process of implementation; US SHIP is currently enrolling participants and is on track to become a permanent USDA program; and the NAHLN laboratories are already equipped to test and communicate information to state and federal animal health authorities.

Materials & Methods: This project relied heavily on simulations run on the USDA Animal

Disease Spread Model (ADSM).

ADSM is public domain software developed by the USDA. It was specifically designed to simulate the spread of an infectious agent in livestock populations. ADSM was initially developed to simulate the spread of foot-and-mouth disease virus (Harvey et al., 2007), but the program is flexible and has been used to simulate the spread of a variety of pathogens. The model uses a static, fixed population and considers animals or groups of animals managed together at a single geographic location, e.g., a production site, as the epidemiological unit. We have previously used ADSM in modeling and are very familiar with its use and capabilities (Trevisan et al., 2024).

To initiate simulations, one randomly selected production site was designated positive for the agent of interest. Thereafter, ADSM tracked the spread of the pathogen among farms. The software produces a record of the status (positive, negative) of each site over time. Subsequently, the resulting output was used to model detection over a range of participatory surveillance parameters. To provide estimates that are broadly applicable to a variety of pathogens, ADSM simulations were performed over a range of values for four parameters: 1. index herd (location, production type); 2. transmission by direct contact (distance for direct contact, daily movement rate, probability of infecting a negative herd); 3. transmission by indirect contact (distance for indirect contact, daily indirect contact rate, probability of infecting a negative herd); 4. probability of local area spread (3 levels). Each scenario was replicated 1000 times to account for the stochastic nature of the ADSM simulations.

The ADSM software requires that each site have a unique ID, initial disease status, inventory, operation type (e.g., breeder, feeder, breeder/feeder), and geolocation (latitude and longitude). As we had done previously, our plan was to use state-level swine CAFO data available through FOIA to construct a dataset representative of the US swine industry. Based on our experience, CAFO permitting data includes production type, total inventory, and geolocation for individual production sites. Surprisingly, repeated attempts to collect CAFO data from state agencies were unsuccessful. Some state agencies were uncooperative; others provided data, but of poor quality.

The remaining option was to use the 2017 Census of Agriculture database to populate the ADSM dataset. This process required us to use some assumptions to provide the data fields required by ADSM and delayed the project significantly. Regardless, the resulting "population" provided a good representation of the U.S. swine industry. Specifically, using the 2017 USDA Census of Agriculture, we created a dataset of 66,637 farms in the contiguous 48 U.S. states (8,080,470 km^2). Each farm was identified by geolocation, production type, and inventory. The spread of a "generic" pathogen within this region was simulated for 180 days over a range of spread parameter values (6,075 scenarios) using the Animal Disease Spread Model (ADSM) software (v3.5.10.0). The output for each scenario included the infection status of each farm by day post-outbreak (DPO).

Thereafter, an R function was used to calculate the probability (P) of detecting ≥ 1 positive farm by DPO as a function of the percentage (%) of herds participating in the surveillance program, herd-level sensitivity, and disease prevalence. The effect of sampling interval was evaluated by comparing P for a specific DPO vs the aggregate P (Pa) based on sampling every 14 days (Equation 1).

(Equation 1) $Pa = [1 - (1 - P_{14}) \times (1 - P_{28}) \times \ldots (1 - P_{DPO})]$

Results and Discussion: Detection simulation results showed that the probability of detection increased both as a function of site-level detection sensitivity and producer participation, but producer participation was the key driver. Furthermore, we found that a 2-week sampling interval would achieve significantly higher probabilities of detection than a single sampling event at a specific DPO. For example, given 40% producer participation (26,654 participating herds) and 10% herd-level sensitivity, a single sampling event on DPO 42 (0.04% prevalence / 29 infected herds) resulted in a 70% probability of detecting ≥ one positive herd. In contrast, sampling at two-week intervals (DPOs 14, 28, and 42) provided a 91% probability detecting ≥ one positive herd at DPO 42 under the same conditions. This reflects the aggregate detection probability resulting from periodic testing over time.

Overall, a two-week sampling interval in a national participatory surveillance program would detect a fast-spreading pathogen at a low prevalence. Such a system could be achieved through national surveillance programs (US Swine Health Improvement Plan) and diagnostic testing performed at NAHLN laboratories. Simplicity (testing a few targeted samples from many herds) should guide surveillance programs. This regional design is globally adaptable and provides low-cost, highly sensitive detection.

References

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