

# A descriptive exploration of animal movements within the United States cull sow marketing network

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## Summary

**Objective:** Collect and describe data regarding sow movements within the US cull sow marketing network, and what implications those movements may have on disease introduction and dissemination within the United States.

**Materials and methods:** Premise identification tags (PITs) were collected with the help of the US Department of Agriculture's Animal and Plant Health Inspection Service-Veterinary Services Brucellosis Laboratory. Collection occurred for a total of 6 months. From each PIT the management/sow identification (ID), premises ID, state, facility, and slaughter

date were recorded. Participating production systems identified the cull dates of individual sows from their system.

**Results:** A total of 17,493 PITs were collected. This study collected PITs from 32 states and 1211 unique premises IDs. Facilities received sows from a median (IQR) of 9.5 (12.5) states and 71 (79.25) unique premises each week.

Sows traveled a median (IQR) distance of 472.7 (453.6) km with a maximum of 2812.8 km. A single premises delivered sows to 1, 2, or 3 or more slaughter facilities 59.7%, 33.4%, and 6.9%, respectively. Removal date from the farm of origin was available for 2886 (16.5%) individual

sows. Of these, 66.1% were in the market channel for  $\leq 3$  days, 25% for 4 to 5 days, and 8.9% for  $> 5$  days.

**Implications:** These results suggest that the cull sow marketing channel provides an independent, but interconnected swine population that can maintain, expand, and transmit pathogens to the US swine herd. Control and elimination plans for novel, transboundary, and foreign animal diseases should include this population.

**Keywords:** swine, sows, market, disease, movement

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## Resumen - Exploración descriptiva de los movimientos de animales dentro de la red de mercadeo de cerdas de desecho de los Estados Unidos

**Objetivo:** Recopilar y describir la información sobre los movimientos de cerdas dentro de la red de mercadeo de cerdas de desecho de EE UU, y qué implicaciones pueden tener esos movimientos en la introducción y diseminación de enfermedades en los Estados Unidos.

**Materiales y métodos:** La identificación de cada sitio (PITs) se recolectaron con la ayuda del Laboratorio de Brucelosis de los Servicios Veterinarios del Servicio de Inspección de Sanidad Animal y Vegetal del Departamento de Agricultura de EE UU. La recolección de información se llevó a cabo durante un total de 6 meses. De cada PIT se registró la identificación (ID) de manejo/cerda, identificación

del sitio, estado, matadero, y fecha de sacrificio. Los sistemas de producción participantes identificaron la fecha individual de desecho de cada hembra de su sistema.

**Resultados:** Se recolectaron un total de 17,493 PITs. Este estudio recolectó PITs de 32 estados y 1211 ID de sitios únicos. Los mataderos recibieron cerdas de una mediana (RIC) de 9.5 (12.5) estados y 71 (79.25) sitios únicos cada semana.

Las cerdas recorrieron una distancia mediana (RIC) de 472.7 (453.6) km con un máximo de 2812.8 km. Un solo sitio entregó cerdas a 1, 2, o 3 o más mataderos, 59.7%, 33.4%, y 6.9%, respectivamente. La fecha de retiro de la granja de origen estuvo disponible para 2886 (16.5%) cerdas individuales. De estas, el 66.1%

estuvo la cadena de mercado durante  $\leq 3$  días, el 25% durante 4 a 5 días, y el 8.9% por  $> 5$  días.

**Implicaciones:** Estos resultados sugieren que la cadena de comercialización de cerdas de desecho es una población porcina independiente pero interconectada que puede mantener, aumentar, y transmitir patógenos al hato porcino de EE UU. Los planes de control y eliminación de enfermedades animales nuevas, transfronterizas, y foráneas deben incluir a esta población.

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## Résumé - Une exploration descriptive des mouvements d'animaux au sein du réseau de commercialisation des truies de réforme aux États-Unis

**Objectif:** Recueillir et décrire des données concernant les mouvements de truies au sein du réseau américain de commercialisation des truies de réforme, et quelles implications ces mouvements peuvent avoir sur l'introduction et la dissémination de maladies aux États-Unis.

**Matériels et méthodes:** Les étiquettes d'identification des lieux (PITs) ont été recueillies avec l'aide du Service d'Inspection de la Santé Animale et Végétale du Département de l'Agriculture des États-Unis et du Laboratoire de Brucellose des Services Vétérinaires.

La collecte a duré 6 mois au total. À partir de chaque PIT, l'identification de la gestion/de la truie (ID), l'ID des locaux, l'état, l'installation, et la date d'abattage ont été enregistrées. Les systèmes de production participants ont identifié les dates de réforme des truies individuelles à partir de leur système.

**Résultats:** Un total de 17,493 PITs a été amassé. Cette étude a collecté des PITs de 32 États et 1211 identifiants de locaux uniques. Les installations ont reçu des truies d'une médiane (IQR) de 9.5 (12.5) états et 71 (79.25) locaux uniques chaque semaine. Les truies ont parcouru une distance médiane (IQR) de 472.7 (453.6) km avec un maximum de 2812.8 km. Un seul local a livré des truies à 1, 2, ou 3 abattoirs ou plus à 59.7%, 33.4%, et 6.9%,

respectivement. La date de sortie de l'exploitation d'origine était disponible pour 2886 (16.5%) truies individuelles. Parmi celles-ci, 66.1% étaient dans le canal du marché pendant  $\leq 3$  jours, 25% pendant 4 à 5 jours, et 8.9% pendant  $> 5$  jours.

**Implications:** Ces résultats suggèrent que le circuit de commercialisation des truies de réforme fournit une population porcine indépendante mais interconnectée qui peut maintenir, étendre, et transmettre des agents pathogènes au troupeau porcin américain. Les plans de contrôle et d'élimination des maladies animales nouvelles, transfrontalières, et exotiques devraient inclure cette population.

The threat of pathogen dissemination posed by the US cull sow market is one of the most significant knowledge gaps within the swine industry today. While the general purpose of the cull sow market is well understood by the industry, transparency (ie, current available data) of the movements that occur within the channel and the resulting risk of disease transmission is limited. With more than 3.2 million cull sows expected to enter the market channel annually,<sup>1</sup> uncontrolled management of this industry segment may lead to negative impacts on the health and production of both breeding and growing herds.<sup>2</sup> With significant concerns about foreign animal disease (FAD) introduction, the swine industry's limited comprehension of the potential for the cull sow marketing channel to both disseminate and serve as a reservoir for pathogens suggests further elucidation of those risks is needed as an essential part of US FAD preparedness.

The US cull sow market is structurally different than the lean hog market. A limited number of centrally located slaughter facilities<sup>3</sup> are fed by a network of local collection points (buying stations) where sows are delivered from the farm. In contrast, the slaughter facilities for the lean hog market, the primary source of pork products in the United States, are predominantly located in pig dense regions resulting in  $> 95\%$  of lean hogs moving directly from farm of origin to the slaughter facility. The structure of the cull sow marketing network results in the opposite effect where  $> 90\%$  pass through an intermediary

collection point before arriving at slaughter.<sup>2</sup> This structure promotes extensive commingling of sows as they move from the farm through buying stations to the slaughter facility.

Collection points located in sow-dense regions allow farms to cull a small number of sows routinely while minimizing trucking cost. Frequently removing sows from the farm spares the added expense of holding sows until full truck load lots can be created and increased number of sows in inventory on the farm. The collection points serve to add value to these animals. Collection points facilitate the creation of truckload lots of a specific type of cull sow (weight, body condition) to meet the preferences of individual slaughter facilities. While complex, this market structure has benefited all parties involved, but drawbacks exist.

Within the United States, the welfare of cull sows has received little scientific attention, however, concerns regarding the fitness of animals at the time of transport have been raised.<sup>4</sup> The pre-transport mixing of cull sows on farm can result in the clinical deterioration of sows in as little as 24 hours.<sup>5</sup> This deterioration is present in animals at the time of arrival at buying stations. Cull sows and boars comprised the majority of swine arriving fatigued, thin, and lame.<sup>6</sup> While there are still significant knowledge gaps regarding fitness during transport, the extended time that some cull sows remain within the marketing channel raises concerns that the current market structure may negatively impact the welfare of cull sows prior to harvest.<sup>2</sup>

The potential for pathogen dissemination through the cull sow marketing network is known but unquantified. The risk for pathogen dissemination originates from three factors: comingling sows from many sources, multiple movements between farm to harvest, and extended time in the market channel. Commingling of sows from many farms allows for uninfected sows from one farm to come in contact with pathogens from other farms in the market channel. The impact of transmission is increased during the movement of sows between multiple, nonterminal points in the marketing channel creating the opportunity for dissemination of disease across broad geographies. It has been estimated that up to 14% of all cull sows make 3 or more stops as they move between different collection points prior to slaughter.<sup>2</sup> The current cull sow marketing channel creates an "off-farm cull sow population" that can both transfer and serve as a reservoir population for pathogens.

While all the sows in the market channel are destined for slaughter, this reservoir population can serve as a source of pathogens for domestic swine herds. During the 2014 US porcine epidemic diarrhea virus (PEDV) outbreak, the lean hog network served as a means of expanding the outbreak when trailers were contaminated at the slaughter facility and returned back to production sites unwashed.<sup>7</sup> The probability of contamination increased with both the temporal proximity of a trailer unloading after a contaminated trailer at the same dock and the viral load present at the slaughter facility.<sup>1</sup> Even with the

implementation of biosecurity practices, compliance failure is common at truck washes or during the loading or unloading of animals creating a route for pathogen introduction into the domestic swine industry.<sup>8,9</sup>

The national scope, structure, and hypothesized complexity of the cull sow market creates a significant opportunity for pathogen transmission, including FADs throughout the US swine industry.<sup>2</sup> This study compiles data from a previously untapped source to generate a dataset capable of describing cull sow movements both spatially and temporally within the United States. By doing so, this study strives to provide a robust descriptive analysis of the US cull sow marketing network to date, serving as a reference to the swine industry in future endeavors.

## Animal care and use

Data was obtained from premises identification number tags (PITs) recovered from sows slaughtered in federally inspected facilities under the authority of the USDA Food Safety Inspection Service.

## Materials and methods

### Data collection

Data collection was in partnership with the USDA Animal and Plant Health Inspection Service-Veterinary Services (APHIS-VS) Brucellosis Laboratory located in Frankfort, Kentucky. The laboratory collected all PITs affiliated with samples submitted for brucellosis surveillance.<sup>10</sup> The samples represent sows randomly sampled from US slaughter facilities as part of the national brucellosis and pseudorabies monitoring program administered by USDA APHIS-VS.

Premises identification number tags serve as the traceability method for sows in the Swine Identification (ID) Plan established by the industry in 2004.<sup>10</sup> The industry compliance with the Swine ID Plan is high as PITs are present in greater than 90% of sows at the time of slaughter.<sup>2</sup> Samples collected by the laboratory originated from 7 US slaughter facilities. To maintain the confidentiality of the slaughter facilities, they are referred to as F1 through F7. Daily slaughter capacities of these slaughter facilities ranged from 20 to over 2800 pigs/day.

Collection of PITs occurred one week per month in May, June, and July of 2018 and February, March, and April of 2019. These dates were selected for ease

of collection for the laboratory and to monitor movements in two different calendar quarters. For each PIT the management/sow ID, premises ID, state, facility, and slaughter date were recorded in a database. The geolocation for each unique premises ID was obtained using the premises verification tool from Pork Checkoff<sup>11</sup> which provides the street address of the farm and was visually confirmed and converted to geocoordinates in Google Maps.

For a subset of PITs, the date of removal from the farm of origin was obtained through the participation of 9 privately owned swine production systems and 2 veterinary management companies. These systems have a collective one-time inventory of > 2.4 million sows representing more than 40% of the US swine breeding herd. Premises IDs for each production system were used to match the management ID to the farm removal date in their production record systems.

### Data analysis

The Euclidean distance between the farm of origin and the slaughter facility was calculated using the geospatial coordinates for each location. Regional price difference for each sow was also calculated. Regional price difference is defined as the price difference between the sow's origin region versus their slaughter facility region. These regional prices were obtained from the Daily Direct Prior Day Sow and Boar report (LM\_HG234)<sup>12</sup> as reported by the USDA Agriculture Marketing Service. A weighted average price for the Iowa/Minnesota, Western Corn Belt, Eastern Corn Belt, and National regions was determined. All premises outside of the Iowa/Minnesota, Western Corn Belt, and Eastern Corn Belt regions were assigned to the National region.

For each slaughter facility, the number of unique premises, the median distance traveled to the slaughter facility, and the number of states animals originated from were determined. For a subset of animals that originated at participating systems, the days in the slaughter market channel was defined as the difference between the farm removal date and the slaughter date. A box and whisker plot of distance traveled was created for each facility. In addition, dot plots of the number of weekly unique premises and states arriving to each facility were generated to elucidate any differences between facilities. All visualizations and statistics for this study were performed using R statistical software.<sup>13</sup>

## Results

A total of 17,493 individual PITs were collected, representing approximately 8.4% of the total number of sows slaughtered each week at the 7 slaughter facilities. These 7 facilities are responsible for 33% of the daily national cull sow slaughter. The collected data represents approximately 2.7% of the weekly national cull sow slaughter. The PITs represented 1211 unique premises and 32 states. Farm removal dates of 2886 individuals were recorded, representing 16.5% of all samples collected.

### Description of sows

Sow PITs came from 7 different federally inspected slaughter facilities (F1-F7). The largest slaughter facility had a slaughter capacity of 2800 sows/day.<sup>2</sup> The smallest slaughter facility capacity was believed to have been < 20 sows/day, as the surveillance sample submitted represented the entirety of their daily slaughter. In this study the slaughter facilities collected sows from a median (IQR) of 9.5 (12.5) states/day (Figure 1). Sows originated from a median (IQR) of 71 (79.25) premises/week (Figure 2).

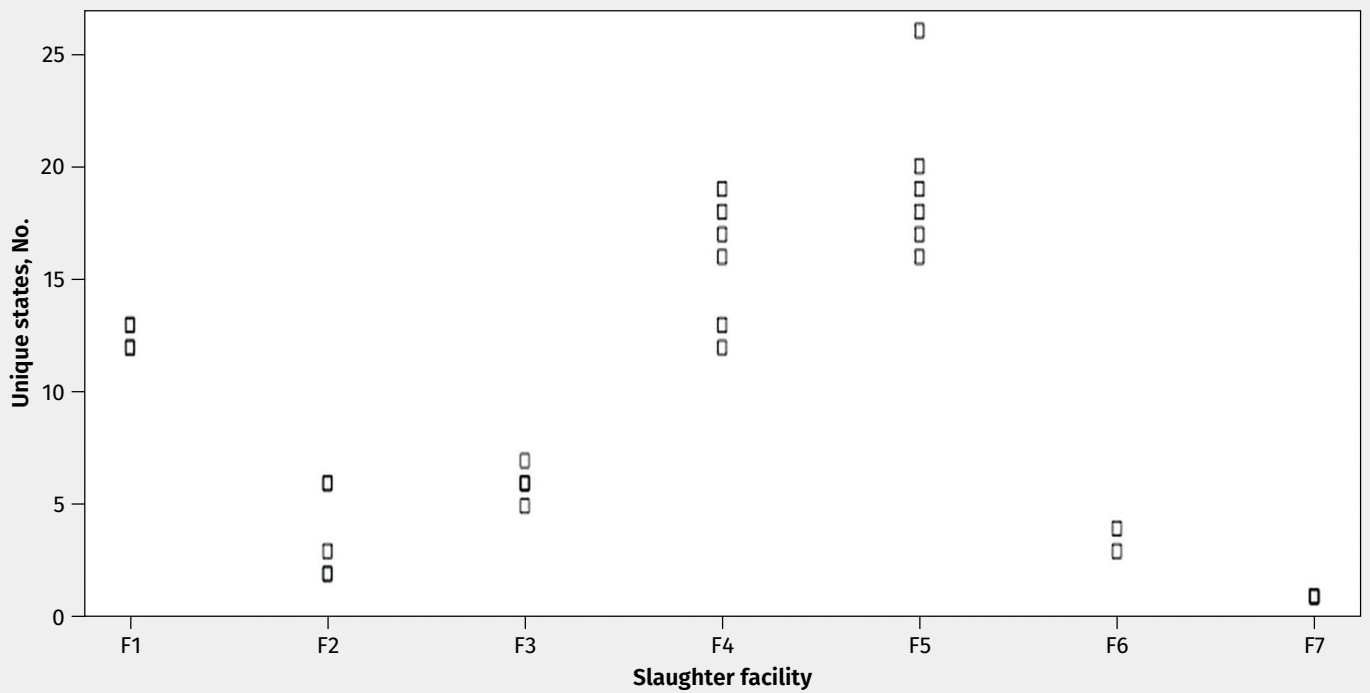
The distance from farm of origin to slaughter facility for sows varied between facilities. Across all slaughter facilities, sows traveled a median (IQR) Euclidean distance of 472.7 (453.6) km (Figure 3). Sows entering F2 traveled the furthest with a median (IQR) of 706.2 (614.4) km while sows entering F6 traveled the least with a median (IQR) of 119.5 (173.1) km (Figure 4).

Some sows remained in the market channel for an extended time. Of the subset of 2886 sows from the seven study slaughter facilities, 66.1% remained in the marketing channel for ≤ 3 days, 25% for 4 to 5 days, and 8.9% for > 5 days. The median (IQR) time from removal to slaughter was found to be 3 (3) days with a maximum of 40 days for 2 individuals.

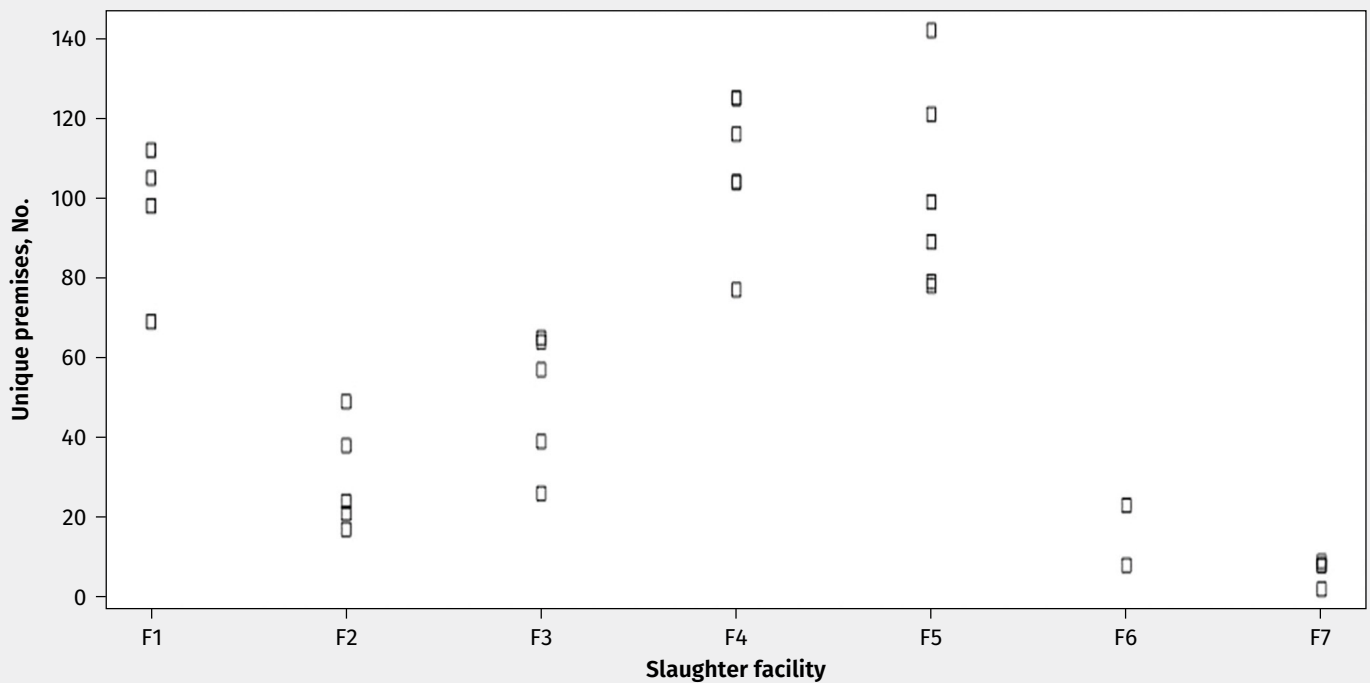
### Premises description

Of the 1211 premises in the dataset, 59.7% had cull sows arrive at a single slaughter facility. In comparison, 33.4% of the premises had animals arrive at two slaughter facilities and 6.9% of the farms were represented at three or more slaughter facilities across all tag collection dates.

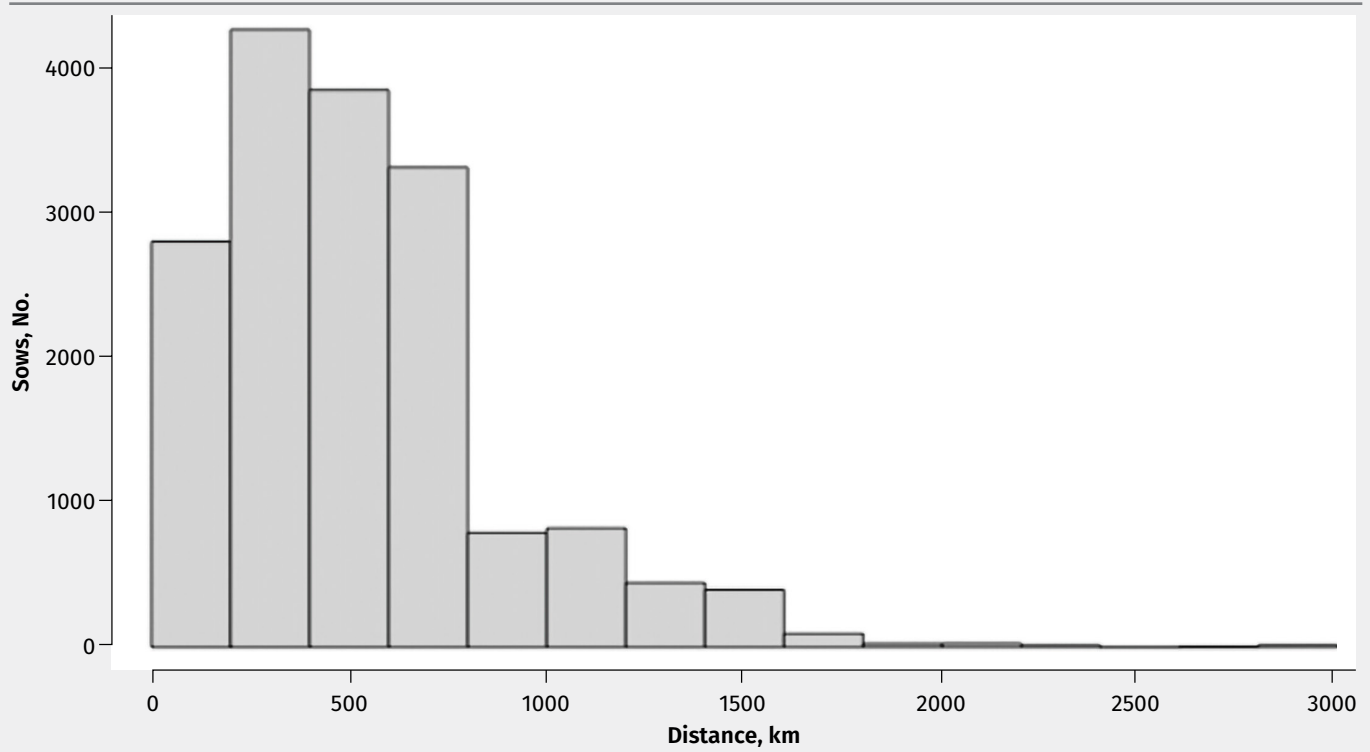
**Figure 1:** Number of unique states represented by sows arriving daily at the slaughter facility.



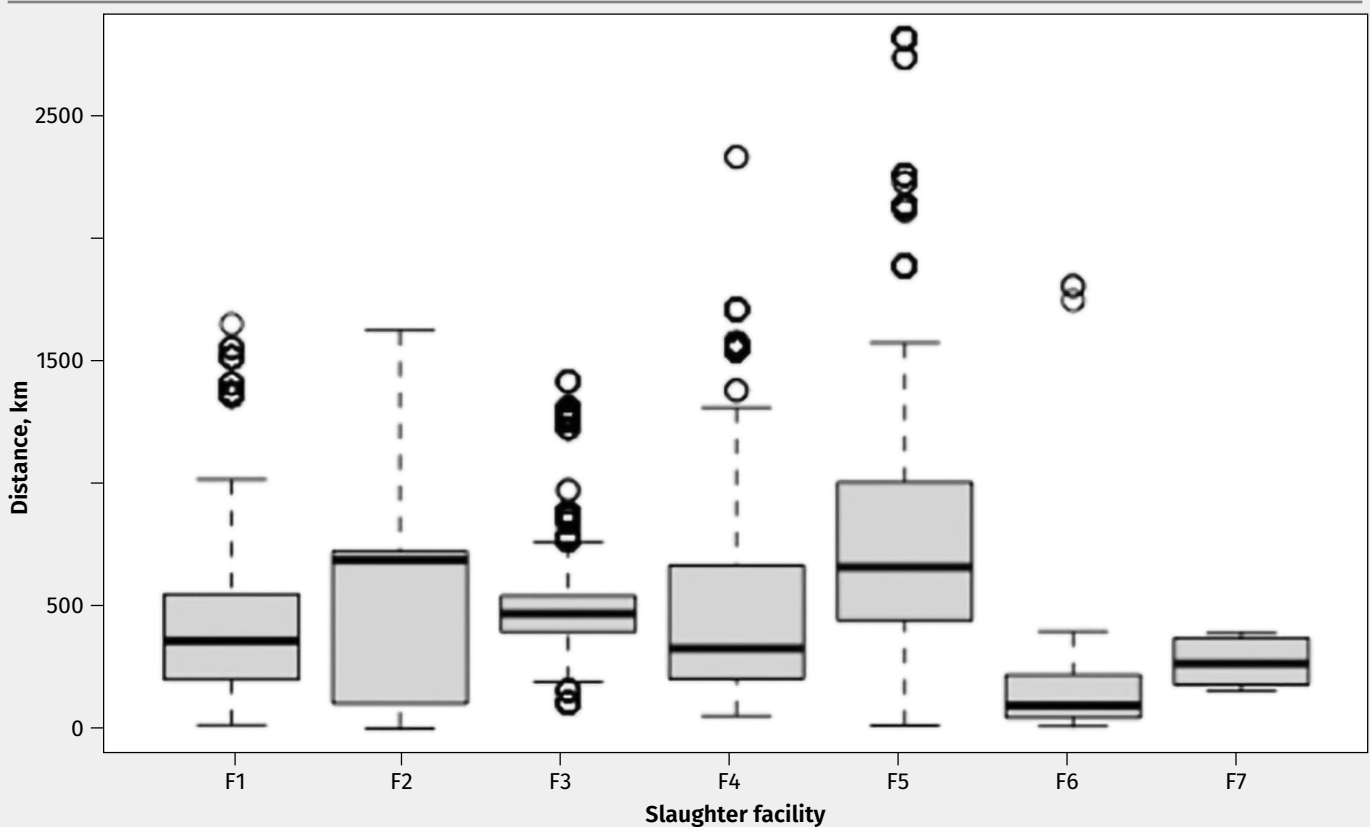
**Figure 2:** Unique number of premises represented by sows arriving weekly at the slaughter facility.



**Figure 3:** Distribution of the Euclidian distance between the farm of origin and slaughter facility.



**Figure 4:** Box plots of the distance traveled by sows to each unique slaughter facility.



## Discussion

This study is the first multiple slaughter facility dataset collected describing the US cull sow marketing network. With 17,493 individual PITs collected from sows representing 1211 unique farms, this dataset is nearly seven times as large as the previously published work.<sup>2</sup> The size and temporal component of this dataset allows for exploration into why and how sows are moving within the marketing channel. These data should be used to facilitate improved policy and biosecurity decisions by the industry and regulators.

As previously hypothesized<sup>3</sup> and further supported by this work, the collection area for each slaughter facility is geographically vast and overlapping. The median distance between the farm of origin and terminal processing facility is 472.7 km, with 16% traveling more than 1000 km to reach their destination up to a maximum of 2812.8 km. This documents that sows consistently travel long distances. In addition to the distance traveled by sows, these are the first data to systemically describe the time animals spend within the cull sow marketing network. Some sows remain in the network for an extended amount of time, well beyond the incubation period of many important pathogens including foot-and-mouth disease, African swine fever, and classical swine fever.<sup>14-16</sup> In combination with the routine mixing of sows, this time within the marketing network is poorly defined and untraced resulting in a dynamic population capable of maintaining pathogens independent of the national on-farm herd. The cull sow marketing network can be considered a dynamic, independent herd capable of acting as a reservoir population for pathogens and could facilitate undetected and unmonitored pathogen movement over great distances. The geographic basin of each slaughter facility is, for all practical purposes, nationwide creating connections between farms from disparate regions of the United States as farms from all regions provide animals to the cull sow marketing herd. Similarly, a study of the animal marketing system in the United Kingdom<sup>17</sup> found movements within the UK network increased the number of indirect connections between farms by 50%. Our data, further supported by the UK study, bring to light the potential dangers of this marketing network model.

The cull sow market is both complex and obscure. As previously hypothesized, up to 14% of sows have an extended period from farm removal to slaughter.<sup>2</sup> This study supports that idea, with 8.9% of sows remaining in the marketing channel for greater than 5 days. Current US guidelines prohibit animals from being at a single location in the marketing channel for more than 120 hours.<sup>18</sup> Assuming that market participants are compliant with federal law, sows in the channel for more than 5 days have been at multiple collection points in the network. In the case where animals were in the marketing channel for 40 days, animals would have been in 8 or more collection points prior to slaughter. In addition to significant disease dissemination concerns, there are animal welfare concerns. The extended time sows spend within the marketing channel may result in a reduced quality of life due to various factors.<sup>4,5</sup>

In both this study and prior work,<sup>2</sup> we were unable to locate data that would facilitate tracking the movement of sows between their entry into the marketing network and their arrival at the slaughter facility. Tracing animals from farm to slaughter is important because sows from a single farm may be sent to multiple slaughter facilities. In this limited but representative data set, greater than 40% of premises had animals identified at two or more slaughter facilities. These data are congruent with known market practices, specifically one of the greatest value creation actions of sorting sows at local collection points to meet the specific sow quality preferences of a slaughter facility.

The results of this study suggest that the characteristics of the US cull sow marketing network holds the potential to transmit disease in an undetected manner prior to arrival at a slaughter facility. The mixing and distribution of sows within the dynamic cull sow market population may result in pathogens being maintained and distributed across large geographic regions. Because of the lack of measurement, there is no direct evidence of disease transmission within the network. However, Senecavirus A infections detected in sows at harvest suggest that infections within the network are common and was further supported by an investigation within the North Carolina swine industry.<sup>19</sup> The discordance between farm status and individual sow status at harvest strongly suggests that infection occurred within the marketing channel.

While these data provide a meaningful snapshot of the US cull sow marketing network, they strongly suggest that comprehensive tracking and monitoring of animals in the cull sow marketing network is necessary. To achieve a comprehensive understanding of the network to facilitate the design of systematic mitigation strategies, capturing and maintaining records of individual sow movements within and between collection points is necessary. Ideally these data would be captured and maintained in a manner that would give regulators and the industry quick and easy access in the face of a novel disease outbreak to limit the impact of the cull sow marketing network on US herd health. The current structure of the US cull sow marketing network warrants a robust reevaluation of biosecurity practices by the industry to ensure business continuity if an FAD is introduced or other novel pathogen emerges in the United States.

## Implications

Under the conditions of this study:

- Cull sow marketing network attributes serve as a potential means of disease spread.
- The time sows are in the channel creates a potential disease reservoir population.
- Sow movements within the marketing network connect geographically diverse regions.

## Acknowledgments

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## Conflict of interest

None reported.

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