Identification of putative factors contributing to pelvic organ prolapse in sows (Grant # 17-224)

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II. Industry Summary

In response to increased sow mortality due to pelvic organ prolapse (POP), the Iowa Pork Industry Center (IPIC) at Iowa State University, with funding from the National Pork Board, assembled a unique team to better understand potential causative factors of sow POP in order to move towards developing and disseminating prevention strategies to help reduce POP incidence. One hundred and four commercial sow farms, representing approximately 385,000 sows across the U.S., were enrolled in a survey-based project. The farms varied in POP incidence rate, production system, geography, genetics, and management practices. This observational study was designed to provide research direction for future projects investigating causative factors of POP and cultivate a collaborative network of multidisciplinary experts within Iowa State University and across the swine industry. Results of the project have allowed better understanding of the degree of the issue and prioritization of risk factors for future research in the pursuit of reducing POP-related sow mortality. During the project period, the average annualized POP incidence for these farms was 2.7% and accounted for 21% of the total mortality. At a farm level, the most apparent relationships with increased POP incidence were farms using untreated water sources and farms whose management strategies included late gestation bump feeding, particularly when targeting thin sows. On an individual sow basis, sows with lower body condition and/or greater swelling and protrusion of the perineal region were more likely to prolapse. Factors with little to no evidence of relationship to POP incidence were herd size and the extent to which sow farms are inducing parturition or assisting in farrowing. A major outcome of this project was direct guidance on the most valuable experimental approaches to better understand the physiology occurring within a sow that precedes POP so that the most effective measurements can be determined when evaluating or testing potential on-farm mitigation strategies. This project also supports the concept of building an ongoing collaboration from commercial farms from multiple production systems across the U.S. swine industry for field research allowing comparisons within and between production systems. Furthermore, the collaborative network to facilitate such investigations has been built.

Producer take home points:

- **An industry-wide survey was conducted with 104 sow farms representing approximately 400,000 sows and nearly half of the US swine industry, including large integrated companies and many independently owned sow farms.**
- **Multiple factors that may contribute to POP in sows were identified, enabling the design of subsequent studies in specific areas of interest.**
- **Many areas of presumed potential influence on pelvic organ prolapse have been shown to be minimally influential if at all.**
- **A perineal scoring system was developed that is reproducible and indicative of risk of prolapse for individual sows.**

III. Keywords

Prolapse, sow mortality, swine, sow farm, reproduction

IV. Scientific Abstract

Sow mortality, specifically as the result of pelvic organ prolapse (POP), has significantly increased in the past five years in the U.S. swine industry. This epidemic sow welfare and production issue, while widely acknowledged among producers, academia and allied swine industry partners, has persisted and continues to worsen. However, the industry lacks mitigation strategies, or even the ability to execute mitigation-based research projects, since a fundamental understanding of the root cause(s) contributing to the increased POP in the swine industry is lacking. The Iowa Pork Industry Center (IPIC) initiated an industry-wide survey involving U.S. swine breeding herds to identify potential risk factors, to direct future research and test mitigation strategies. A comprehensive survey was administered to 104 swine breeding herds across 15 states including farms ranging from breeding herds within large productions systems to smaller, independent producers, totaling approximately 385,000 sows. The survey examined data associated with potential factors associated with herd dynamics and management approaches, facility types, nutritional strategies, and animal-based measurements. On 62 of these farms, IPIC staff collected individual sow measurements including, but not limited to, perineal score, tail length, and body condition. Each week, all farms reported the number of sow deaths along with putative causes categorized into POP and non-POP deaths. This information was used to create the weekly POP incidence rate per 1,000 sows and an annualized POP rate. A Poisson mixed regression model using PROC GLIMMIX in SAS® (SAS Institute, Inc., Cary, NC) was utilized to assess risk factors associated with POP incidence rate. The weekly count of POP per farm was the outcome variable and the log of the inventory was included as an offset variable. System was included as a covariate in the analysis. The annualized POP mortality across the dataset was 2.7% (of the total inventory) with a range from 0.3% to 10.3% during a 52-week period starting with week 6 of 2018 during which time 21% of all mortality reported was due to POP. Sow farms that had the greatest incidence of POP also had greater variability in comparison to farms with average or below average POP incidence rate. Several factors that do not demonstrably influence POP incidence were herd size, the extent to which sow farms are inducing parturition or assisting in farrowing when using $P < 0.05$ as the threshold of significance. Feeding strategy prior to farrowing was identified as being important as utilization of bump feeding during late gestation was associated with reduced POP. This was consistent with our observation that sows with the lowest body condition score had a greater probability of POP compared to sows in optimal body condition or overweight. Utilization of water treatment systems also appeared to be associated with reduced POP incidence, as those farms using a water treatment system had lower POP than those farms that did not during the project period. It was also observed that the utilization of antibiotics in the feed may be associated with decreased incidence of POP. Results from this study have preliminarily identified several different risk factors needing further investigation to verify their causality for increased POP risk and potential mitigation strategies. Additional evaluation will be completed to further define and prioritize risk factors likely contributing to a greater incidence in POP in the farms evaluated in this study for additional testing.

V. Introduction

Sow mortality, specifically as the result of pelvic organ prolapse (POP; uterine, rectal, or vaginal), has significantly increased in the past five years in the U.S. swine industry. This epidemic sow welfare and production issue, while widely acknowledged among producers, academia and allied swine industry partners, has persisted and continues to worsen. However, the industry lacks mitigation strategies, or even the ability to execute mitigation-based research projects. The inability to execute hypothesis driven research projects is the result of our lacking a fundamental understanding of the root cause(s) contributing to the increased POP in the swine industry as we have previously reviewed[1]. In response to this industry issue, the Iowa Pork Industry Center (IPIC; www.ipic.iastate.edu) at Iowa State University initiated an industry-wide survey involving U.S. swine breeding herds to identify potential risk factors that will be used to generate hypotheses and test mitigation strategies to prevent POP on sow farms.

VI. Objectives

The long-term objective of our team is to identify causation for the elevated industry incidence of POP so that mitigation strategies can be developed and employed. In response to the targeted request for proposals, the IPIC assembled a unique team to accomplish the primary objectives of the targeted request for proposals from the National Pork Board. The internal team consisted of scientists with diverse research expertise in genetics and statistics (Dr. Ken Stalder), nutrition (Drs. Nick Gabler and John Patience), animal welfare (Drs. Anna Johnson and Suzanne Millman), reproductive physiology (Dr. Jason Ross), and reproductive toxicology (Dr. Aileen Keating) along with veterinarians with extensive swine disease production background (Dr. Chris Rademacher), epidemiology and statistics (Drs. Daniel Linhares and Gustavo Silva), diagnostic database management (Dr. Kent Schwartz) and swine extension specialists (Amanda Chipman and Colin Johnson).These subject matter experts served as the internal IPIC team to guide, influence, collect, analyze and interpret the results of our study with additional support from our external network of producers and scientists to enable the completion of the central proposal objective. The central objective of the IPIC team was to work coordinately with industry partners to establish a fundamental understanding of potential contributing sow POP factors. This central objective was accomplished by the following specific objectives:

Specific Objective 1: Establish a network of industry partners and sow farm managers that enabled our team to seamlessly collect data on severely affected, moderately affected, and unaffected sow farms from varying geographic locations and production systems.
Specific Objective 2: Develop an intensive herd and individual sow survey tool to objectively collect sow farm data and conduct statistical analysis to identify potential contributing factors to sow POP.
Specific Objective 3: Establish a POP-associated communication and advisory network of producers, allied industry, university faculty and staff.
Specific Objective 4: Establish an accessible repository of data, samples and information related to sow POP for use by the scientific communities interested in developing, providing, and evaluating mitigation strategies and solutions.

VII. Materials and Methods

<u>Specific Objective 1</u>: Establish a network of industry partners and sow farm managers that enabled our team to seamlessly collect data on severely affected, moderately affected, and unaffected sow farms from varying geographic locations and production systems.

One hundred and four commercial sow farms across the U.S. (85 farms from 13 larger production systems and 19 farms representing independent producers) were enrolled in this project with varying POP incidence, production systems, geographical locations, genetics, and management practices. Within production systems, enrollment from farms with high incidence, average incidence, and low incidence of POP was requested.

A data collection form was developed for all farms to submit weekly mortality and POP data using a standardized code to categorize cause of mortality in a consistent manner across all production systems and farms. The 8 categories were vaginal/uterine prolapse, rectal prolapse, both vaginal and rectal prolapse, difficulty farrowing/retained pig(s), disease, intestinal complication/ulcer, lame/injured/downer, and unknown/other. This information was used to create weekly POP incidence rate per 1,000 sows and annualized weekly POP rates (number of POP for a week multiplied by 52 and divided by mated female inventory). Weekly data collection occurred from week 6 of 2018 (February 4) through week 5 of 2019 (February 2). In addition, this effort has created a database of non-POP causes of mortality which is important for the U.S. swine industry.

<u>Specific Objective 2</u>: Develop an intensive herd and individual sow survey tool to objectively collect sow farm data and conduct statistical analysis to identify potential contributing factors to sow POP.

The IPIC team developed a comprehensive survey to examine herd level factors such as the farm’s facility type, genetics, health status, nutrition strategies, farrowing management protocols, environmental conditions, among others. A portion of the survey was completed through communication with herd nutritionists, veterinarians, and production supervisors. Additional information was collected during farm visits by one of four IPIC team members. Sixty-two of the enrolled farms were visited, and many of the other farms completed portions of the information that were less subjective via personal communication with IPIC staff. Feed samples of both lactation and gestation diets were collected during farm visits for proximate analysis, particle size and mycotoxin analysis.

Individual animal measures of tail length, body condition score, and perineal score were collected on almost 5,000 late gestating sows during site visits to the farms. A perineal scoring system was developed and utilized to assess potential for POP during late gestation. Individual sows were scored with a three-point perineal scoring system depicted in Figure 1 (right; Score 1: a presumed low risk of POP; Score 2: a presumed moderate risk of POP; and Score 3: a presumed high risk for POP). For body condition scores, a three-point scoring system was used where a score of 1 was classified as thin, a score of 2 as normal, and a score of 3 as overweight. During the on-site visits, if the sow farm maintained gilts on site prior to and during breeding, a flank-to-flank girth measurement was collected to use as the farm's average body weight at breeding.

Data Analysis

This was an observational study, which used descriptive statistics to identify trends for further specific hypothesis driven research. More specifically, this study is guiding the group towards future work by identifying risk factors associated with POP under field conditions. The major outcome of this study was defining risk factors associated with POP incidence, defined as the number of POP per 1,000 sows per week. The risk factors assessed in the study were related to farm-level management practices, nutrition factors, individual animal-based measures and performance data.

Farm-level risk factors

A Poisson mixed regression model using PROC GLIMMIX in SAS® (SAS Institute, Inc., Cary, NC) was used to assess risk factors associated with POP incidence rate. The weekly count of POP per farm was used as outcome variable and the log of the inventory as an offset variable. The production system was included as a random effect in the analysis. At the univariate analyses the independent variables assessed were related to: facilities, management protocols, nutrition strategies, health status, and genetics.

Correlations

Correlation coefficients were calculated by PROC CORR procedure in SAS between farm POP incidence and various nutritional and management strategies that were continuous variables.

Figure 1 (Above). A scoring system of the perineal region to identify sows with potential risk for POP. All sows in Figure 1 are week 14 of gestation. A Score 1 is considered a presumed low risk of POP; 2, a presumed moderate risk of POP; and 3, a presumed high risk for POP.

Individual measurements, productivity and parity order

A logistic regression model was used to assess risk factors associated with POP in sows. The outcome variable was if the sow had or had not prolapsed during the investigated period. The risk factors were related to individual measurements of animal tail length, distance between the rectum and vulva, perineal score, and body condition score. Linear mixed regression models were used to evaluate differences in productivity (number of total born and born alive) between sows that had or had not prolapsed during the investigated period. In these models, the production system was used as a random effect. To test if there is any linear trend of occurrence of POP as parity order increases, the chi-square test for trend in proportions was used. For this analysis, the sows were classified by parity order and if it had or not prolapsed. All the analyses described in this subsection were done in R program version 3.4.2.

Specific Objective 3: Establish a POP-associated communication and advisory network of producers, allied industry, university faculty and staff.

The IPIC engaged producers, faculty, and other stakeholders in the industry that were impacted by and/or had the desire to collaborate in mitigating the incidence of POP in U.S. sow farms. Commitment and enthusiasm for collaboration in this project was seen throughout the industry. Those desiring to actively participate in this project provided input on the study design, enrolled farms for the study, delivered feedback throughout the duration of the study, and/or participated in conference calls, webinars, round table discussions, or presentations. Throughout the duration of the project, mortality data has also been summarized and emailed weekly to participants and other interested collaborators.

Specific Objective 4: Establish an accessible repository of data, samples and information related to sow POP for use by the scientific communities interested in developing, providing, and evaluating mitigation strategies and solutions.

Weekly updates and this final report have been and will be accessible through the IPIC website (www.ipic.iastate.edu). Fact sheets and short videos summarizing some of the information from this study as well as our future steps have been and will be accessible through the POP page of the Improving Pig Survivability project (https://piglivability.org/pelvic-organ-prolapse). When additional publications and resources become available they will also be linked to these sites for public access.

VIII. Results

Specific Objective 1: Establish a network of industry partners and sow farm managers that enabled our team to seamlessly collect data on severely affected, moderately affected, and unaffected sow farms from varying geographic locations and production systems.

Table 1 summarizes the mortality rates for the 104 farms participating in the project. The annualized POP mortality across the dataset was 2.7% (of the total inventory) with a range among farms from 0.3% to 10.3% during the cumulative 52 weeks of the project period.

Table 1. Summary of inventory and mortality for 104 farms from 15 U.S. states.

	Average Bred Sow Inventory	POP Incidence (POP/1,000 sows/week)	Annualized Total Mortality	Annualized POP Mortality	Annualized Non-POP Mortality
Average	3,713	0.52	12.7%	2.7%	10.0%
Minimum	614	0.07	4.1%	0.3%	3.4%
Maximum	10,606	1.98	23.8%	10.3%	21.4%
Standard Deviation	2,000	0.34	4.0%	1.8%	3.4%
Total	386,166		100%	21%	79%

Each bar in Figure 2 represents the annualized POP rate for an individual farm contributing data to the project. The figure demonstrates the wide variation in POP mortality among the enrolled farms which was critical for the success of the project as differences observed between high and low incidence herds may help the understanding of underlying causes of POP. The average mortality due to all causes was 12.7%, and when dividing mortality into POP and non-POP mortality, 2.7% of all deaths were attributed to POP and 10.0% were attributed to non-POP mortality (Figure 3).

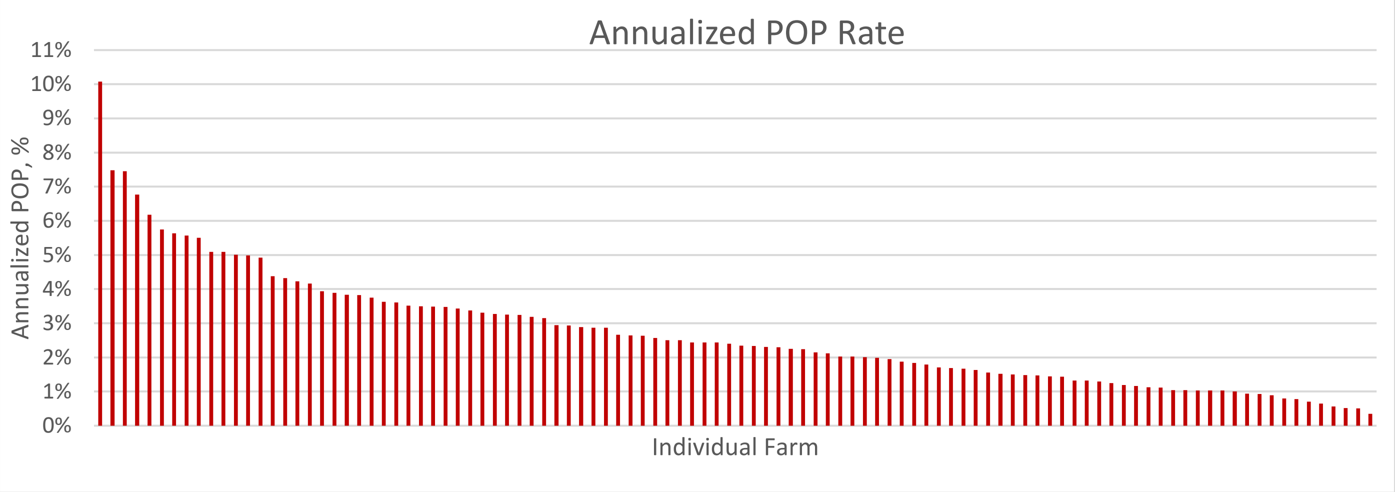


Figure 2 (above). Average annualized POP rate for 104 sow farms. Annualized POP ranged from 0.3% to 10.3% and averaged 2.7% for the 104 farms. To ensure complete anonymity of farms, the ID for each farm was removed.

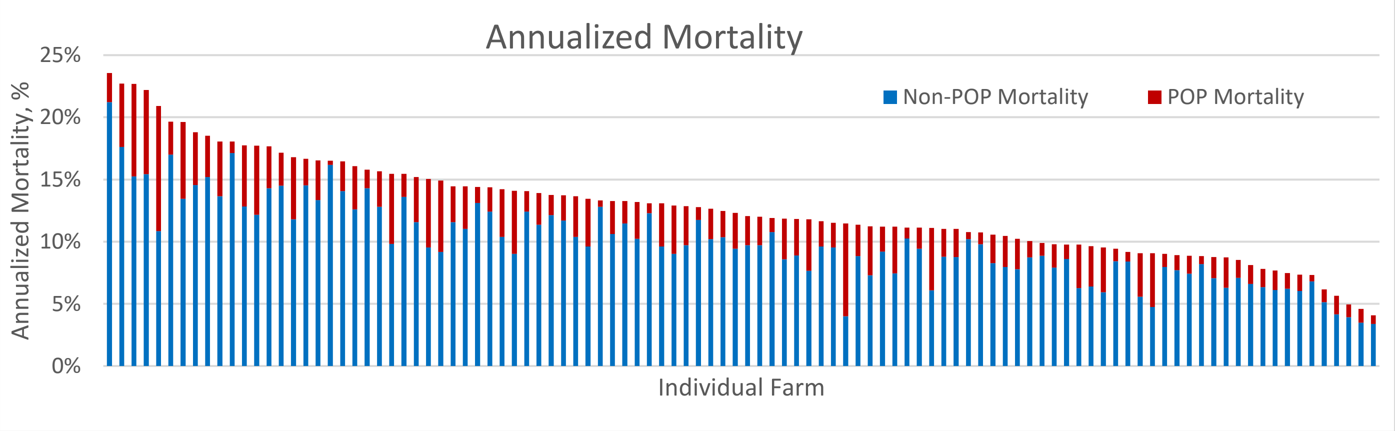


Figure 3 (above). Average annualized total mortality broken down by POP and non-POP mortality for 104 sow farms. The blue portion of the bars represent the proportion of the sow mortalities that occurred that were not due to POP while the red portion of the bars indicates the proportion occurring due to POP. Annualized non-POP mortality averaged 10.0% and POP mortality averaged 2.7% for the 104 farms. To ensure complete anonymity of farms, the ID for each farm was removed.

The average annualized POP rate was 0.9%, 2.4%, and 5.5% for the lowest incidence herds, average incidence herds, and highest incidence herds, respectively (Figure 4). Separating the farms into these groups revealed that farms most afflicted by higher annualized mortality as the result of the POP experienced greater change over time and is not observed in the farms experiencing lower incidence rate of POP. In Figure 5, total mortality is presented across farms with average, low and high incidence rates during the project period. The average annualized total mortality was 18.9%, 12.5%, and 7.5% for the herds with the highest, average, and lowest total morality, respectively.

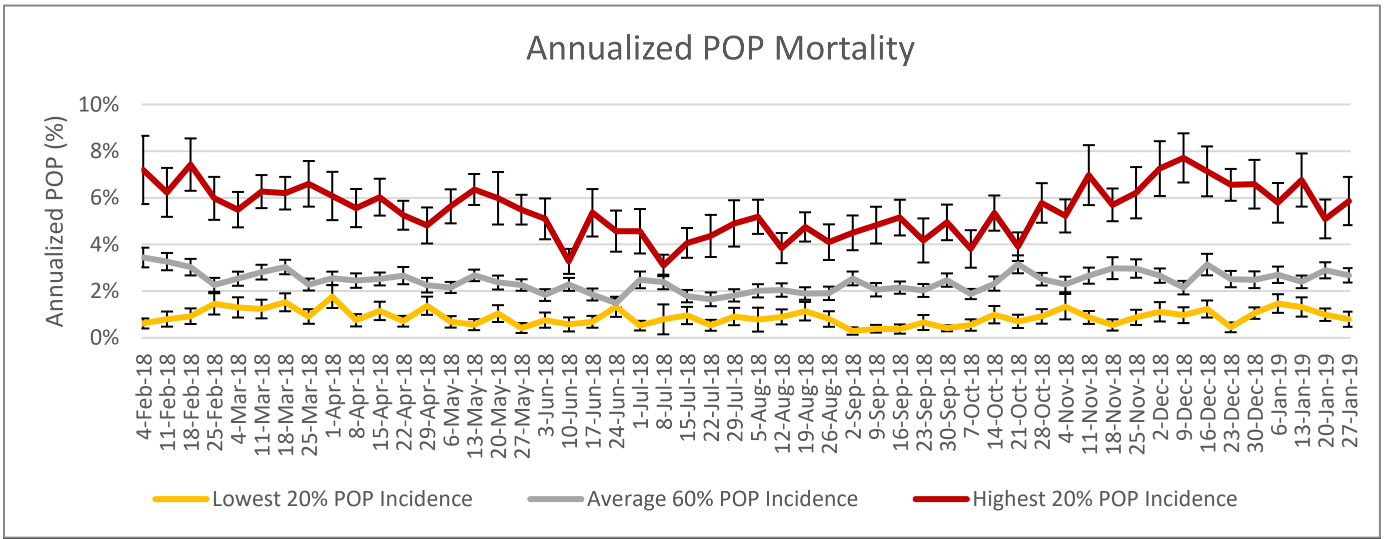


Figure 4 (above). Weekly annualized POP mortality. POP mortality is represented for farms for which the average POP rate is in the lowest 20% of all farms (gold line), the 60% of farms considered to have an average POP rate (gray line), and the farms for which the average POP rate is in the highest 20% of all farms (red line). Mortality data was collected for 52 weeks starting February 4, 2018.

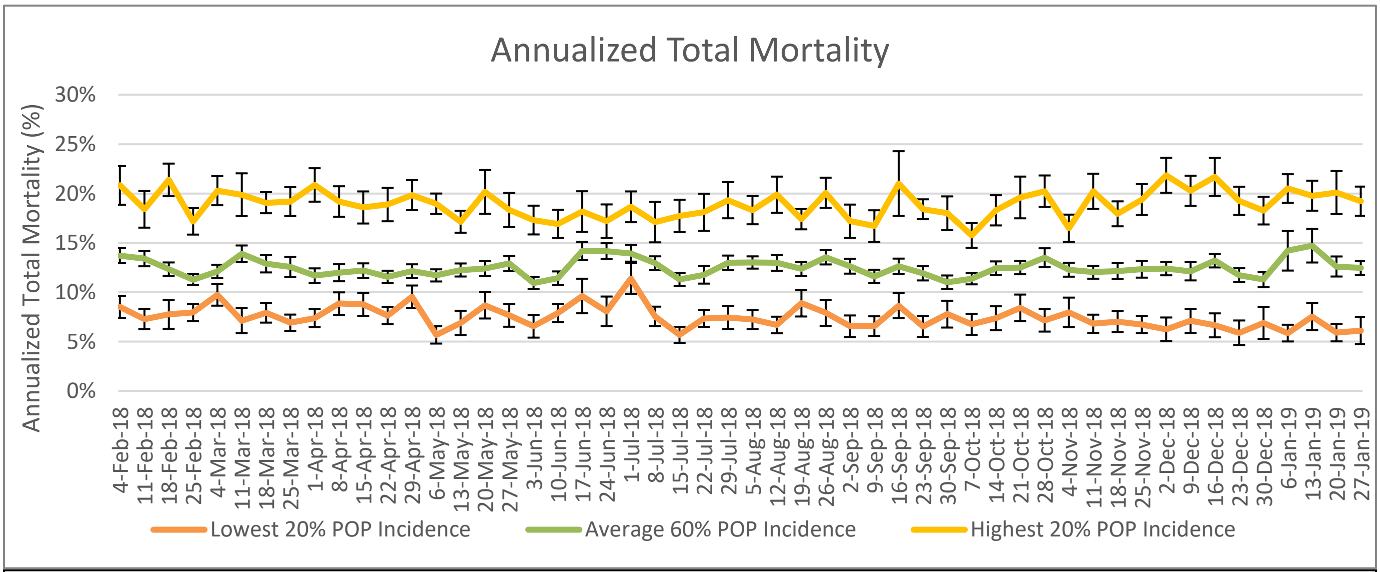


Figure 5 (above). Weekly annualized total mortality. Total mortality is represented for farms divided by the 20% of farms with the lowest average total mortality (shown in the orange line), the 60% of farms with the average total mortality (shown in the green line), and the 20% of farms with the highest average total mortality (shown in the yellow line) regardless of POP incidence rate. Mortality data was collected for 52 weeks starting February 4, 2018.

Figure 6 demonstrates the breakdown of total mortality into our 8 standardized causes. POP was attributed to 21% of all mortality reported. The largest category was unknown/other including 39% of the total mortality. Lameness, at 29%, was the second largest category. Long term, the IPIC team intends to utilize this data and information to help the industry pursue reductions in overall sow mortality, particularly mortality caused by POP.

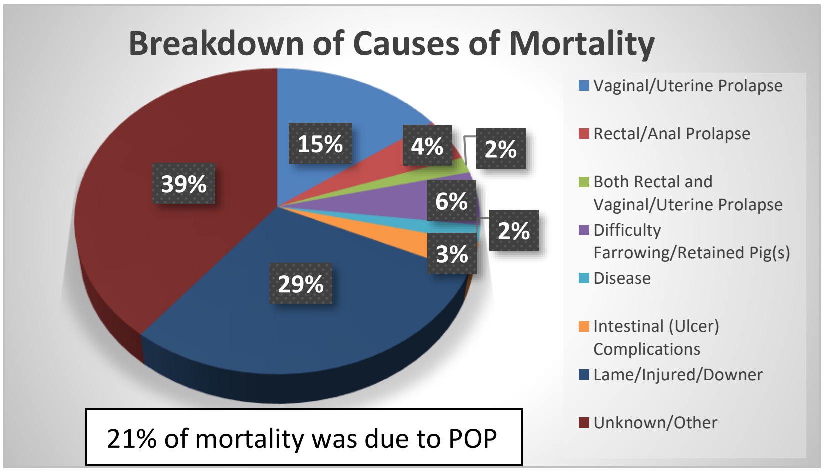


Figure 6 (left). Breakdown of causes of mortality for 104 farms. All farms submitted weekly mortality data using 8 causes of death categories (vaginal/uterine prolapse, rectal/anal prolapse, both rectal and vaginal/uterine prolapse, and difficulty farrowing/retained pig, disease, intestinal (ulcer) complications, lame/injured/downer, and unknown /other). POP accounted for 21% of all mortality during the year of data collection.

In order to normalize POP incidence across farms with varying herd size, many analyses were conducted on the number of POP per 1,000 sows per week for any given farm. For example, by comparison to the annualized rate of POP, a 0.1 POP/1000 sows/week would be equivalent to approximately 0.5% annualized mortality due to POP.

POP contributes, on average, 21% of total mortality, so it was not surprising that annualized POP rate was positively related to annualized total mortality (Figure 7A, $R^2 = 0.32$, $P < 0.01$) in that farms with higher POP rate generally experienced higher total mortality. Non-POP mortality, however, was not significantly correlated to POP mortality, and the amount of POP variation attributed to the relationship with non-POP mortality was much smaller (Figure 7B, $R^2 = 0.16$, $P = 0.11$) than the relationship between POP incidence and total mortality. This suggests there are different underlying causes of POP and non-POP mortality based on the farms included in this study.

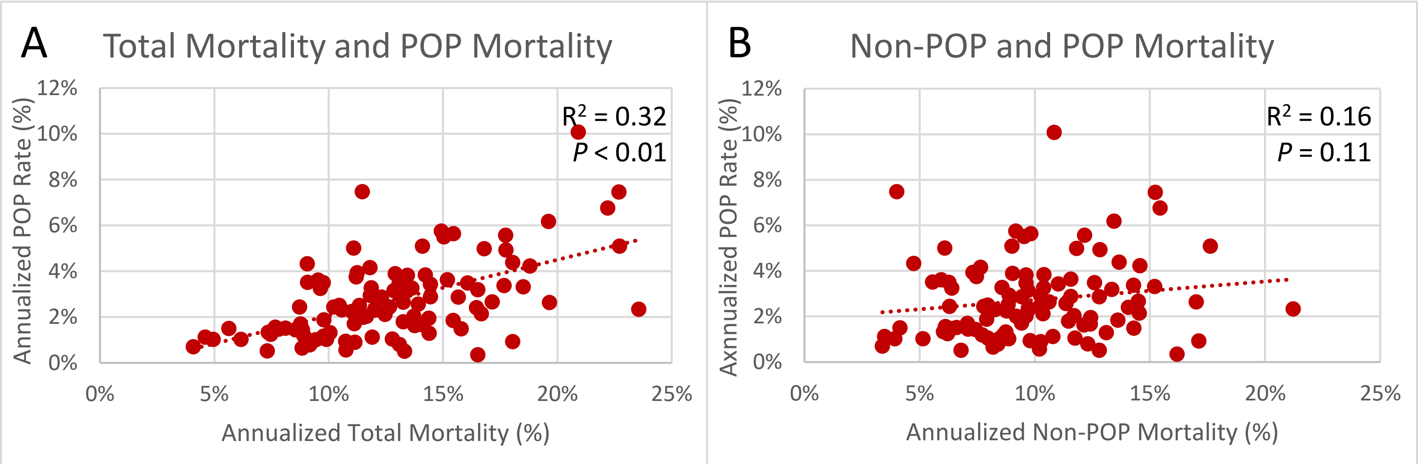
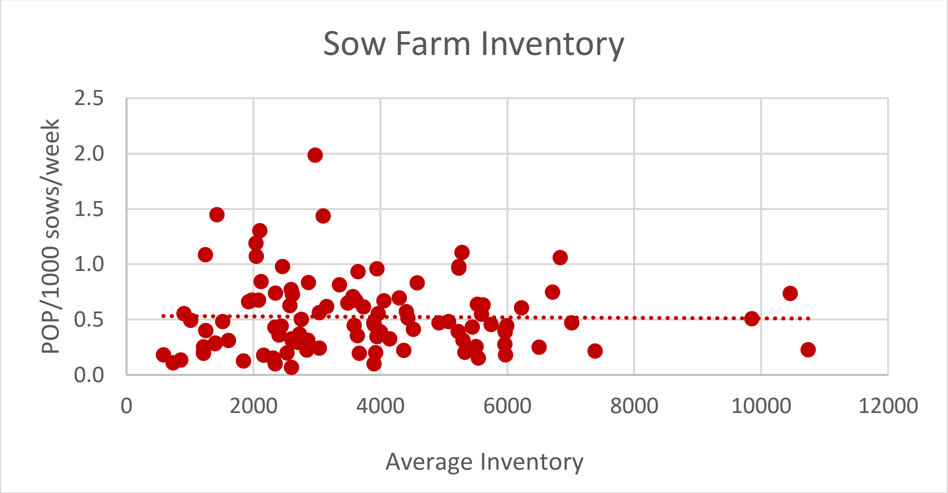


Figure 7 (above). Total mortality is positively related with POP mortality, but non-POP mortality was not significantly related to POP mortality. There was a significant correlation between farms with higher total mortality and farms with higher POP mortality (A). The relationship between non-POP mortality and POP mortality was much weaker (B). Collectively, these data suggest that variation in POP incidence across farms can explain a significant portion of the variation in total mortality but explains little of the variation that occurs in non-POP mortality.

Specific Objective 2: Develop an intensive herd and individual sow survey tool to objectively collect sow farm data and conduct statistical analysis to identify potential contributing factors to sow POP.

Farm Size

The survey developed for this study was conducted with 104 farms, and 62 of them included site visits to collect additional individual animal and herd level measurements. The farms ranged in inventory from 581 to 10,739 sows. Farm size, assessed as the average sow inventory, was not associated with POP incidence (Figure 8; $R^2 < 0.01$, $P = 0.90$).



Inventory	
Number of Samples	104
Mean	3,713
Max	10,739
Min	581
R^2	< 0.01
P value	0.90

Figure 8 (above). Sow farm inventory is not associated with farm POP incidence. The average bred sow inventory for 104 farms ranged in inventory from 581 to 10,739 sows. Farm size, assessed as the average sow inventory, was not associated with POP incidence.

Parity and Litter Size

Sow records extracted from farm record databases for a subset of 33 farms were examined for the relationship of POP with parity and litter size. The same records were used to determine parity distribution of all the sows that did not prolapse and are still alive compared to the sows that were removed due to a POP or removed due to any other reason. The POP distribution appears to follow a parity distribution similar to the parity distribution of the overall inventory (Figure 9). Figure 10 uses the same extracted data to illustrate the percentage of sows that prolapse per 1000 sows for each parity. Further, the results from the *chi-square* test for trend in proportions suggests a linear trend where the proportion of prolapsed sows increases ($P < 0.01$) as parity increases (Figure 10) suggesting risk for POP increases slightly with parity.

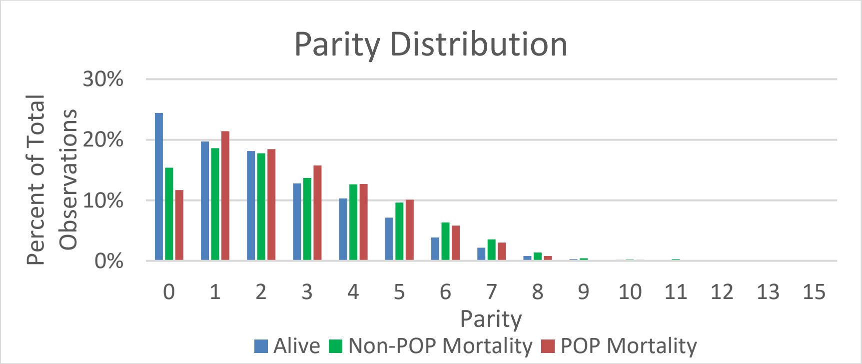


Figure 9 (left). Parity distribution of alive sows and those removed due to mortality. Records from sows that farrowed from February to May 2018 were extracted from sow databases for 33 farms to evaluate the distribution of sows across parities that remained alive (blue bars), died due to POP (red bars) or died unrelated to POP (green bars).

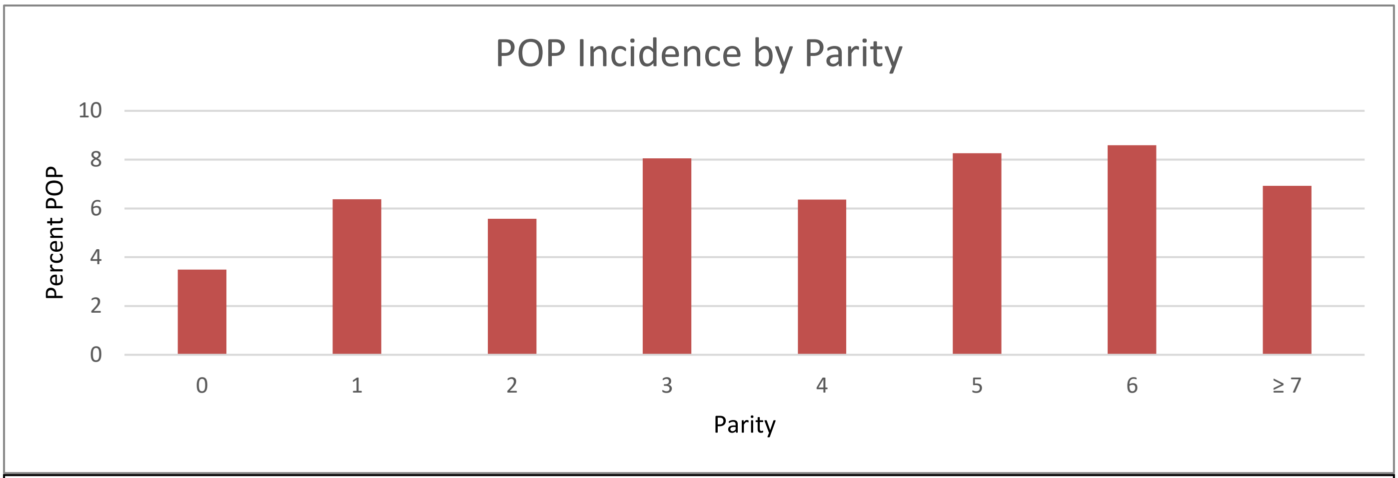


Figure 10 (above). Proportion of POP per parity. Records from sows that farrowed from February to May 2018 were extracted from sow databases for 33 farms to evaluate the distribution of POP in sows across parities. Distribution of POP is quantified as the percentage of POP per parity after normalization for parity distribution of sow inventory. A *chi-squared* test for trend in proportions suggests a linear trend where the proportion of prolapsed sows increases ($P < 0.01$) as parity increases.

There was no difference in total born between sows that prolapsed and sows that did not (Figure 11A; $P = 0.15$). Prolapsed sows had lower live born numbers compared to sows that did not prolapse (Figure 11B; $P < 0.01$). The difference in live born is accounted for by an increase in stillborn piglets for sows that prolapsed (Figure 12; $P = 0.04$), which may indicate signs of farrowing difficulty.

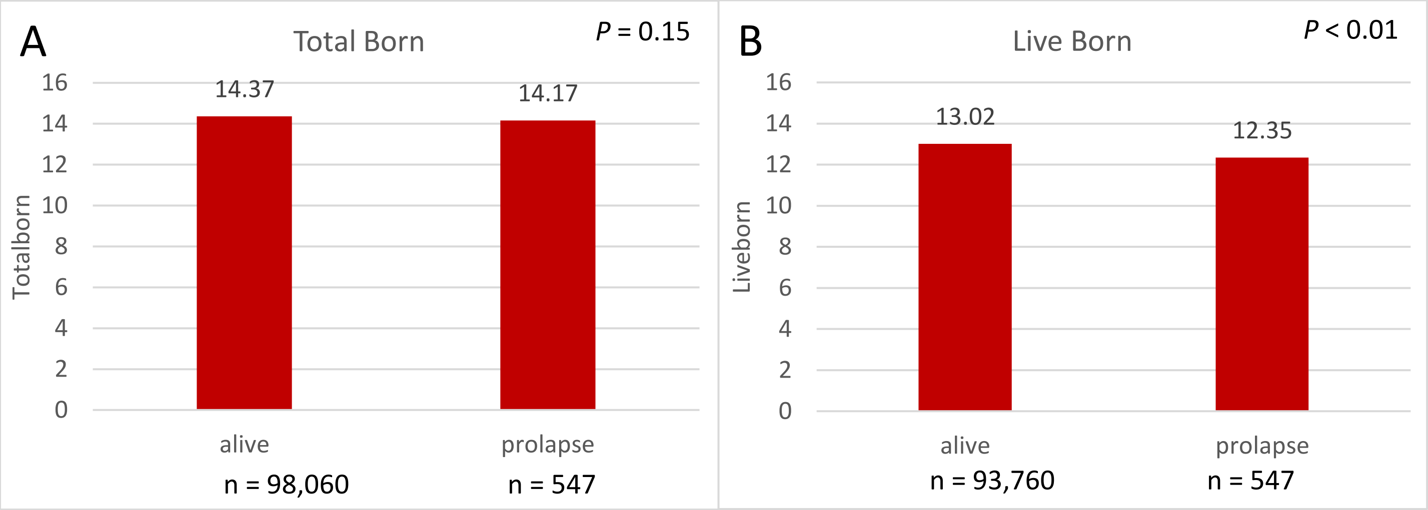


Figure 11 (above). Total born and live born of sows that did not prolapse and are still alive compared to sows that died due to POP 2-30 days post farrowing. Litter size data from a subset of 33 farms was extracted from databases containing information for sows that farrowed between February and May 2018 (culled sows were excluded). To ensure farrowing was completed and no piglets were retained thereby complicating the interpretation of the analysis, only sows that died due to POP between days 2 and 30 post-farrow were included in the analysis. There was no difference in total born between sows that prolapsed and sows that did not (A). Prolapsed sows had lower live born numbers compared to sows that did not prolapse (B).

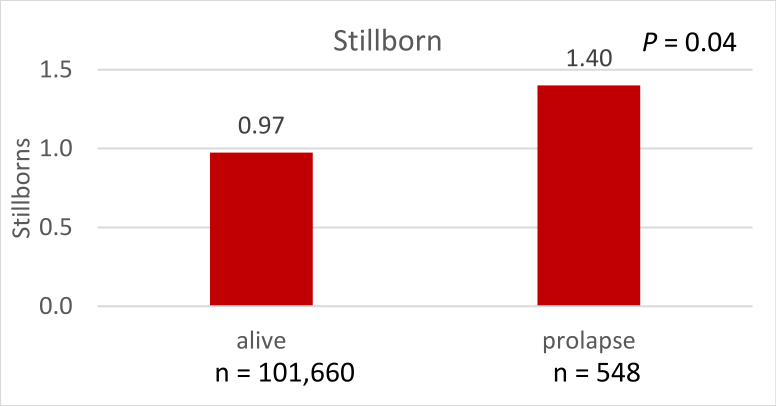


Figure 12 (left). Stillborn piglets of sows that did not prolapse and are still alive compared to sows that died due to POP 2-30 days post farrowing. Prolapsed sows had more stillborn piglets compared to sows that did not prolapse. Data was extracted from 33 farms using farrowing information from February to May 2018.

Farrowing Assistance

For farms that were visited by one of our team members, information about farrowing assistance protocols, such as sleeving and inductions, was collected. If inductions and sleevings were recorded on sow cards by the farm staff, a tally was taken on the number of inductions and sleevings for individual sows in 1 to 2 farrowing rooms that had completed farrowing, and averages for the farm were estimated. When looking at the farms' overall assistance strategies, these data showed no significant relationship between POP incidence and percentage of sows induced (Figure 13A, R^2 = 0.05, *P* = 0.13), percentage of sows never sleeved (Figure 13B, R^2 = 0.01, *P* = 0.53), or percentage of sows sleeved 3 or more times (Figure 13C, R^2 = 0.01, *P* = 0.66).

Figure 13 (right). Farm management strategies (farrowing induction and assistance frequency) and POP incidence. Induction of farrowing was assessed by identifying the percentage of sows that were induced to farrow as indicated on sow cards during site visits (A). Assessment of farrowing assistance (B and C) as a management strategy was determined by calculating the percentage of sows that were never assisted (B) or were assisted more than 3 times during the farrowing process (C) as determined from sow cards during farm visits. No significant relationships between POP incidence from weeks 6-18 of calendar year 2018 when site visits occurred and the strategies related to farrowing management were observed.

Genetics

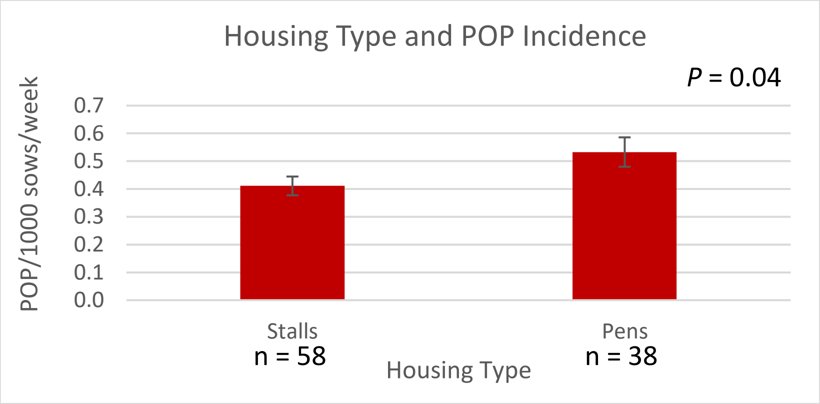
There were 10 different genetic sources represented across the sow farms in the study, although the study was not balanced for genetic source resulting in some genetic sources being represented on very few sow farms. Further investigation is warranted as recent reports indicate a lack of heritability of POP risk. Compared to herds with commercial sow genetics, herds with maternal sow genetics had lower POP incidence (*P* = 0.02) but there was no difference in non-POP mortality (*P* = 0.23). Further analysis will be needed to determine if specific genetic by environment interactions may contribute to POP incidence.

Facilities and Hygiene

Gestation Housing

Farms where pigs were housed in pens during gestation had a higher POP incidence compared to farms where pigs were housed in stalls during gestation (Figure 14, *P* = 0.04). The interpretation of this data is critical as investigation into other factors such as stocking density, group size within pens, or length of time they spend in stalls before moving to pens is needed. If farms had a portion of animals in stalls and a portion in pens (due to remodels or additions to the facility for example) they were excluded from this analysis.

Figure 14 (right). Sow housing type and POP incidence. For the farms represented in this study, those using stalls exclusively had a lower POP incidence rate compared to farms using pen gestation. Factors such as stocking density, group size, or timing of movement into pens was not accounted for in this analysis and may influence the incidence of POP.



Water Delivery

We were not able to measure water intake in this study, but information on drinker type was collected. POP incidence was not different for farms with trough, nipple, or cup waterers in gestation (Figure 15, *P* = 0.48).

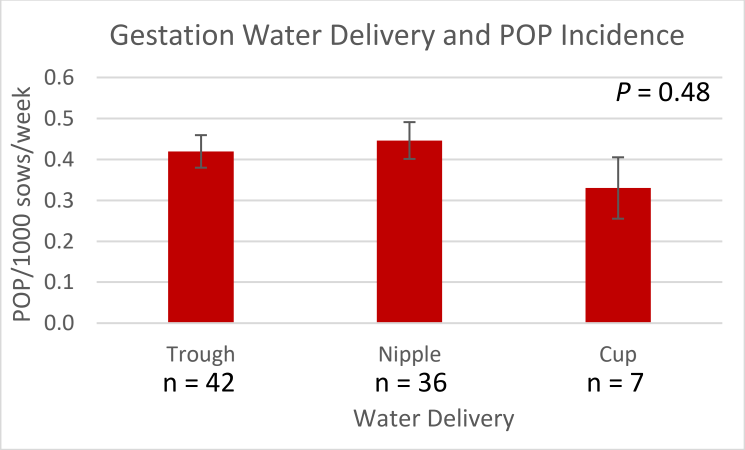


Figure 15 (above). Gestation water delivery and POP incidence. Water delivery type in gestation was classified as trough, nipple, or cup waterer and was not found to have an influence on POP incidence.

Manure Storage in Gestation

POP incidence was also not different for farms with or without pit fans (Figure 16A, *P* = 0.29). Farms with shallow pits in gestation had significantly greater POP incidence compared with farms with deep pits in gestation (Figure 16B, *P* < 0.01). Measurements of how full the pits were during the visit, or on average, were not taken thus limiting the conclusions that can be drawn from this information.

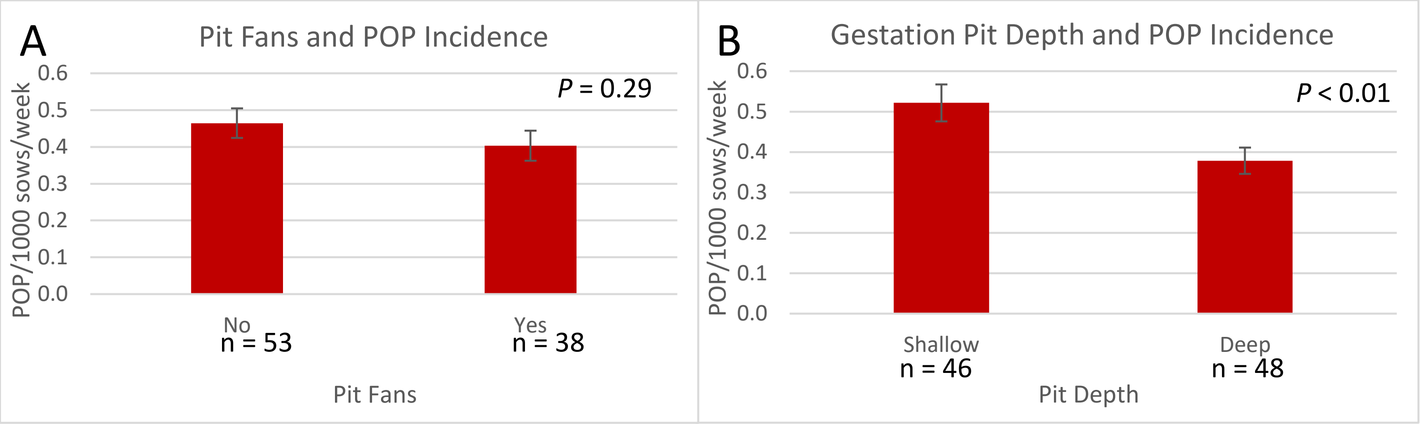


Figure 16 (above). Presence of pit fans and the pit depth in gestation on POP incidence. POP incidence was not different with farms having pit fans in gestation or not having pit fans (A). Farms with deep pits in gestation had a lower POP incidence compared to farms with shallow pits (B). Measurements of how full the pits were during the visit, or on average, were not collected.

Breeding and Insemination Strategies

Farms using post-cervical artificial insemination (PCAI) did not differ in POP incidence compared to farms using traditional AI (Figure 17, *P* = 0.20). There was no difference in POP incidence for farms routinely washing breeding stalls between groups and farms that were not routinely washing breeding stalls between groups (Figure 18A, *P* = 0.82). No difference was seen in POP incidence if manure was wiped off the vulvas prior to breeding or not (Figure 18B, *P* = 0.57). During farm visits estimations of manure coverage of both the breeding area and the gestation area were made and no difference in POP incidence was observed with different percentages of manure coverage in these areas (Figures 18C, *P* = 0.99 in breeding and Figure 18D, *P* = 0.53 in gestation).

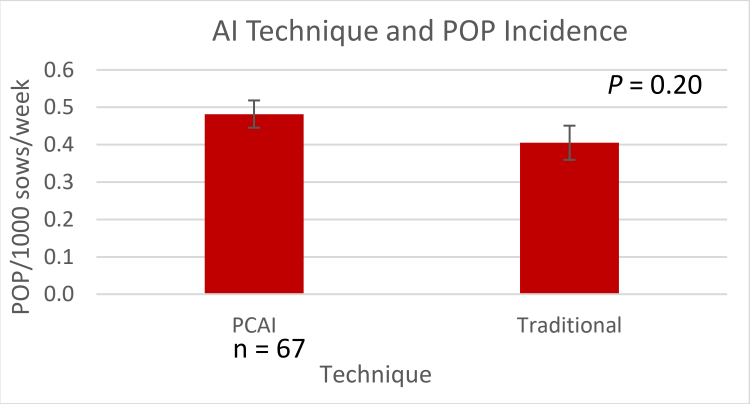


Figure 17 (above). AI technique on POP incidence. Farms were classified based on the AI technique used on most sows on the farm. Use of PCAI did not significantly affect POP incidence rate on the farms included in this study.

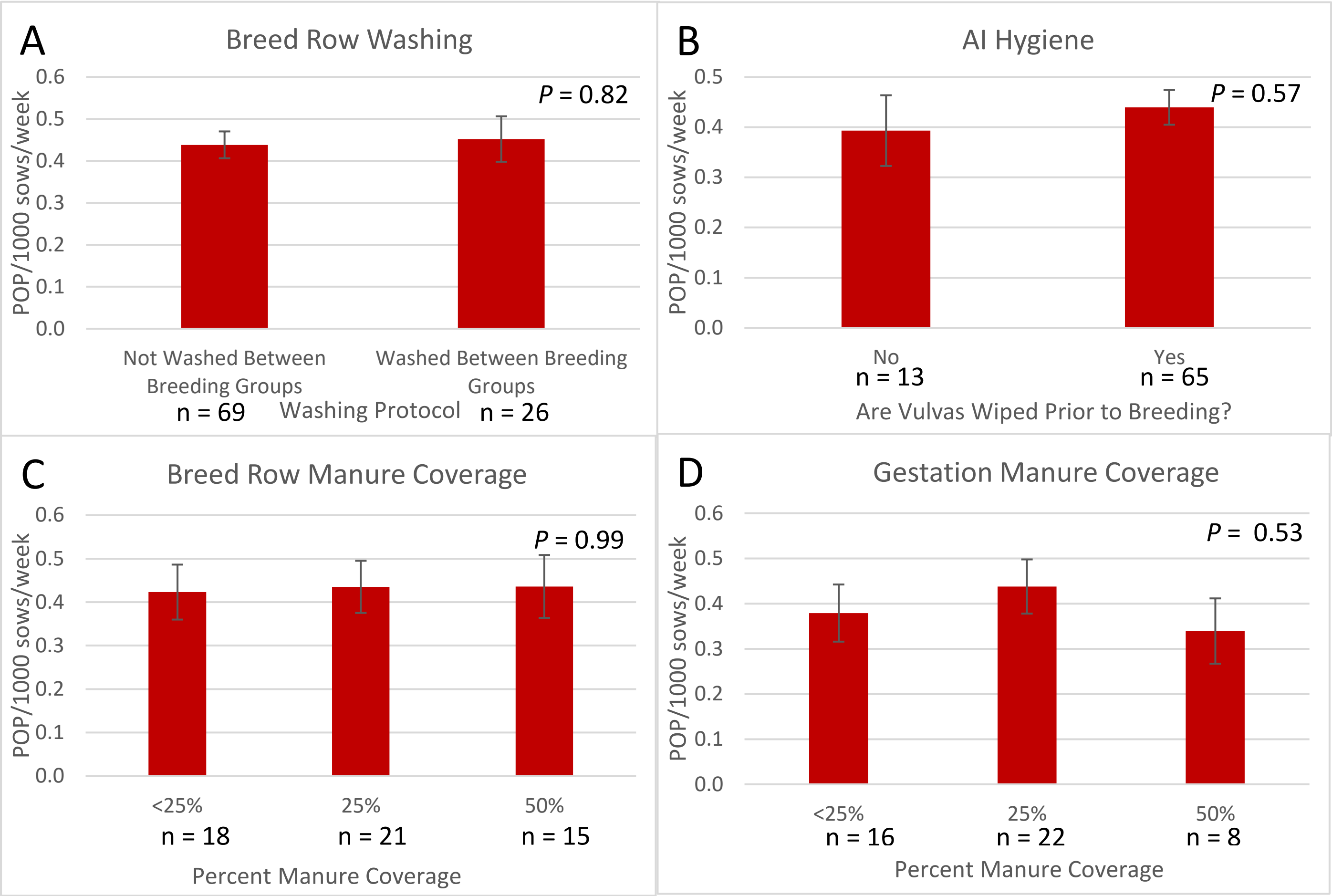


Figure 18 (above). Breed row hygiene and POP incidence. Estimates of farm hygiene had no relationship with POP incidence. Whether or not the breed row was washed before placing weaned sows was a standard practice for a farm did not affect farm POP incidence (A). Artificial Insemination (AI) hygiene is defined by whether a farm regularly wipes/cleans vulvas prior to breeding or not (B) and did not appear to affect POP incidence. Further, estimations of manure coverage on the breed row (C) and gestation housing (D; stalls or pens) during site visits to farms and did not have a statistical effect on POP incidence.

Water Treatment

Interestingly, farms using a water treatment system had lower POP incidence than farms that did not (Figure 19A, $P < 0.01$). The type of treatment did not seem to be as important as the treatment itself, since farms that treated with either a hydrogen peroxide or chlorine-based treatment system had a lower POP incidence ($P < 0.01$) compared to those farms that did not treat their water (Figure 19B). When examining water source, untreated well water had higher POP incidence ($P < 0.01$) compared to treated well and treated pond water, and rural water was not different in POP incidence from treated or untreated water (Figure 19C).

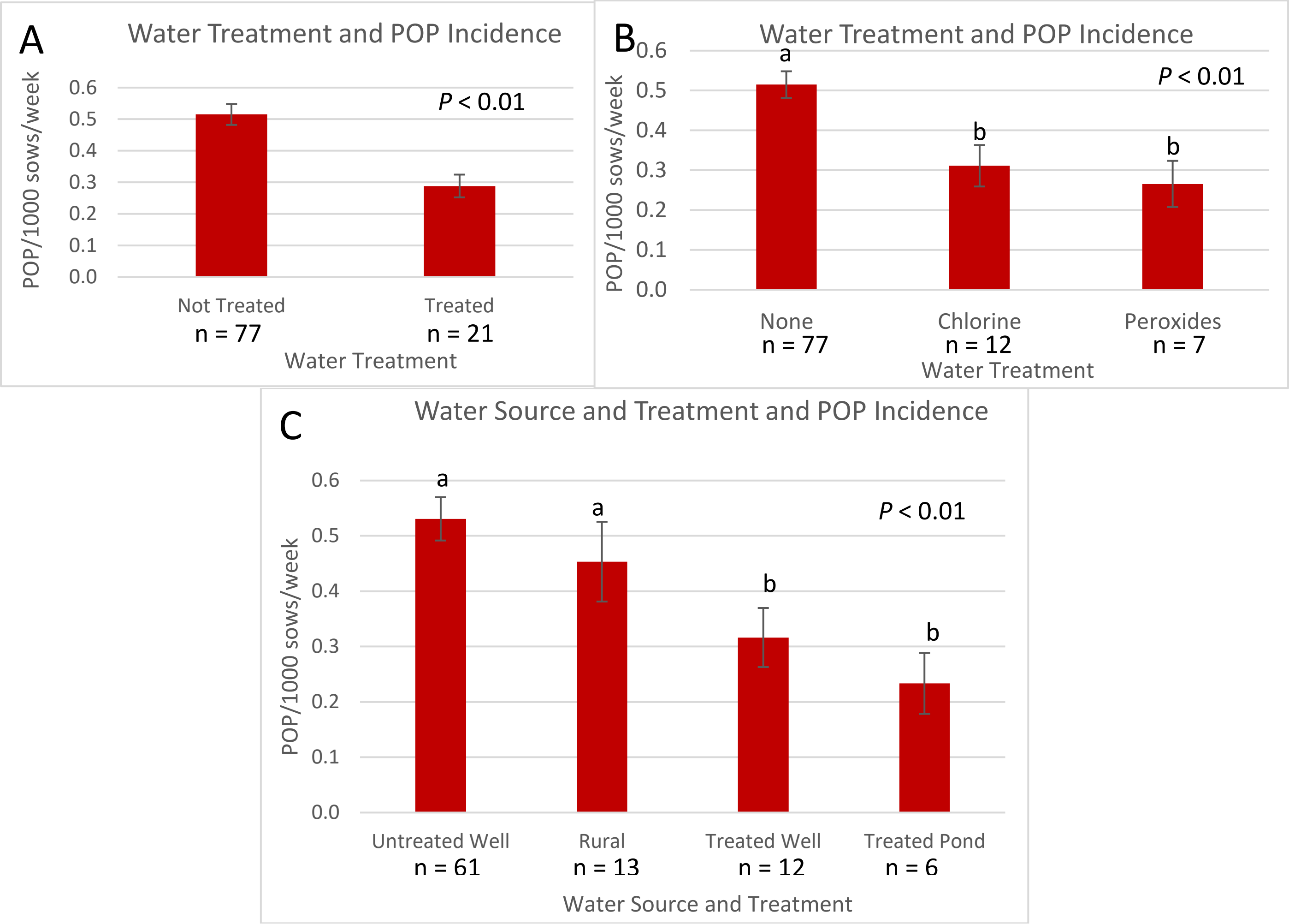


Figure 19 (above). Water treatment and POP incidence. For farms involved in the study, information on water source and utilization of water treatment systems was collected. Regardless of water source, farms that treated their water with either a chlorine or hydrogen peroxide-based system had lower POP incidence than farms that did not treat water (A and B). Farms using untreated well water had higher POP incidence compared to farms using treated well or treated pond water while farms using rural water did not differ in POP incidence compared to farms using treated or untreated water (C). Bars with different superscripts differ significantly ($P < 0.05$).

When analyzing the weekly mortality rates of those farms treating their water compared to those not treating water, POP mortality (Figure 20) and total mortality (Figure 21) were lower in farms using water treatment systems compared to those not using treated water for almost every week during the data collection period. On average, POP mortality was 1.5% lower and total mortality was 2.7% lower in herds using water treatment compared to those using untreated water.

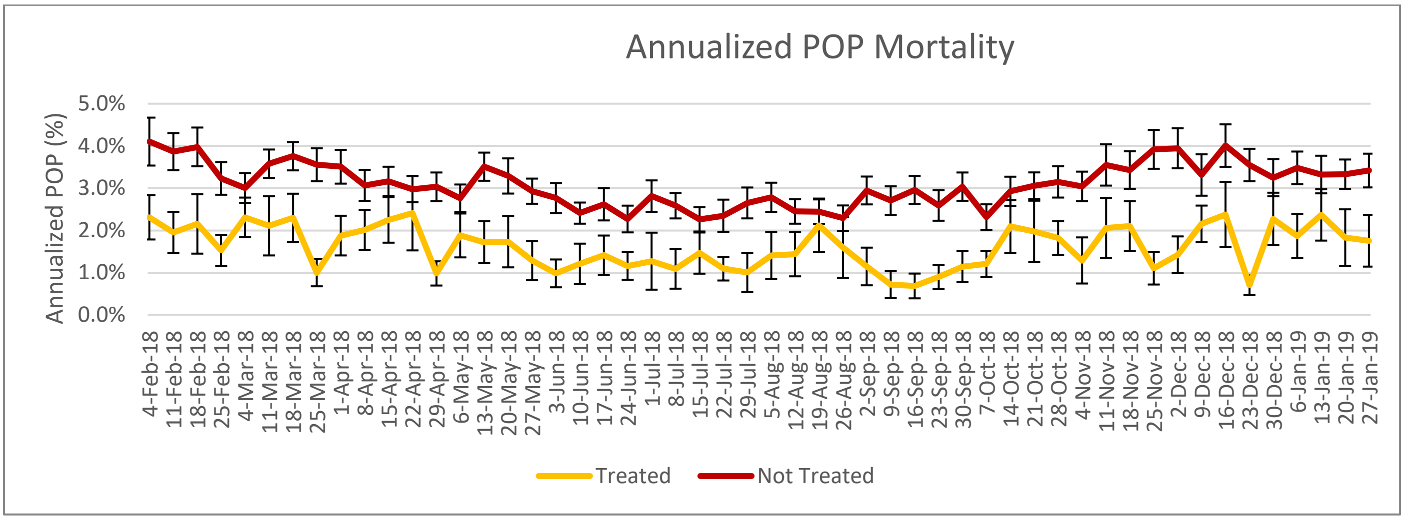


Figure 20 (above). Weekly annualized POP incidence rate for farms using treated vs. untreated water. The average POP incidence of farms with untreated water (red line) was on average 1.5% higher than the average POP incidence of farms that did treat their water (yellow line).

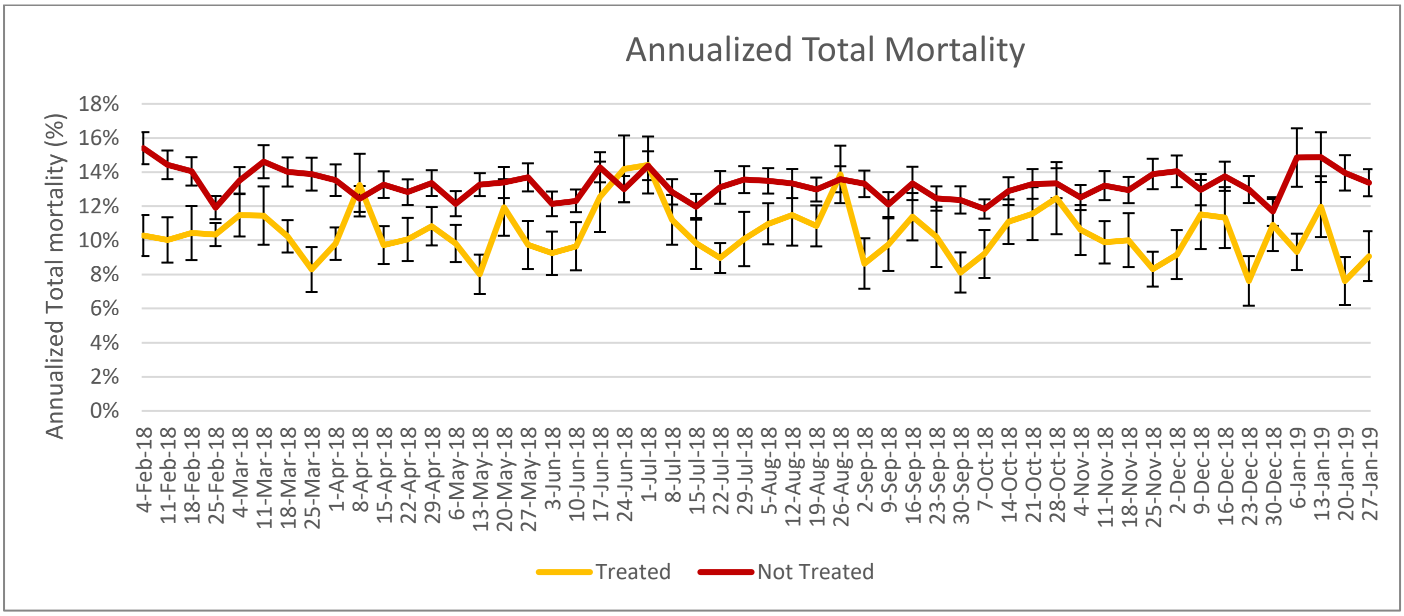


Figure 21 (above). Weekly annualized total mortality for farms using treated and untreated water. The average annualized total mortality of farms with untreated water (red line) was on average 2.7% higher than the average annualized total mortality of farms that did treat their water (yellow line).

Nutrition and Feeding Strategies

The use of chemical laxatives has been suggested to influence the risk of POP. In this study, there was no difference in POP incidence when comparing farms that did not use laxatives to those which used laxatives in any dose or delivery method (Figure 22A, *P* = 0.67). However, farms using laxatives both in the diet and top dressed have a greater POP incidence compared to those farms with no laxative usage or only using laxatives in the diet without top dressing (Figure 22B, *P* = 0.02). Since these data cannot determine causality, a possible interpretation of these data is that farms with the greatest incidence of POP have included laxatives in their management strategies in hopes of reducing POP, thus resulting in the observed association between laxatives and POP incidence. Further investigation into different laxative products and levels used by different farms could be beneficial. Additionally, the use of laxatives (most commonly potassium magnesium sulfate) in feed also likely altered the amount of specific minerals (potassium, sulfur, and magnesium) in the lactation diet shown later in Tables 4 and 5.

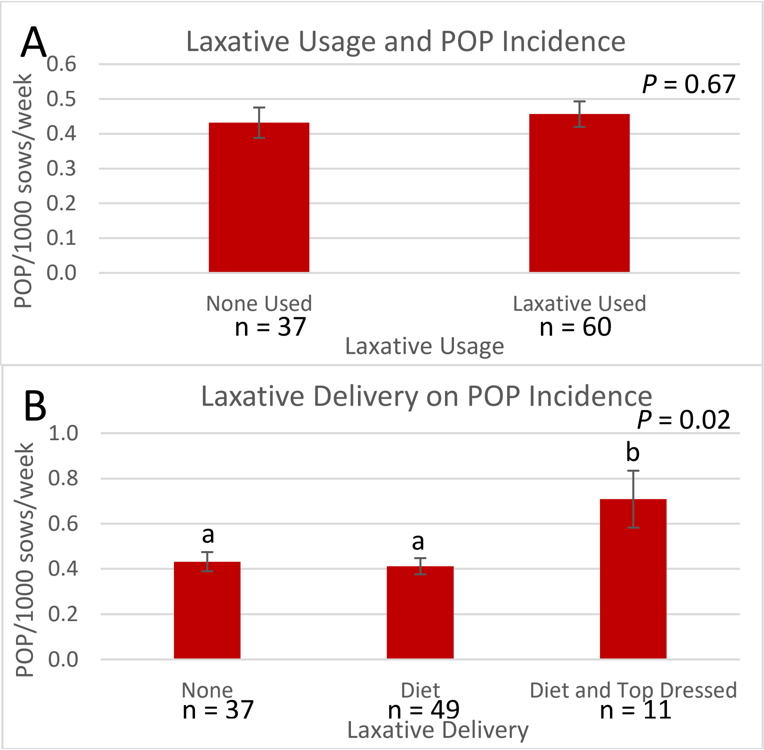


Figure 22 (above). Laxative usage on POP incidence. Laxative usage (primarily in lactation diets) includes any laxative product and dose either in the feed or top dressed in the diet. No difference (*P* = 0.67) in POP was discovered for farms using laxatives to those that did not (A). The farms (n = 11) that top dressed laxatives as well as include them in the diet had higher (*P* = 0.02) POP incidence than those farms that either did not use laxatives or used them only in the diet (B). This could be an indication that farms with higher POP incidence are utilizing laxatives as a mitigation strategy, albeit without success, or that excessive laxative usage could contribute to POP. Bars with different superscripts differ significantly (*P* < 0.05).

Wet feeding (using either wet/dry feeders or a hose to soak the lactation feed in each feeder) compared to dry feed in lactation was not related to POP incidence for farms on our study (Figure 23A; *P* = 0.32). The number of days prior to farrowing that sows were loaded into crates was not accounted for, but when categorizing farms by feed allotment in farrowing crates prior to farrowing (fed less than 5 pounds/day or 5 or more pounds/day) , the farms feeding less than 5 pounds had a significantly higher POP incidence (Figure 23B; *P* < 0.01).

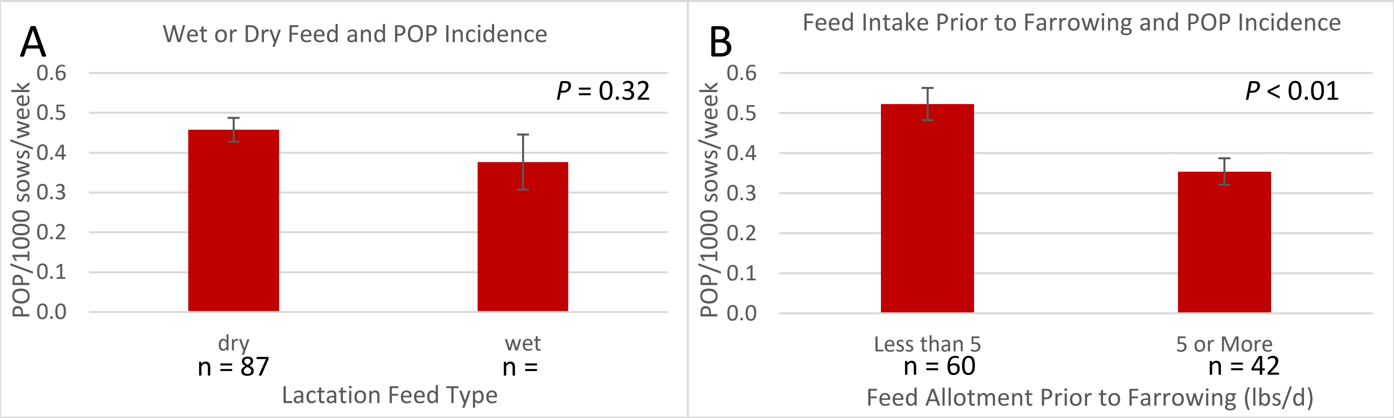


Figure 23 (above). Lactation feeding strategy and POP incidence. Wet feed is defined as either using wet/dry feeders or using a hose daily to soak the lactation feed in each feeder (A). Farms were categorized as either feeding less than 5 pounds per sow per day or feeding 5 pounds or more per sow per day in farrowing crates prior to farrowing. Differences in the number of gestating days in the farrowing crate were not taken into account (B).

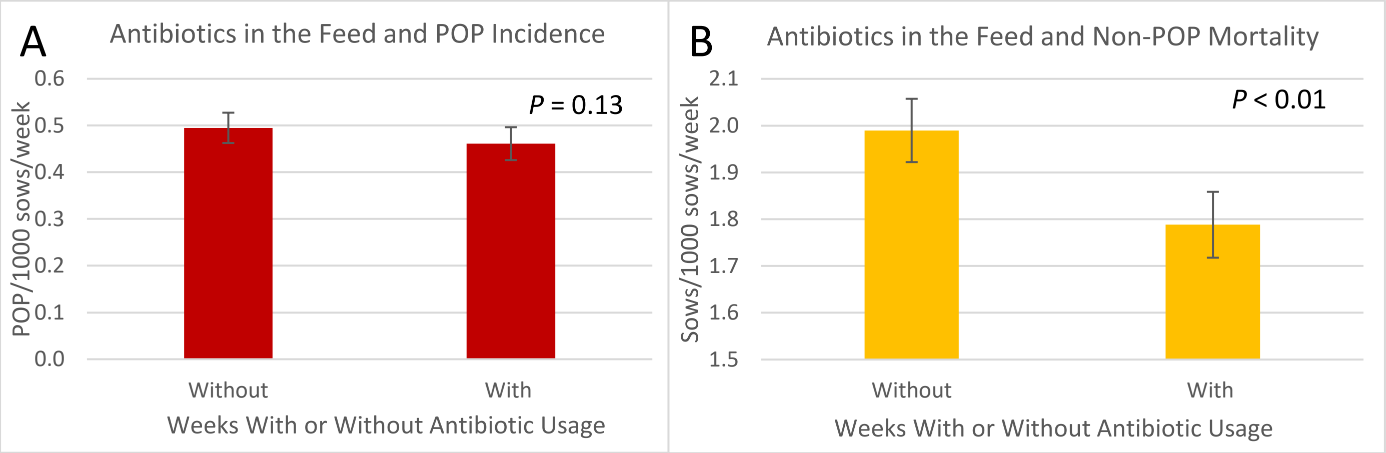


Figure 24 (above). Antibiotics in the feed on POP incidence. All types and doses of antibiotics were used in these analyses to understand if antibiotics in general could have a relationship to POP incidence. Figure 24 compares the POP incidence (A) and non-POP incidence (B) of weeks farms were not feeding antibiotics to weeks farms were feeding antibiotics. Analysis was conducted using incidence from week 6 of 2018 to week 5 of 2019.

The use of feed grade antibiotics was recorded for farms. When comparing all the weeks with antibiotics in the feed to all the weeks without antibiotics in the feed, there was a lower non-POP mortality (Figure 24B, *P* < 0.01), but not POP mortality (Figure 24A, *P* = 0.13), when antibiotics were included. Thirty farms had chlorotetracycline (CTC) included in feed for short durations (10-14 days) during the study time period. When comparing the four weeks before antibiotic inclusion in the feed, the weeks during antibiotic inclusion, and the four weeks after antibiotic inclusion, POP incidence was not different during the inclusion compared to time periods preceding or following inclusion (Figure 25; *P* = 0.48). We did observe a lower non-POP mortality during the antibiotic pulse compared to the weeks prior to or after the pulses (Figure 25; *P* < 0.01).

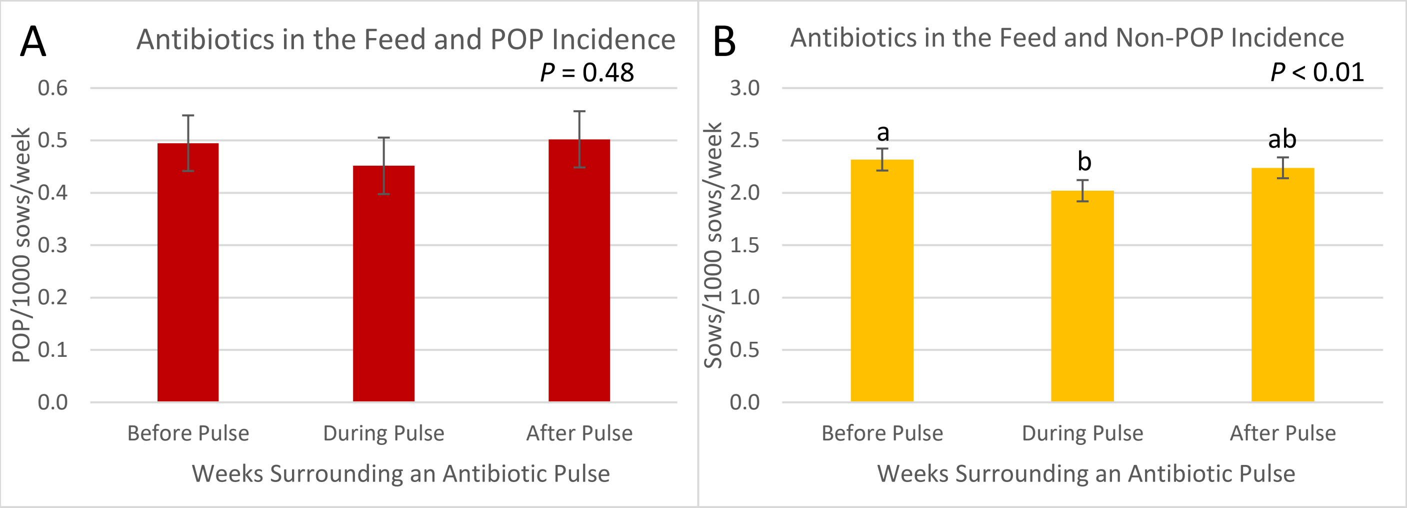


Figure 25 (above). Antibiotic inclusion in feed on sow mortality. Inclusion of chlorotetracycline (CTC) for short periods of time (~10-14 days) were done on 30 farms. Analysis was conducted from week 6 of 2018 to week 5 of 2019 including 4 weeks before the inclusion (before pulse), 1-2 weeks during the inclusion (during pulse), and 4 weeks after the inclusion (after pulse).

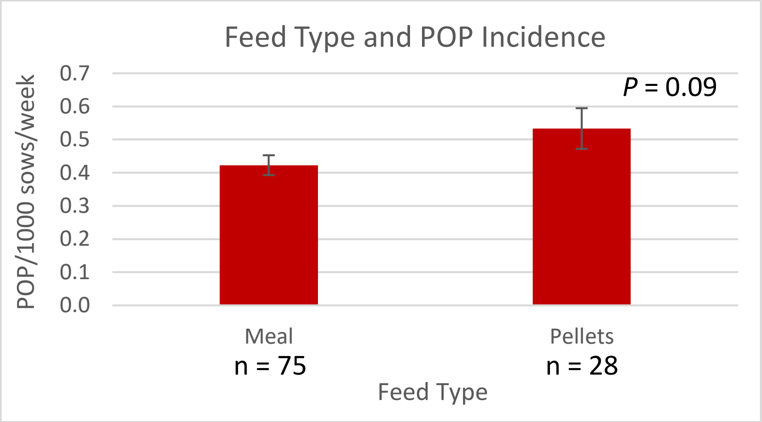
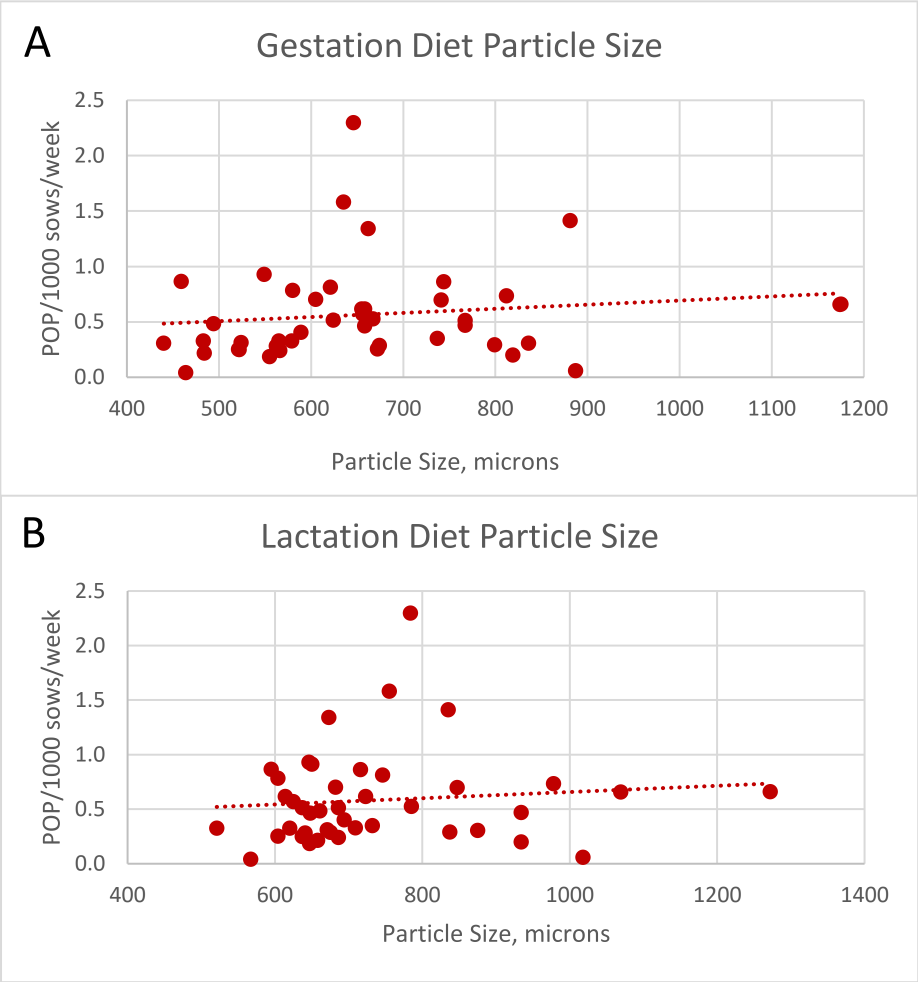


Figure 26 (above). Evaluation of feed type and POP incidence. Farms included in the study either fed complete diets as meal or were pelleted. Farms feeding pelleted diets had a higher (*P* = 0.09) POP incidence compared to farms feeding meal diets.

Farms feeding pelleted feed tended to have a higher (*P* = 0.09) POP incidence compared to farms feeding meal (Figure 26). Particle size was unable to be determined from individual ingredients or complete pelleted feeds, but for farms feeding meal diets, there was not a significant relationship between POP incidence and complete feed particle size for either gestation (Figure 27A; R^2 = 0.02, *P* = 0.39) or lactation diet (Figure 27B; R^2 = 0.01, *P* = 0.50).



Gestation Diet	
Number of Samples	43
Mean	663
Max	1175
Min	440
R^2	0.02
P value	0.39

Lactation Diet	
Number of Samples	43
Mean	735
Max	1272
Min	521
R^2	0.01
P value	0.50

Figure 27 (above). Diet particle size and POP incidence. During calendar weeks 6-18 of 2018, 62 farms were visited of which 43 used meal diet samples were collected for gestation and lactation diets. Particle size was determined for all gestation and lactation meal feed samples and was analyzed using the average POP incidence from weeks 6-18 of calendar year 2018 when site visits occurred. Particle size was not analyzed for pelleted diets. No significant relationship between POP incidence and the particle size of gestation (A) or lactation (B) diets was observed.

According to dietary formulations, a variety of fat types and levels were being used across the different farms on the study (Figure 28). Fat types used included choice white grease (CWG), corn oil, animal fat, yellow grease, and animal vegetable blend (AV Blend). Farms using different dietary fat types had different ($P < 0.01$) POP incidence rates, although this analysis lacks the ability to assign causality. The level of added fat in lactation diets had a significant, but weak association with POP incidence (Figure 29; $P = 0.01$, $R^2 = 0.08$), in that farms with higher added fat levels had a higher POP incidence.

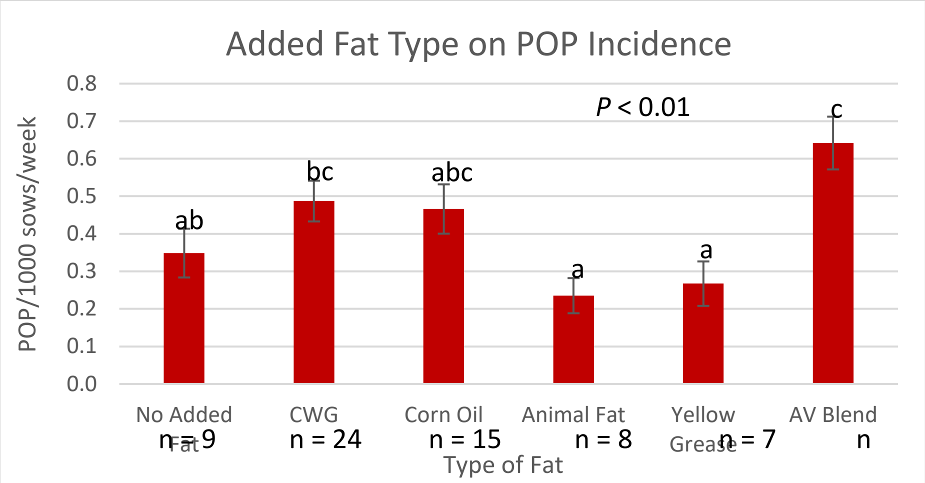
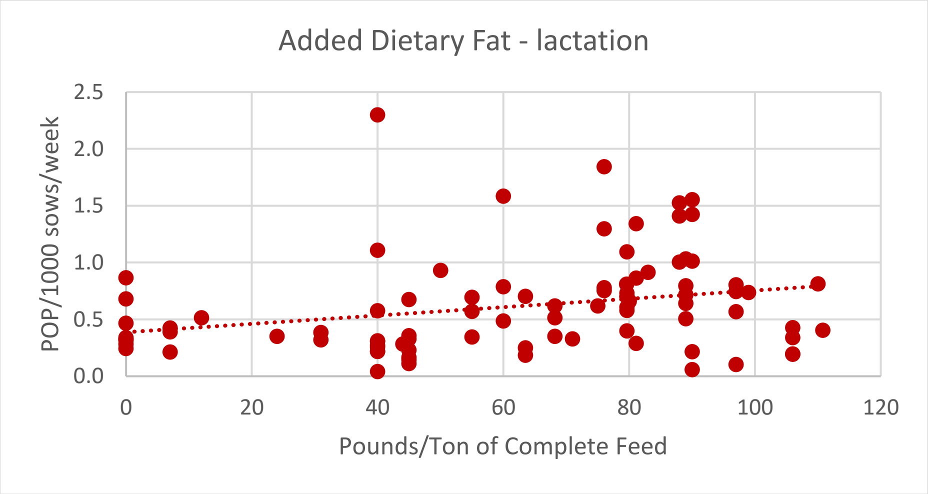


Figure 28 (left). Dietary fat source and POP incidence. During calendar weeks 6-18 of 2018 gestation and lactation diet formulations were collected and analyzed to determine if farms using different dietary fat types had differences in POP incidence from weeks 6-18 of calendar year 2018 when formulations were collected. Farms either included no dietary fat or one of 5 different types of fat (choice white grease (CWG), corn oil, animal fat, yellow/restaurant grease, or an animal-vegetable (AV) blend). Bars with different superscripts differ significantly ($P < 0.05$). We did not verify that formulations provided did not change during the analysis period.

Figure 29 (below). Fat level in lactation diets on POP incidence. During calendar weeks 6-18 of 2018, based on formulations, dietary added fat levels averaged 60.8 lbs/ton complete feed and ranged from 0 to 110 pounds per ton of complete feed for 91 farms. Lactation dietary fat was analyzed using the average POP incidence from weeks 6-18 of calendar year 2018. Higher added dietary fat, not considering fat type, was associated ($R^2 = 0.08$; $P = 0.01$) with higher POP incidence.



Added Dietary Fat – Lactation (lbs/ton)	
Number of Samples	91
Mean	60.8
Max	110.8
Min	0
R^2	0.08
P value	0.01

Proximate analysis was conducted on lactation and gestation feed samples collected from farms during site visits. The results are displayed in Tables 2-5, and Figure 30. While hypocalcemia is thought to be associated with uterine prolapses in dairy cattle, dietary calcium and phosphorus levels in feed samples collected during calendar weeks 6-18 of 2018 in both gestation and lactation diets were not associated with POP incidence on those farms contributing samples. Importantly, this study did not evaluate mineral quantities in serum or specific tissues of sows that prolapsed or that were at a higher risk of prolapsing.

Alternatively, fiber level could influence POP incidence as farm POP incidence was associated with gestation acid detergent fiber (ADF; Figure 30A; $R^2 = 0.07$, $P = 0.05$), lactation ADF (Figure 30B; $R^2 = 0.11$, $P = 0.01$), and lactation neutral detergent fiber (NDF; Figure 30C; $R^2 = 0.08$, $P = 0.03$). Other significant relationships observed with POP incidence were lactation ash ($R^2 = 0.11$, $P = 0.01$), lactation sulfur ($R^2 = 0.13$, $P < 0.01$), lactation potassium ($R^2 = 0.15$, $P < 0.01$), and gestation magnesium ($R^2 = 0.08$, $P = 0.03$). One commonly used laxative in the industry is composed of potassium and magnesium sulfate. The addition of this product in lactation diets on farms with higher POP incidence may partially explain the positive relationships of lactation sulfur and potassium with POP incidence if farms having higher incidence of POP are utilizing laxatives in a mitigation attempt.

With additional financial support from BIOMIN America Inc., feed samples were also evaluated for mycotoxin levels at the ISU Veterinary Diagnostic Laboratory. The mycotoxin analysis results are displayed in Table 6 (gestation feed samples) and Table 7 (lactation feed samples). There were no samples with detectable aflatoxin B2, aflatoxin G1, aflatoxin G2, nivalenol, ochratoxin A, T2 toxin or zearalenol, and only 5 samples had detectable levels of aflatoxin B1. This made understanding the relationship between mycotoxins and POP incidence difficult. Neither vomitoxin nor zearalenone had a significant relationship with POP incidence on these farms. No significant correlations between analyzed toxins and the POP incidence rate for farms during weeks 6-18 of 2018 were detected ($P \geq 0.10$). However, taking into account only the POP incidence data for the week prior, week of, and week after feed samples were collected, there was a positive, but weak relationship between total fumonisins in the gestation diet and POP incidence ($R^2 = 0.09$, $P = 0.02$). No relationships were noted between POP incidence and any of the mycotoxins in lactation diet samples. We acknowledge the difficulty with mycotoxin analysis when taking feed samples at only a single time point during the study. The intent of this project to determine which potential factors to prioritize for future, more controlled studies, mycotoxins were evaluated within the context of the data collected. Given that some statistical relationships between toxins in feed were discovered in relation to POP incidence, this may warrant future studies to determine causality.

Table 2. Proximate analysis of gestation diets[1]

	Gestation Proximate Analysis			
	DM[2]	CP[3]	ADF[4]	NDF[5]
Number of Samples	58	58	58	58
Mean	86.6	16.0	5.7	13.9
Median	86.6	15.1	5.4	13.6
Minimum	82.6	9.8	2.7	7.7
Maximum	90.1	22.2	13.5	27.3
Standard Deviation	1.07	2.78	2.18	3.78
[6]R^2	0.02 (-)	0.00 (+)	0.07 (-)	0.03 (-)
***P*-value**	0.32	0.97	0.05	0.18

[1] All values are presented on a dry matter basis.
[2] Dry Matter expressed as a percentage.
[3] Crude Protein expressed as a percentage.
[4] Acid detergent fiber expressed as a percentage.
[5] Neutral detergent fiber expressed as a percentage.
[6] R^2 values were calculated for correlations with week 6-18 POP incidence from r values. The sign in parentheses for the R^2 value indicates if the r value was positive (+) or negative (-).

Table 3. Proximate analysis of lactation diets[1]

	Lactation Proximate Analysis			
	DM[2]	CP[3]	ADF[4]	NDF[5]
Number of Samples	58	58	58	58
Mean	87.2	22.3	4.4	10.0
Median	87.3	21.6	4.3	9.8
Minimum	83.2	16.9	2.9	7.1
Maximum	90.2	28.6	6.9	17.0
Standard Deviation	0.98	2.76	1.01	2.25
[6]R^2	0.00 (-)	0.01 (+)	0.11 (-)	0.08 (-)
***P*-value**	0.79	0.43	0.01	0.03

[1] All values are presented on a dry matter basis. R^2 values were calculated for correlations with week 6-18 POP incidence from r values. The sign in parentheses for the R^2 value indicates if the r value was positive (+) or negative (-).
[2] Dry Matter expressed as a percentage.
[3] Crude Protein expressed as a percentage.
[4] Acid detergent fiber expressed as a percentage.
[5] Neutral detergent fiber expressed as a percentage.
[6] R^2 values were calculated for correlations with week 6-18 POP incidence from r values. The sign in parentheses for the R^2 value indicates if the r value was positive (+) or negative (-).

Table 4. Macromineral and micromineral analysis of gestation diets[1]

	Gestation Macrominerals							Gestation Microminerals			
	Total Ash[2]	P[2]	K[2]	S[2]	Mg[2]	Ca[2]	Na[2]	Fe[3]	Mn[3]	Cu[3]	Zn[3]
Number of Samples	58	58	58	58	58	58	57	58	58	58	58
Mean	5.4	0.74	0.77	0.27	0.21	1.06	0.29	383	96	35	290
Median	5.4	0.74	0.75	0.26	0.21	1.06	0.27	366	91	31	265
Minimum	4.1	0.52	0.55	0.16	0.15	0.66	0.17	171	50	16	129
Maximum	7.3	1.01	1.07	0.53	0.37	1.63	0.56	709	151	73	1781
Standard Deviation	0.63	0.09	0.12	0.08	0.04	0.20	0.07	120.2	25.6	13.2	217.0
Nutritional Requirement		0.58	0.20		0.06	0.78	0.15	80	25	10	100
[4]R^2	0.00 (-)	0.01 (+)	0.00 (-)	0.00 (+)	0.08 (-)	0.00 (-)	0.01 (-)	0.04 (+)	0.00 (-)	0.03 (+)	0.04 (-)
***P*-value**	0.78	0.45	0.82	0.90	0.03	0.91	0.59	0.15	0.79	0.22	0.14

[1] All values are presented on a dry matter basis.

[2] Total ash, phosphorus (P), potassium (K), sulfur (S), magnesium (Mg), calcium (Ca), and sodium (Na) expressed as a percentage.

[3] Iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) expressed as parts per million (ppm).

[4] R^2 values were calculated for correlations with week 6-18 POP incidence from r values. The sign in parentheses for the R^2 value indicates if the r value was positive (+) or negative (-).

Table 5. Macromineral and micromineral analysis of lactation diets[1]

	Lactation Macrominerals							Lactation Microminerals			
	Total Ash[2]	P[2]	K[2]	S[2]	Mg[2]	Ca[2]	Na[2]	Fe[3]	Mn[3]	Cu[3]	Zn[3]
Number of Samples	58	58	58	58	58	58	58	58	58	56	57
Mean	6.3	0.74	1.09	0.33	0.26	1.10	0.29	394	101	38	306
Median	6.4	0.73	1.08	0.32	0.23	1.09	0.27	385	104	36	261
Minimum	5.2	0.51	0.78	0.19	0.17	0.72	0.18	189	60	22	137
Maximum	8.2	1.07	1.44	0.51	0.60	1.68	0.54	676	163	78	1974
Standard Deviation	0.63	0.09	0.14	0.07	0.10	0.20	0.07	102.7	21.5	11.7	259.2
Nutritional Requirement		0.61	0.20		0.06	0.70	0.20	80	25	20	100
[4]R^2	0.11 (+)	0.01 (+)	0.15 (+)	0.13 (+)	0.00 (+)	0.00 (+)	0.01 (-)	0.03 (-)	0.00 (-)	0.02 (+)	0.04 (-)
***P*-value**	0.01	0.40	0.00	0.01	0.63	0.82	0.56	0.20	0.83	0.36	0.16

[1] All values are presented on a dry matter basis

[2] Total ash, phosphorus (P), potassium (K), sulfur (S), magnesium (Mg), calcium (Ca), and sodium (Na) expressed as a percentage.

[3] Iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) expressed as parts per million (ppm).

[4] R^2 values were calculated for correlations with week 6-18 POP incidence from r values. The sign in parentheses for the R^2 value indicates if the r value was positive (+) or negative (-).

Table 6. Mycotoxin analysis for gestation feed samples collected during site visits.

Gestation	Aflatoxin B1[3]	Fumonisin B1	Fumonisin B2	Fumonisin B3	Total Fumonisins[4]	Nivalenol[5]	Ochratoxin A[5]	T2 Toxin[5]	Vomitoxin	Zearalenol[5]	Zearalenone
	ppb	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppb**
Number of Samples	59	59	59	59	59	59	59	59	59	59	59
Samples with Detectable Levels	3	51	35	28	51	0	0	0	15	0	43
Average of positive samples	16.7	2.3	0.5	0.5	2.9	0	0	0	0.2	0	56.2
Maximum Value	20	12.9	1.9	2	15.9	0	0	0	0.5	0	249
Detection Limit	< 5	< 0.1	< 0.1	< 0.1		< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 20
Risk Limit[1]	100	10	10	10	10		0.2	2	1		0
[6]Week 6-18 POP R^2	0.05 (+)	0.05	0.04	0.02	0.04	N/A	N/A	N/A	0.01	N/A	0.00
Week 6-18 POP *P*-value	0.10	0.11	0.13	0.24	0.11	N/A	N/A	N/A	0.51	N/A	0.73
[6,2]Weeks around visit POP R^2	0.06 (+)	0.09 (+)	0.08 (+)	0.05 (+)	0.09 (+)	N/A	N/A	N/A	0.01	N/A	0.00
[2]Weeks around visit POP *P*-value	0.08	0.02	0.03	0.09	0.02	N/A	N/A	N/A	0.60	N/A	0.97

[1] Risk limits from Iowa State University Extension

[2] Includes average POP incidence for 1 week prior to site visit, 1 week during visit, and 1 week after visit

[3] No detectable levels of Aflatoxin B2, G1, or G2 in any of the samples analyzed

[4] Total Fumonisins calculated as the sum of Fumonisin B1, B2, and B3

[5] No detectable levels of Nivalenol, Ochratoxin A, T2 Toxin, or Zearalenol in any of the samples analyzed

[6] R^2 values were calculated for correlations with week 6-18 POP incidence from r values. The sign in parentheses for the R^2 value indicates if the r value was positive (+) or negative (-).

Table 7. Mycotoxin analysis for lactation feed samples collected during site visits.

Lactation	Aflatoxin B1[3]	Fumonisin B1	Fumonisin B2	Fumonisin B3	Total Fumonisins[4]	Nivalenol[5]	Ochratoxin A[5]	T2 Toxin[5]	Vomitoxin	Zearalenol[5]	Zearalenone
	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb
Number of Samples	59	59	59	59	59	59	59	59	59	59	59
Samples with Detectable Levels	2	47	28	24	48	0	0	0	10	0	37
Average of Positive Samples	9.5	2.2	0.3	0.3	2.5	0	0	0	0.2	0	68.3
Maximum Value	13	13.9	0.9	0.9	15	0	0	0	0.5	0	516
Detection Limit	< 5	< 0.1	< 0.1	< 0.1	N/A	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 20
Risk Limit[1]	100	10	10	10	10		0.2	2	1		0
[6]Week 6-18 POP R^2	0.00	0.01	0.00	0.00	0.01	N/A	N/A	N/A	0.01	N/A	0.00
Week 6-18 POP *P*-value	0.92	0.47	0.72	0.90	0.54	N/A	N/A	N/A	0.45	N/A	0.71
[6,2]Weeks around visit POP R^2	0.00	0.02	0.01	0.02	0.02	N/A	N/A	N/A	0.00	N/A	0.00
[2]Weeks around visit POP *P*-value	0.93	0.36	0.60	0.31	0.35	N/A	N/A	N/A	0.70	N/A	0.97

[1] Risk limits from Iowa State University Extension

[2] Includes average POP incidence for 1 week prior to site visit, 1 week during visit, and 1 week after visit

[3] No detectable levels of Aflatoxin B2, G1, or G2 in any of the samples analyzed

[4] Total Fumonisins calculated as the sum of Fumonisin B1, B2, and B3

[5] No detectable levels of Nivalenol, Ochratoxin A, T2 Toxin, or Zearalenol in any of the samples analyzed

[6] R^2 values were calculated for correlations with week 6-18 POP incidence from r values.

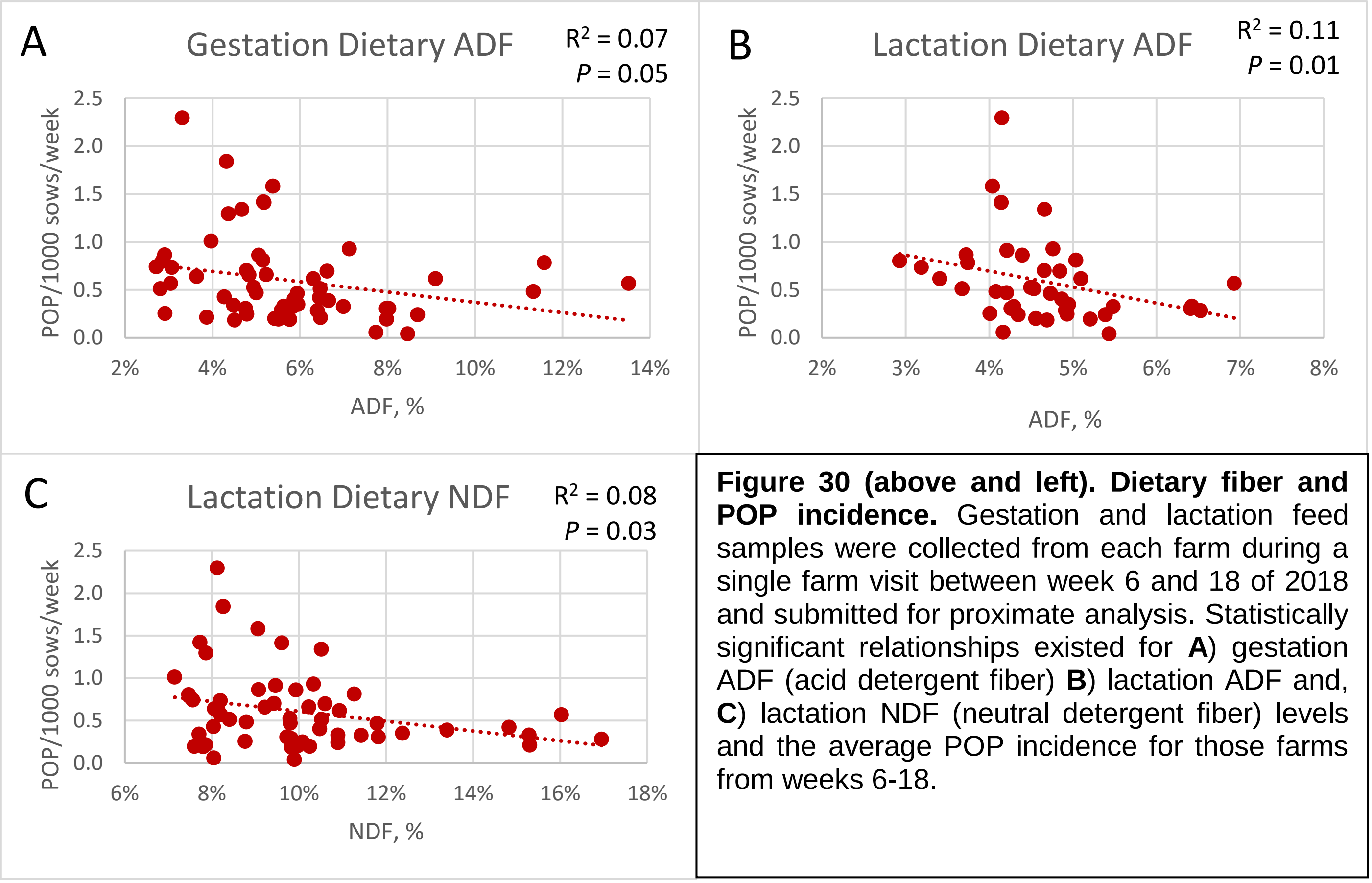
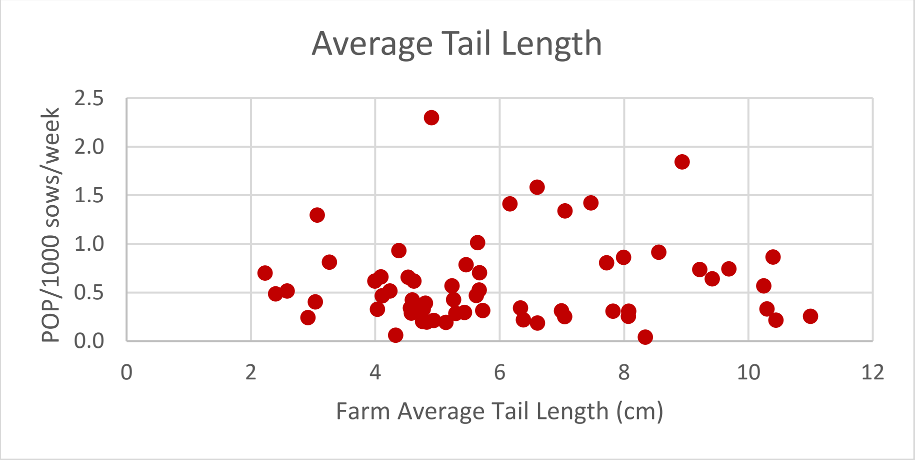


Figure 30 (above and left). Dietary fiber and POP incidence. Gestation and lactation feed samples were collected from each farm during a single farm visit between week 6 and 18 of 2018 and submitted for proximate analysis. Statistically significant relationships existed for **A**) gestation ADF (acid detergent fiber) **B**) lactation ADF and, **C**) lactation NDF (neutral detergent fiber) levels and the average POP incidence for those farms from weeks 6-18.

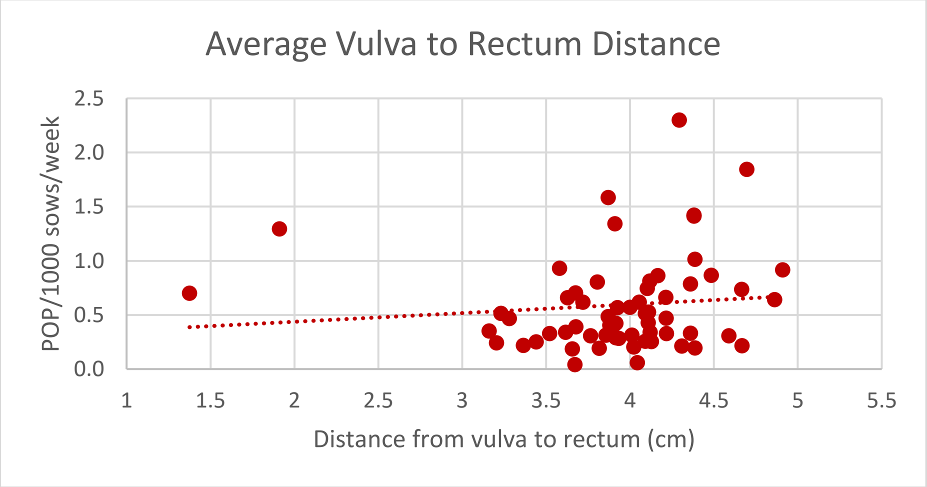
Individual Animal Measures

During farm visits to 62 farms, approximately 5,000 sows in total were measured for tail length, distance from the rectum to the top of the vulva, body condition score, and perineal score. All sows were measured just prior to farrowing (just before or after sows were placed into farrowing crates). Analysis for all individual animal measures were made using the farm average POP incidence from weeks 6 through 18 as that was the time period when all site visits were conducted. On a herd level, the average tail length measured from sows during late gestation was not associated with POP incidence of the farm (Figure 31; $R^2 < 0.01$, $P = 0.60$). Based on individual sow tail-length measurements (i.e. not the sow farm average) sows that subsequently prolapsed after measurement tended to have longer tails (6.4 cm) when compared to animals that did not prolapse (5.8 cm; $P = 0.08$). The distance from the rectum to the top of the vulva was measured as an indication of stretching in the perineal area. The average measure for the farm was not significantly correlated to POP incidence (Figure 32, $R^2 = 0.008$, $P = 0.48$). When looking at individual animals that prolapsed compared to the ones that did not prolapse, the longer rectum to vulva distance did increase the odds of POP ($P < 0.01$). Importantly, this may be related to the increased perineal swelling (i.e. perineal score) that is associated with sows at high risk of prolapse and not necessarily a predisposing factor.



Tail Length	
Number of Samples	62
Mean	6.0
Max	11.0
Min	2.2
R^2	< 0.01
P value	0.60

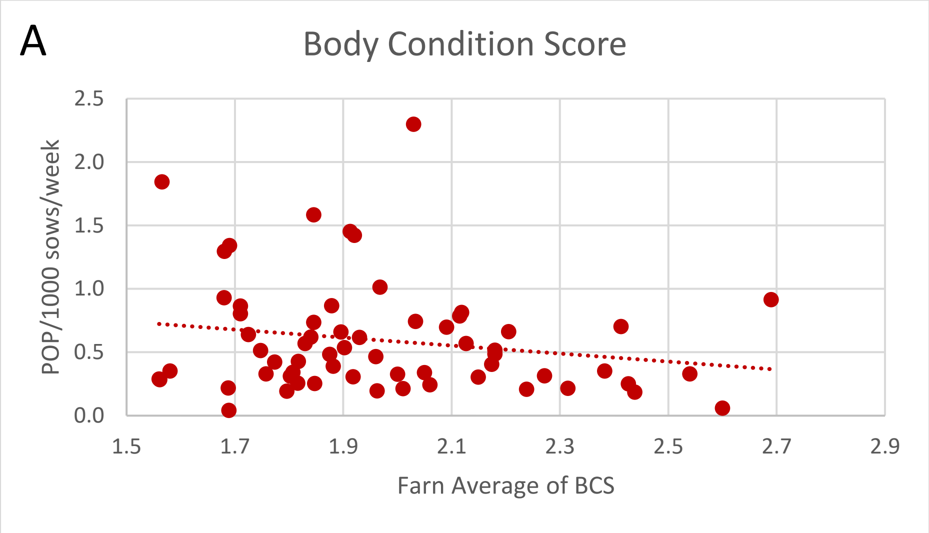
Figure 31 (above). Farm average tail length and POP incidence. Tail length was measured on 4954 sows from 62 farms. Average tail length for each farm was calculated and analyzed using the average POP incidence from weeks 6-18 of calendar year 2018 which is the time period when site visits occurred.



Vulva to Rectum Distance	
Number of Samples	62
Mean	3.9
Max	4.9
Min	1.4
R^2	0.01
P value	0.40

Figure 32 (above). Farm average vulva to rectum distance and POP incidence. As a measure of stretching in the perineal region, the distance from the rectum to the top of the vulva was measured on 4952 sows from 62 farms. Average vulva to rectum distance for farms was calculated and ranged from 1.4 to 4.9 cm. Average vulva to rectum distance analyzed using the average POP incidence from weeks 6-18 of calendar year 2018 which is the time period when site visits occurred.

During farm visits, a total of 4953 sows were assigned a body condition scores (BCS) during late gestation using a three-point scale. A total of 884 sows were considered a BCS 1 (thin), 3,378 sows were a BCS 2 (normal body condition), and 691 sows were a BCS 3 (overweight). The farm average of sow BCS was not correlated with POP incidence during the period of time when site visits were conducted (Figure 33A, R^2 = 0.04, *P* = 0.14). Of all the sows that were assigned a BCS, 65 prolapsed (1.3%). A greater percentage of thinner sows prolapsed compared to normal condition or overweight sows (Figure 33B). Twenty-one of the BCS 1 sows prolapsed (2.4%), 41 of the BCS 2 sows prolapsed (1.2%), and 3 of the BSC 3 sows prolapsed (0.4%). Compared to a normal conditioned sow (BCS 2), the odds of having a POP increased by 2 for BCS 1 sows (*P* = 0.01) and decreased by 0.35 for BCS 3 sows (*P* = 0.08).



Body Condition Score	
Number of Samples	62
Mean	2.0
Max	2.7
Min	1.6
R^2	0.04
P value	0.14

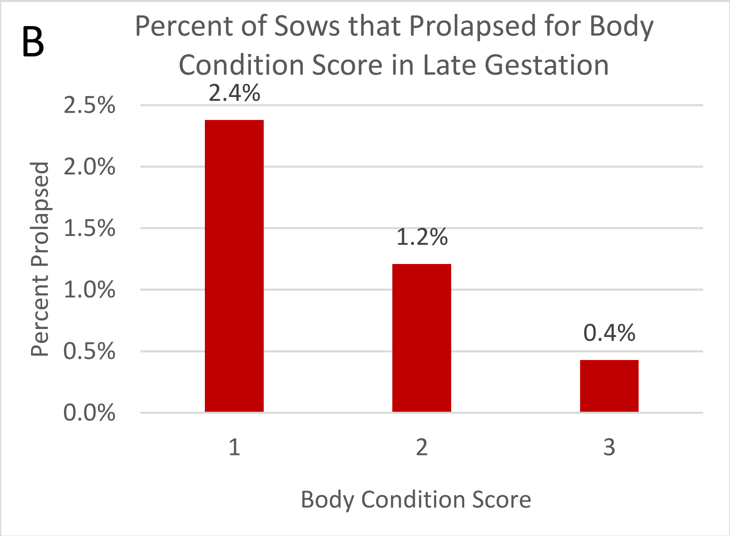


Figure 33 (above). Body condition score and POP incidence. Body condition scores were assigned using a three-point scale on 4953 sows from 62 farms. Thin sows were considered a BCS 1, normal body conditioned sows were considered a BCS 2, and overweight sows were considered a BCS 3. Average BCS was analyzed to average POP incidence from weeks 6-18 which is the time period when site visits occurred (A). When the measured sows were followed beyond farrowing, 65 of them prolapsed (1.3% of all animals scored; B). Twenty-one of the BCS 1 sows prolapsed (2.4%), 41 of the BCS 2 sows prolapsed (1.2%), and 3 of the BSC 3 sows prolapsed (0.4%).

The observation that sows with the lowest BCS had a greater probability of POP compared to sows in optimal body condition or overweight sows is consistent with our observation that feeding strategy prior to farrowing was associated with POP incidence. Specifically, farms that use a bump feeding strategy (i.e. increasing feed intake) during late gestation for sows having a low BCS had lower (Figure 34A; $P = 0.03$) POP rates compared to farms not using a bump feeding strategy. The same trend was not observed for total mortality, suggesting energy intake and/or body condition prior to farrowing has some effect on risk of POP induced mortality, however, it was observed that sow farms that used a bump feeding strategy including all sows during late gestation observed lower total mortality (Figure 34B).

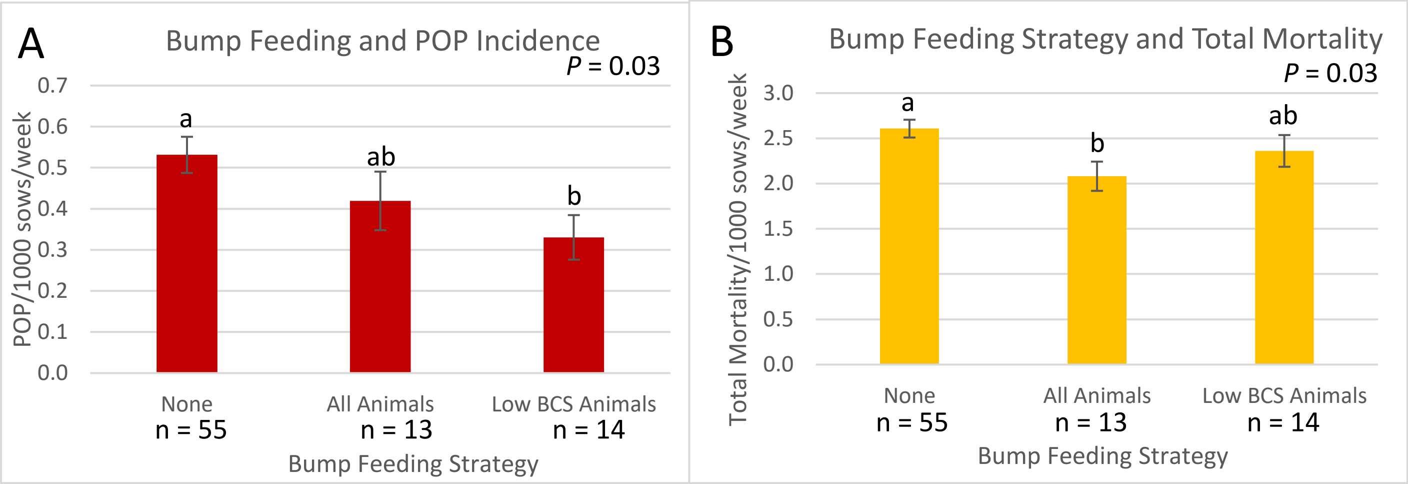
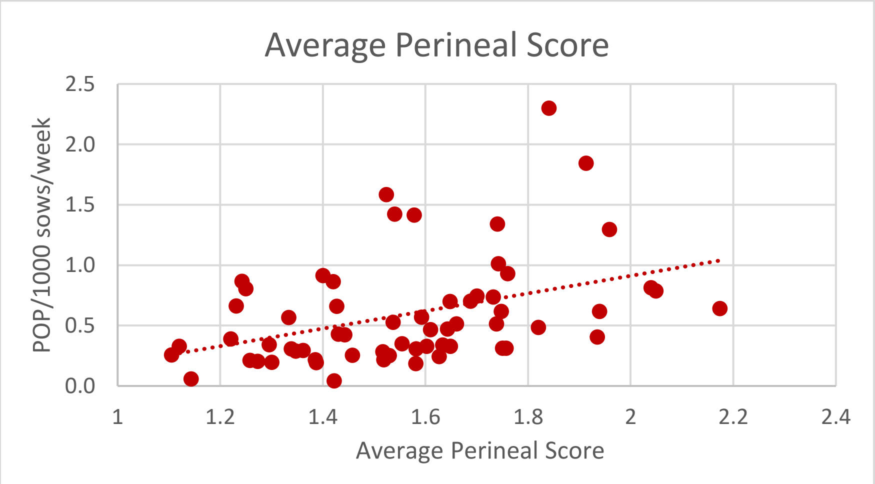


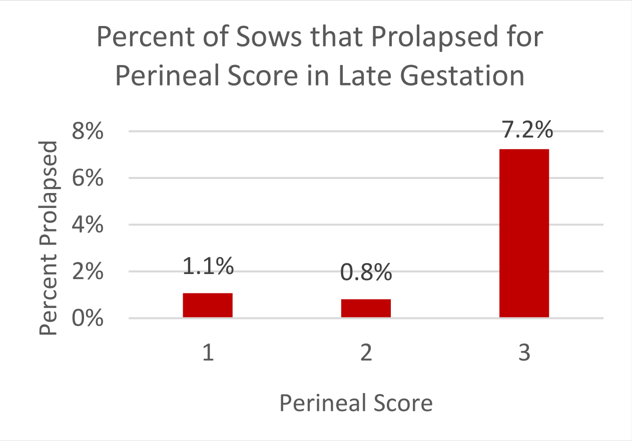
Figure 34 (above). Bump feeding strategy in late gestation and POP incidence and total mortality. Farms either did not use bump feeding, bump fed all animals, or only bump fed those considered to have a low body condition score (BCS). Average POP incidence from week 6 of 2018 to week 5 of 2019 was used for this analysis. Bars with different superscripts differ significantly ($P < 0.05$).



Perineal Score	
Number of Samples	62
Mean	1.6
Max	2.2
Min	1.1
R^2	0.16
P value	< 0.01

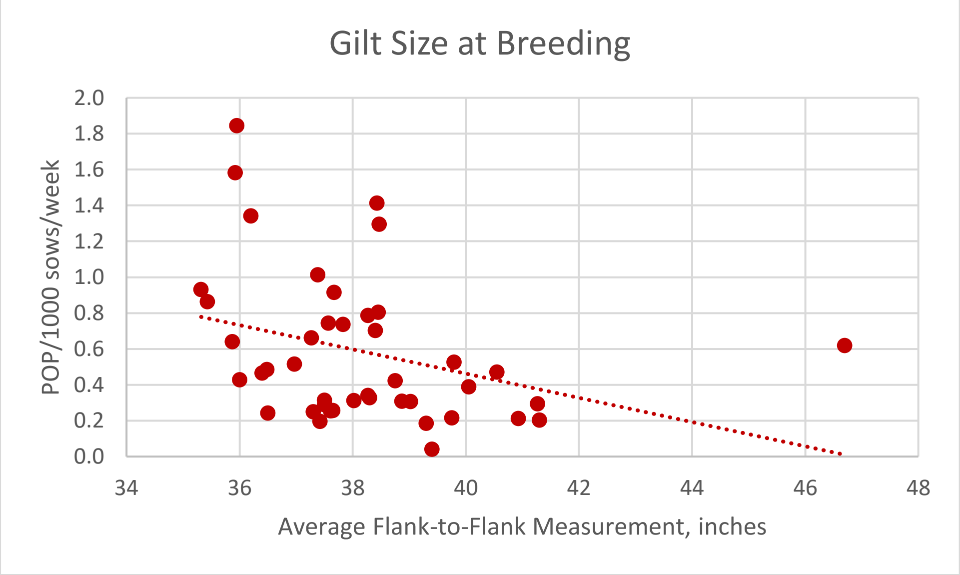
Figure 35 (above). Perineal score and POP incidence. A perineal scoring system was developed and utilized to assess potential for POP during late gestation. Individual sows in a laying position were scored with a three-point perineal scoring system depicted in Figure 1 (Score 1: a presumed low risk of POP; Score 2: a presumed moderate risk of POP; and Score 3: a presumed high risk for POP). Average perineal score for a farm was analyzed to average POP incidence from weeks 6-18 which is the time period when site visits occurred.

Figure 36 (right). Perineal score and POP incidence. A perineal scoring system was developed and utilized to assess potential for POP during late gestation. Individual sows in a laying position were scored with a three-point perineal scoring system depicted in Figure 1 (Score 1: a presumed low risk of POP; Score 2: a presumed moderate risk of POP; and Score 3: a presumed high risk for POP). Out of the 2906 animals scored, 1.1% of sows prolapsed that scored a 1 (14 of 1310), 0.8% of sows prolapsed that scored a 2 (11 of 1361), and 7.2% sows prolapsed that scored a 3 (17 of 235).



After collection of the perineal score data, it was concluded that scores taken while the sows were standing up instead of laying down did not give an accurate score, therefore, sows that were scored while standing up were removed from the analysis. Of the 4689 perineal scores taken 2906 of them were recorded while the sow was laying down. The average perineal score of the farm was positively associated with herd level POP incidence. (Figure 35, $R^2 = 0.16$, $P < 0.01$). For all 62 farms 45.1% of the sows were a perineal score 1 (n = 1310), 46.8% were a perineal score 2 (n = 1361), and 8.1% were a perineal score 3 (n = 235). Figure 36 shows the distribution of perineal scores for the sows that prolapsed after the scored sows underwent opportunity for farrowing. Of the 2906 animals scored, 1.1% of score 1 sows prolapsed (14 of 1310), 0.8% of score 2 sows prolapsed (11 of 1361), and 7.2% of score 3 sows prolapsed (17 of 235). Sows with a perineal score of 3 (high risk of POP), compared to a 1 (low risk of POP), had increased odds of having a POP by 7.2 ($P < 0.001$). This scoring system has potential to be used in further investigation to better assess the biological causes and the effectiveness of POP mitigation strategies.

Forty-three farms had gilts at breeding available for observation during the time period in which farm visits occurred. Flank-to-flank measurements were taken on approximately 30 gilts at breeding or considered eligible for breeding at each of the 43 farms conducting on-site breeding of gilts. Farms with lighter gilts at breeding, measured by flank-to-flank girth, were correlated with a higher POP incidence (Figure 37, $R^2 = 0.11$, $P = 0.03$).



Gilt Size	
Number of Samples	43
Mean	38.2
Max	46.7
Min	35.3
R^2	0.11
P value	0.03

Figure 37 (above). Herd average gilt flank-to-flank girth measurement and POP incidence. Flank-to-flank measurements (inches) were collected on approximately 30 gilts eligible for breeding or recently bred gilts on 43 farms. The average gilt size at breeding for a farm was negatively correlated to POP incidence ($R^2 = 0.11$, $P = 0.03$).

Specific Objective 3: Establish a POP-associated communication and advisory network of producers, allied industry, university faculty and staff.

We have been actively engaging the industry in open forums to provide updates and seek input. The following is a brief summary of when and where we have sought such feedback. We have also conducted individual consultations with many of our industry partners throughout the project period and will continue to do so. The following are examples of when we have distributing information and had open discussions.

Completed Outreach/Communication/Information Seeking Efforts
2-14-18: NPB Animal Science Committee Meeting, Des Moines, IA
6-5-18: Pre-World Pork Expo Nutritionist Round Table Meeting, Des Moines, IA
6-6-18: World Pork Expo, Des Moines, IA
6-12-18: Webinar with sow farm managers and industry collaborators on the project
6-28-18: Iowa Swine Day 2018, Ames, IA
7-9-18: National Pork Industry Conference, Wisconsin Dells, WI
7-16-18: Missouri Pork Swine Health Symposium, Sedalia, MO
7-26-18: NPB Animal Science Committee Meeting, Chicago, IA
7-31-18: Iowa Farm Bureau Swine Advisory Committee Meeting, Ames, IA
8-28-18: NBP Webinar
8-28-18: Carthage Annual Swine Conference, Macomb, IL
9-17-18: Allen D. Leman Swine Conference, Saint Paul, MN
10-10-18: Hubbard Feeds Swine Stretch, Columbus, NE
10-24-18: Standard Nutrition, Omaha, NE
11-1-18: James D. McKean Swine Disease Conference, Ames, IA
11-29-18: National Swine Improvement Federation, Nashville, TN
1-9-19: NPB Joint Meeting
2-18-19 through 2-22-19: Iowa Pork Regional Conferences
3-10-19: AASV Annual Meeting, Orlando, FL
4-3-19: Sow Bridge Webinar
5-20-19: NCERA-57 Multistate Meeting of Swine Reproductive Physiologists, Starkville, MS
5-24-19: Ralco Nutrition Webinar

Specific Objective 4: Establish an accessible repository of data, samples and information related to sow POP for use by the scientific communities interested in developing, providing, and evaluating mitigation strategies and solutions.

Weekly and final reports will be accessible through the IPIC website (www.ipic.iastate.edu). Fact sheets and short videos summarizing some of the information from this study as well as our future steps have been and will be accessible through the POP page of the Improving Pig Survivability project (https://piglivability.org/pelvic-organ-prolapse). When publications become available they will also be linked to our site to be accessible to the public.

IX. Discussion

Risk Factors Identified

Results from this study have preliminarily identified several aspects related to sow farm production practices and sow health that justify further investigation to pursue establishing causality of specific factors for increased POP risk so that potential mitigation strategies can be tested. Table 8 represents a categorization and prioritization of areas of investigation based on this study's results. Factors categorized as green, although causation cannot be attributed, have been identified as having significant relationships with POP incidence among these 104 farms within the context of this study. Factors categorized as yellow could have a relationship with POP incidence, but they are categorized as yellow either because the association is weaker, or our sample size was too small to detect strong statistical associations. Within the context of this project, factors in red had a low or non-existent statistical relationship to POP incidence observed. Recommendations for future research are prioritized with the green factors first, followed by the yellow factors. Red factors are not recommended as areas for future research at this time.

Table 8. Summary of information collected and suggested prioritization for future research[1].

Priority Level	Risk Factor	Page of report
Green – high priority	Water Treatment	15-16
	Body Condition	28
	Bump Feeding Strategy	29
	Perineal Score	29-30
Yellow	Antibiotic Usage	18-19
	Mycotoxins	24-25
	Feed Type	19
	Dietary Fat	21
	Dietary Nutrient Composition	22-23, 26
	Genetics	12
	Sow Housing	12
	Laxative Usage	17
	Pit Depth	13
	Gilt Size at Breeding	30
Red – low priority	Farm size	9
	Herd Level Farrowing Assistance protocols	11
	Herd Level Induction protocols	11
	Gestation Water Delivery	12
	Pit Fans	13
	AI Technique	13
	Breed Row Hygiene	14
	Wet or Dry Lactation Feed	18
	Particle size of diet	20
	Tail Length	27

[1] Surveyed factors have been divided into green, yellow, and red categories based on their prioritization for further investigation. Factors that have a relationship with POP and therefore need further investigation to establish causation are classified as green. Factors that may have a relationship with POP, but have weaker evidence based on this study are classified as yellow. Factors that don't seem to have a relationship with POP according to this study are classified as red.

Additionally, the perineal scoring system has potential to be used in further investigations to better understand the biological causes of POP and the effectiveness of mitigation strategies employed to reduce POP. It can be used to gain a larger pool of individual sows for biological samples since POP incidence, while a significant issue in the industry, still has a relatively low incidence rate. This makes it difficult to detect statistical differences during shorter term, intensively controlled studies. By using the perineal scoring system to identify sows at risk for POP, we may be able to identify associated factors and implement mitigation strategies before POP occur.

Limitations of the Data Set

This observational study, which used descriptive statistics to identify trends for further specific hypothesis driven research, is unable to assign causation of any measured factor to the incidence of POP. Due to the nature and scope of the study, the recruitment of farms was based partially on historical POP incidence to include a wide variation of POP incidence among farms, therefore, the farms were not balanced for management system, genetics, sow housing, or other management factors. Even though system was included in the statistical model as a covariate, a system bias could still be present in the data as this is difficult to fully account for. This resulted in limited number of herds for some variables and will warrant further investigation. Additionally, future studies further investigating causality or testing potential mitigation strategies may be best served if contained within a specific management system which would contain fewer variables (i.e. genetic source, diet formulations, etc.) Additionally, some values which were collected during a site visit (i.e. breeding row manure coverage and feed sampling) may not be fully representative of those farms on yearly basis.

In some portions of this report, POP rates were annualized to align with industry standards of data presentation. Whole farm averages of certain factors could also mask what is happening with those animals that actually prolapse. It is quite possible that prolapses occur more frequently in the tails of a normal distribution instead of the middle of the bell-shaped curve for some factors (i.e. farrowing assistance and induction strategies). The average incidence of POP over time could also mask what is occurring in farms where POP occurs in spikes (a low incidence most of the time with an occasional dramatic increase in POP incidence). Continued evaluation of the data coupled with additional research projects will continue to further define and prioritize risk factors likely contributing to a greater incidence in POP in the farms evaluated in this study.

Future Directions

This project supports the concept of building an ongoing collaboration with commercial farms from multiple production systems across the US swine industry for field research allowing comparisons within and between production systems. The IPIC team will continue to build a network of interested experts and reliable sow farm managers as we take the next steps in understanding causative factors of POP in sows. Increased POP is a welfare and economic issue in today’s industry; this survey allowed benchmarking of the current situation, and identified some potential causative factors. Moving forward, experiments will be designed to test specific hypotheses generated from the knowledge and new information acquired from this survey to validate causality of POP and test mitigation strategies. Input and collaboration from the established network of industry partners will be invaluable as experiments are designed for this complex issue, as they must be conducted in commercial conditions where POP are occurring. Some experiments will be conducted at the herd level while other individual animal level experiments will include intensive biological sample collection and analysis. The partnerships with sow farm managers across the country will be essential in maintaining high quality data that can be used to clarify our understanding of the root causes of POP.

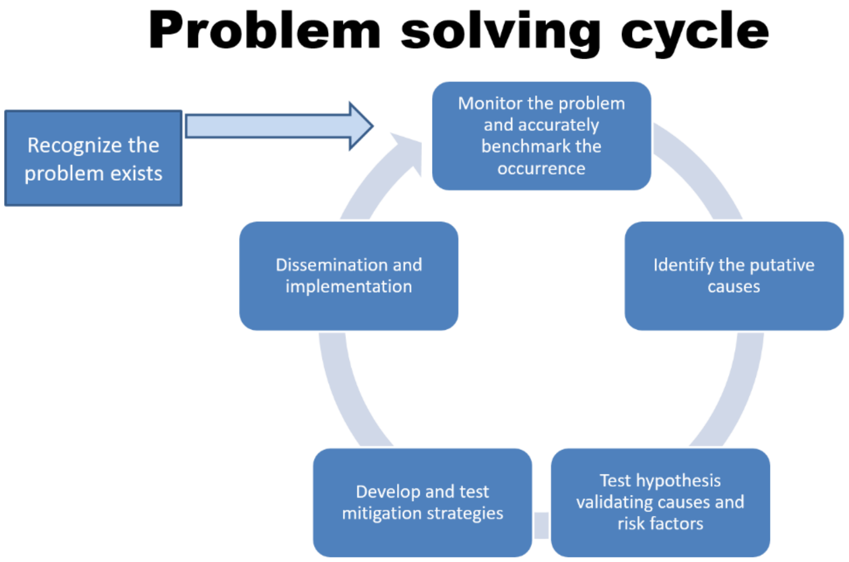


Figure 38. Problem solving cycle used in the pursuit of reducing POP incidence.

Acknowledgements

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References

1. Supakorn, C., Stock, J. D., Hostetler, C. & Stalder, K. J. Prolapse Incidence in Swine Breeding Herds Is a Cause for Concern. *Open Journal of Veterinary Medicine* 15