**Title:** Capturing genetic potential for greater sow lifetime productivity -
NPB #: 14-149, 15-140, 16-148 and 17-139

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**Co-Investigators:**
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- Dr. Robert Knox – University of Illinois

**Project Manager:** Jennifer Patterson

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**Note on format:** The four-year project described below was completed under a multi-year funding agreement with the NPB and constituted a Preliminary Phase 1 Trial, followed by the Main Phase 2 Trial. Two specific objectives were also met through collaborative research with North Carolina State University and with the University of Illinois. Each component of the overall project is, therefore, presented in sequence, followed by a brief overall discussion of the results and industry implications.

**Industry Summary: Preliminary, Phase 1, Trial (#14-149 and #15-140)**

1. **Objectives:** The specific objectives of the Preliminary (Phase 1) Trial included:

   i) Describing a repeatable sow birth weight phenotype as the basis for studying the impact of gilt “litter of origin” on sow lifetime productivity (SLP)

   ii) Identifying appropriate early selection strategies for potential replacement gilts

   iii) Validating efficiencies of using purpose-designed facilities for puberty stimulation and heat detection, and key intervention strategies (PG600) to reduce gilt non-productive days
2. **How research was conducted:** The research built on existing collaborations between Holden Farms Inc. (HFI), university-based research groups, and Genus/PIC to identify and validate key management strategies that will allow producers to capture more of the existing genetic potential for excellent SLP. There is compelling evidence that “litter of origin” has a critical impact on developmental potential and SLP. “Litter of origin” effects include the genetic merit (G) for reproductive performance inherited from the sire and dam, plus “environmental effects” (E) of the particular dam and litter that pre-program lifetime growth potential and reproductive performance. The first step in linking litter of origin to SLP was to establish a repeatable birth weight phenotype over three successive parities in Line 3 sows in the production nucleus/multiplication population of HFI. Ultimately these Line 3 sows were bred to produce the Camborough replacement gilts for which lifetime data were collected in the Main Trial.

However, in their earlier parities some L3 sows were bred to produce L3 replacement gilts for which litter data was routinely recorded in the nucleus/multiplication herd and for which gilt retention information could be captured. This allowed to opportunity to conduct some preliminary analyses on the link between “litter of origin” and gilt retention.

Based on the extensive experience of the research team in the use of designated Gilt Development Units (GDUs) that incorporate purpose designed Boar-Estrus Stimulation Areas (BEARS), a previous collaboration with HFI had been implemented to standardise GDU/BEAR protocols in an off-site GDU and extensive data had been captured for further analysis. Therefore, the Preliminary (Phase 1) Trial also provided the opportunity to validate the impacts of final gilt selection protocols and pre-breeding management on SLP in a large commercial system. To the benefit of the developing NPB study, the proven and standardized programs of gilt selection and pre-breeding management were then implemented across the HFI GDUs and sow farms receiving “litter of origin” gilts to allow the impacts of gilt “litter of origin” on SLP to be determined.

3. **Research findings:**

3.i. **Extensive collection of data on litter birth weight phenotypes** was a key part of the Preliminary Phase Trial and involved weighing successive litters born to over 1,000 Line 3 sows.

- Repeatability of litter birth weight phenotype was confirmed and four litter birth weight phenotypes were established for SLP analysis.
- Sows with the Low and High birth weight phenotypes, respectively, represented approximately 15% of the overall sow population.
- A repeatable birth weight phenotype was established, irrespective of the total number of pigs born, confirming that increased sow prolificacy is not the principal cause of low birth weight offspring.

3.ii. **Preliminary analysis of litter of origin effects on gilt selection programs suggested:**
• Large variations in the proportion of gilts selected from particular litters.
• Using existing selection criteria, in some 15% of litters born, between 50 and 75% of gilts are designated as “non-select” at weaning or around 140 days of age, on the basis of relatively poor growth performance. Our prediction is that these gilts are born to sows with a repeatable low birth weight phenotype.

3.iii. Validation and application of efficient programs of gilt selection and pre-breeding management. Data collected included information on vulval development scores, observed standing heat, and estimated weights on over 3,000 naturally cyclic gilts and on over 1,000 gilts that were induced to cycle using PG600 treatment. Outcomes included:

• Standardized protocols for gilt exposure to boar stimuli and remixing.
• Standardized protocols for the efficacious use of PG600 to induce pubertal estrus.
• Objective scoring of gilts responses using wall charts and data recording sheets.
• Demonstrated value of moving gilts to breeding farms based on a recorded “heat-no-serve” event, and at a recorded weight, followed by controlled pre-breeding management programs.
• For naturally cyclic gilts, excellent breeding and farrowing rates were recorded and retention to parity 3 was above industry benchmarks.
• PG600-induced puberty was associated with slightly lower percentages of gilts bred and farrowing but still resulted in excellent retention to parity 3.
• Standardized protocols at the GDU and breeding farm were established that optimized the chance of linking “litter of origin” traits to differences in SLP.

4. Industry implications

4. i. An established and repeatable litter birth weight phenotype.
• Allowed the possibility in the Main Trial of establishing links to gilt retention and SLP.
• If negative consequences of a low birth weight phenotype were established, knowledge of sow birth weight phenotype at production nucleus level could be used as the basis for effective culling strategies.

4. ii. Gilt selection efficiency:
• Retention of sows producing relatively few replacement gilts in the nucleus/multiplication farm leads to inefficiencies in replacement gilt production and genetic transfer to the terminal-line level of production.
• One possibility is to designate complete litters as “non-select” at processing on the basis of a low litter average birth weight. Additionally, Line 3 sows with a repeat low birth weight phenotype could be aggressively culled and not used to generate Line 3 replacements at production nucleus level, or Camborough replacement gilts at multiplication level.
• However, data from other recent NBP SLP trials demonstrated that growth performance of most gilts met the minimal lifetime growth requirement (0.55 kg.d) for early
attainment of pubertal estrus, begging the question whether lower birth weight gilts should actually be designated as “non-select” on the basis of relative size.

- Linking the complete range of litter birth weight phenotypes to gilt selection rates and SLP will, therefore, be a critical outcome of the Main, Phase 2, Trial.

4.iii. GDU and pre-breeding management

- Well managed GDU/BEAR facilities and good protocol compliance allow up to 80% of gilts entering the GDU to be identified as “breeding eligible” (known HNS and weight) before moving to the sow farm.
- These targets can be met in a 28- to 30-day selection program.
- Meeting these targets minimizes gilt non-productive days (entry-to-service intervals), results in excellent breeding and farrowing rates at parity 1, and excellent retention to parity 3.
- Implementing a high quality GDU/pre-breeding program is the major first step to achieving NPB targeted improvements in SLP.

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Keywords: Litter of origin; birth weight; gilt selection; sow lifetime productivity.

Scientific Abstracts (See specific sections i, ii and iii below)

General Introduction:

One of the most critical factors driving the reproductive performance of the sow herd is gilt development and management of the first parity sow. Large variation exists with respect to the successful introduction and retention of high value replacement gilts into the herd (Culbertson, 2008). On average, approximately 50% of sows are culled and replaced every year and wean only 30 to 40 piglets per lifetime. Furthermore, nearly 20% of premature culling of females from the breeding herd occurs at parity 0, with 65% of these culls attributed to reproductive disorders or failure (Engbom et al., 2008; Gill 2007; PigChamp 2006; Lucia et al. 2000: Stalder, 2012).

Developing management practices that produce gilts with the greatest potential lifetime performance is crucial to the productivity of conventional production systems. Even minor improvements in gilt management can lead to major increases in breeding herd efficiency by meeting replacement targets from smaller pools of “select” gilts with improved lifetime performance.

Measuring the variation in the growth and sexual maturity of replacement gilts has received increasing attention and has led to definitive studies in both North and South America that have indicated minimum growth requirements (0.5 kg per day to the time of boar contact) to prevent any delays in estrus onset due to growth limitations. The implementation of the “Magic
The “42 days” concept from Chile and the development of purpose built BEAR systems for Gilt Development Units (GDUs) recognize the value of having a properly implemented system of final gilt development and pre-breeding management. These systems, linked to rigorous recording of sexual development and estrus behavior, are equally critical to executing effective studies on the links between gilt development and SLP. Additionally, at commercial production level, there is increasing evidence for “environmental effects of the dam” on the performance of her progeny. Effects on the survivability and growth of terminal line offspring are likely mirrored in similar “litter of origin” effects on replacement gilts and boars and preliminary evidence to support this concept is available.

The literature supporting these ideas is presented below as the basis for developing a second major NPB sponsored study on SLP that focuses on “litter of origin” as a key driver of variability in SLP. Defining and managing these effects will make a major contribution to achieving the goals of the SLP initiative. The earlier part of this review builds on a previous presentations on the topic of gilt development (Foxcroft et al., 2006a,b; Patterson et al., 2008).

**Sow Lifetime Performance.** Sow productive lifetime can be defined both at the sow and herd level (Holtkamp, 2007). Measures of longevity at the sow level include parity at removal, days in herd at removal, lifetime pigs born or weaned and percent productivity. At the herd level, removal rate, culling rate, replacement rate and parity distribution are good measures of longevity. Heritability of sow longevity is low to moderate at best (Stalder et al., 2007). Therefore, improvements to sow longevity must be made by other means and this paper will focus on management practices that improve longevity.

One of the most critical factors driving sow longevity and reproductive performance of the sow herd is gilt development and management (Foxcroft et al., 2006). Producers should set high targets with respect to anticipated gilt performance. Realistic performance targets should be >86% farrowing rates (highest in the herd), >12.5+ total born, >70% of gilts served farrowing the 3rd litter, no “2nd parity dip”, and >50 pigs weaned lifetime (Sporke, 2006). The successful introduction of select gilts is generally associated with improved retention of high value replacement females in the herd (Culbertson, 2008). Implementation of effective gilt pool management strategies will also:

- Improve utilization of building space
- Improve flow of “eligible” gilts
- Increase efficiency of labor
- Achieve body condition at first service
- Reduce annual replacement rates
- Achieve desired physiological targets at first service
- Improve long term sow fitness
- Maintain economic efficiency of a small gilt pool

The trend towards larger breeding sow herds seems to be decreasing the efficiency of breeding herd management. PigChamp data for 2006 showed that on larger breeding sow farms in the USA and Canada, annual herd replacement rates were often between 60 and 70%, with a number of important consequences:

- A larger pool of replacement gilts is needed to meet increased replacement requirements.
• Suboptimal gilts are bred to meet breeding targets; they have lower performance and will be prematurely culled.
• Breeding herd parity distribution is unstable and biased towards lower parity females.
• Chronic over-crowding of pens in the gilt development area is needed to meet replacement needs
• Negative impacts on health and welfare result.
• Pressure to meet breeding targets results in less fertile gilts being bred using pharmacological interventions.
• Gilts are bred below target weights.
• General performance and morale of GDU staff declines and staff retention is low.

Longevity, in terms of parities in production, is also maximized in females that were initially mated at a younger age. Gilts initially bred > 10 months of age were less efficient, produced fewer pigs born alive lifetime, were culled sooner and showed a negative economic return over their economic lifetime (Culbertson and Mabry, 1995). Typically, most sow removals occur in the lower parities (ranging from 3.1 to 4.6), are unplanned, and primarily due to reproductive failure; only a smaller proportion of culls are due to lameness and/or locomotive problems (Engblom et al., 2007). At least three parities (potentially five, depending on the herd) are required from a sow before there is positive cash flow to a producer (as reviewed by Engblom et al., 2007). Koketsu (2005) investigated relationships between herd age/parity structure and productivity in breeding herds. In this study sow herds were classified based on their parity structure stability as measured by the percentage of parity 0 and parities 3-5 in the herd. Herds that were considered stable, outperformed those herds that had high fluctuations in parity structure, stable herds had more pigs weaned per year, fewer NPD, higher farrowing rate, fewer gilts on inventory, lower replacement rates and a higher parity at culling.

Overall Project Objectives:

The key mission identified for the NPB Sow Lifetime Productivity (SLP) initiative was “To conduct research, identify key controlling factors, and develop new technologies to improve the SLP productivity of the US swine industry, resulting in a 30% improvement in the average lifetime productivity in the US sow herd.”

Recommended areas of research concentration identified by the NPB advisory groups were:
1) Increase sow life in the herd through focused research on increasing average number of parities per sow and decreasing herd fall-out in the early parities.
2) Increasing number of pigs weaned through improved litter size at birth and decreased pre-wean mortality.
3) Optimized gilt development to increase lifetime productivity

The present research proposal built on an existing collaboration between Holden Farms Inc., university based research groups and Genus/PIC to identify key gilt selection strategies and breeding herd management practices that capture more of the existing genetic potential for
excellent SLP. The project provided extensive data on the following aspects of SLP:

1. Litter of origin as a key factor determining SLP
2. Rearing environment of targeted replacement gilts as a key component of improved SLP
3. Efficiencies of using a purpose designed BEAR system for puberty stimulation and heat detection
4. Effectiveness of key intervention strategies (PG600) to reduce gilt NPD in the breeding herd
5. The physiology and management of “silent estrus” in gilts
6. Key strategies to optimize first litter performance as a key factor in SLP
7. Key strategies to maximize retention of weaned first parity sows
8. Key strategies to reduce post-natal mortality in predicted low birth weight litters

General Materials & Methods:

The above overall objectives were met against a background of research experience in the use of designated Gilt Development Units (GDUs) that incorporate purpose designed Boar-Estrus Stimulation Areas (BEARS). Another key driver of the approach taken was compelling evidence that “litter of origin” would have a critical impact on gilt developmental potential and SLP. Project implementation involved expanded collaborations centred on the tagging of gilts with a known “litter of origin” in the sense of being born to nucleus/multiplication sows with an established litter birth weight phenotype. Gilts born to these sows then flowed through purpose-built GDUs within the Holden Farms system that optimized the management of gilt exposure to boar stimuli and breeding of gilts based on a recorded heat (Heat-No-Serve; HNS) event. Data collected at final selection included an observed standing heat and a weight at HNS. The aim was to have some 3,240 bred gilts “recruited” to the project over a 15-month period for which data on “litter of origin”, growth performance, age at first heat, etc., was available and for which SLP would be available up to at least third parity within the three-year period of the Main Trial.

IV.i Scientific Abstract:

Determining birth weight phenotype in a sow population.
G. Foxcroft1, J. Patterson1, N. Holden2, T. Werner2, M. Allerson2, E. Triemert2, L. Bruner3, J-C Pinilla4, University of Alberta1, Holden Farms Inc.2, Swine Vet Center3, PIC4.

ABSTRACT: Decades of selection for increased litter size has resulted in a population of sows with an extreme low average litter birth weight phenotype (ALBW_P), irrespective of litter size. We hypothesize that this phenotype is the result of poor placental development driven by extreme intra-uterine crowding of embryos in early gestation and involves an interaction of reproductive traits that are not responsive to current selection practices. However, measuring and managing this sow-dependent phenotype at production nucleus level would improve overall breeding herd efficiency and the number of quality weaned pigs per sow lifetime. In a NPB-funded project designed to test this concept, individual piglet weights (n = 47,338) were recorded in litters born to parity 1 - 7 multiplication sows producing Camborough replacement gilts (n = 1097; PIC). ALBW_P was determined over at least two successive parities for litters with >9 total born. Sows
(n = 651: mean ALBW_P = 1.36 kg) were then classified as having a low (L, < 1.15 kg, n=63), low-medium (LM, ≥1.16 to ≤ 1.36 kg, n=281), medium-high (MH, > 1.36 and ≤ 1.6 kg, n=254) or high (H, > 1.6 kg, n=53) ALBW_P based on their successive litter records.

**IV ii. Scientific Abstract: Preliminary results (Line 3 gilts).**

Efficiency of replacement gilt production is affected by litter birth weight phenotype. G. Foxcroft1,*, J. Patterson1, N. Holden2, T. Werner2, M. Allerson2, E. Triemert2, L. Bruner3, J. C. Pinilla4, 1University of Alberta, Edmonton, Canada, 2Holden Farms Inc., Northfield, MN, 3Swine Veterinary Center, St. Peter, MN, 4PIC, Hendersonville, TN.

The successful selection for increased litter size has resulted in an overall decrease in litter average birth weight (LBW). However, irrespective of litter size, a genotype x environment interaction has also been reported to result in a repeatable low LBW phenotype in a subpopulation of mature sows. In the preliminary phase of a National Pork Board-funded project to investigate links between LBW phenotype and sow lifetime productivity (SLP), conducted in collaboration with Holden Farms Inc., LBW was determined in parity 2 to 4 PIC Line 3 sows in a commercial genetic nucleus population (n = 1150). Excluding sows with a total born (TB) of < 7 and > 20, TB was negatively correlated (P < 0.0001) to LBW [LBW = – 0.037 (TB) + 1.87, R² = 0.20], representing a 500 g difference between the smallest and largest litters. In contrast, the variation in LBW among litters with the same TB was greater (mean = 950 g, range 600 to 1400 g). Sows with 2 consecutive parity records (n = 183, to date) were classified as having a repeatable low (LLBW, n = 24) or high (HLBW, n = 28) LBW phenotype, if LBW fell 1 standard deviation below or above the population mean, respectively, and a repeatable medium (MLBW, n = 131) phenotype for intermediate weight litters. Overall, there was a significant correlation between LBW measured at consecutive farrowings (r = 0.4; P < 0.0001). Furthermore, supporting previous results, no sows first giving birth to a LLBW litter produced a HLBW litter at the next farrowing. An extreme LLBW phenotype is, therefore, repeatable and predictable within sows. Considering L3 sows bred to produce replacement L3 gilts in the nucleus population, preliminary analyses identify entire sets of littermate gilts that are subjectively designated “non-select” at weaning or at the preselection stage on the basis of being “small” or “thin”, suggesting that a LLBW phenotype has a major impact on the efficiency of replacement gilt production. Further evidence to substantiate the hypothesis that “a repeatable low LBW phenotype will negatively impact the production of selectable replacement gilts at nucleus and multiplication level” will continue to be a major component of this ongoing collaborative study.

**V. i and ii. Introduction:**

Litter birth weight phenotype. The successful selection for increased litter size has resulted in decreased birth weight of piglets and an increase in within-litter variation in piglet birth weight (Quiniou et al., 2002). As reviewed by Foxcroft et al. (2007) and shown in Figure 4 from Smit (2007), very large litters born to the most prolific sows will consistently show a lower litter average birth weight phenotype than that seen in the best sows with between 10 and 15 pigs total born.
However, even across the whole range of litter sizes, the total number of pigs born explains only a small part of the variation in litter average birth weight ($R^2 > 0.2$). In litters of 10 to 15 total pigs born, although litter average birth weight can be 2 kg or higher, the variation in litter average birth weight between litters in this population (as high as 1 kg) is even greater than the variation of individual birth weight within litters (600 to 800 g). Furthermore, the number of pigs born between 10 and 15 accounts less than 5% of the variation in litter average birth. This means that other mechanisms must play a role in determining the low litter average birth weights seen in mature sow populations. Litters with a low average birth weight had more piglets born dead, and higher pre-weaning mortality, than did litters with a high average birth weight. As a result, the number of piglets weaned per litter was 1.35 piglets lower in litters with low average birth weight compared to litters with high average birth weight, even though total number of pigs born was similar between the two groups. This shows that piglets from low birth weight litters were weaker overall and need to be a real focus for management interventions in commercial units.

Low average birth weight (LBW) litters, especially in higher parity sows, are hypothesised to be the result of a cascade of pre-natal events, starting with high ovulation rates (>25 ovulations) and reasonable to good embryonic survival. This leads to intrauterine crowding (IUC) in early gestation and limited placental development day 30 of gestation onwards, which then leads to measurable effects on fetal development by d50 of gestation (reviewed by Foxcroft et al, 2007, 2009, 2012). Fetal reprogramming due to IUC results in a change in the number and type of muscle fibers, influencing the growth rate potential of piglets after birth (see reviews of Foxcroft et al., 2006c; Rehfeldt and Kuhn, 2006). As a higher proportion of LBW piglets will be present in litters with a low average birth weight, these litters are expected to make the biggest contribution to lightweight offspring with a compromised growth rate after birth. The lower individual birth weights are also associated with lower organ weights, and higher brain:organ weight ratios as measured in still-born littermates (Smit et al., 2013a). With respect to post-natal growth performance of terminal line progeny, Smit et al. (2013a) reported significantly poorer growth performance in gilts and barrows from LBW litters, as reported in previous studies for low birth weight pigs drawn from within litters. Based on data from multiplication level dams and litters (Harding, Foxcroft and Patterson, unpublished), similar effects of low litter birth weight can be anticipated in gilts recruited from low birth weight litters from pure bred females. However, these associations need to be verified in a larger scale study. A critical question here is whether gilts that are not “pre-selected” for further development as breeding herd replacements are actually largely originating from the litters of mature pure-line dams that show a repeatable LBW phenotype (see below). The study of Smit et al. (2013a) did demonstrate negative impacts of the low birth weight litter on testicular development measured in male offspring at the time of castration, which would be expected to limit sperm production of these boars at maturity and data showing such relationships has been reported by Flowers (personal communication). Similar prenatal programming effects on ovarian development and lifetime reproductive performance in the female would also be expected to go beyond the simple question of lower birth weight and growth performance.

**Repeatability of litter birth weight phenotype within sows.** As a general rule, most sows giving birth to a LBW litter, again give birth to a LBW or at best medium BW litter at the next farrowing. No sows with LBW litters subsequently gave birth to HBW litters (Smit, 2013: Smit et al., 2103a).
Similarly, only one of the populations of HBW described in the successive studied of Smit et al. (2013a,b) moved to the LBW category at the next farrowing. Together with the observations that the correlation coefficient is reasonably high ($r=0.49$ for the later farrowings), it can be concluded that litter average birth weight is repeatable, and thus predictable, within sows. These results are again consistent with analyses based on a population of commercial multiplication level sows in Canada (J. Patterson, personal communication and unpublished data). Finally, a working visit to Tempel Genetics, a swine genetics company located in Indiana, USA, provided Miranda Smit (Smit, 2013 in General Discussion section) the opportunity to calculate repeatability of birth weight in a dataset collected for about 1.5 years and including information of 1,465 purebred sows, of which 278 survived to parity 8. The correlation coefficients for the first 4 parities were as follows; $r=0.68$ for parity 1 vs. 2, $r=0.74$ for parity 2 vs. 3, $r=0.72$ for parity 3 vs. 4, $r=0.65$ for parities 1 and 2 vs. 3, $r=0.70$ for parities 1, 2 and 3 vs. 4, and $r=0.71$ for parities 2 and 3 vs. 4. All correlation coefficients were highly significant ($P<0.001$). These correlation coefficients were much higher than those observed in the studies of Smit et al. (2013a,b) in terminal line sows and litters and suggests that repeatability of litter birth weight may be even higher in purebred sows than crossbred sows. The data also show that, as having information of more parities did not improve the correlation coefficient in purebred sows, it should be possible to predict litter birth weight phenotype in purebred populations based on one or two litter records.

The practical implications of a predictable LBW litter phenotype for SLP are of immediate interest. At nucleus level, LBW litters will lead to a low selection of gilts from these litters as replacements, either because the gilt fail to meet growth requirements, or because being born in a LBW litter will also have a negative impacts on reproductive performance in the gilt, independent of growth related effect.

VI.i and ii. Objectives:

Collection of litter phenotype data from L3 sows in the nucleus/multiplication farm and implementation of individual gilt ID and tissue (DNA) banking. This Preliminary, Phase 1, Trial identified “litter of origin” for gilts entering the GDU program (meeting the first essential part of Objective 1). Available data on the fate of pure bred Line 3 replacement gilts within the production nucleus also allowed some preliminary consideration of “litter of origin” effects on gilt retention rate, also contributing to Objective 1.

VII.i and ii. Materials & Methods:

The study was performed in accordance to the guidelines of Pork Quality Assurance Plus® and Holden Farms Inc. ethical guidelines and with approval of the Faculty Animal Care and Use Committee-Livestock University of Alberta. The primary study location was the production nucleus multiplication farm ($n=2,400$ sows) of Holden Farms Inc.(HFI) located in Northfield, Minnesota, USA and associated down-stream gilt development units and commercial sow farms within the HFI system. The study was initiated in March 2014.

Data collected in the preliminary phase of the study were used to establish a repeatable sow litter birth weight phenotype (LBWP) using a similar approach to that described by Smit et al. (2013).
Nucleus Line 3 (L3) sows (PIC, Hendersonville, USA) ranging between parity 1 and 3 were initially allocated to trial. Within 24 hours after birth and before cross-fostering, Sow ID, parity, date of birth, total number of piglets born, number of piglets born alive, number of stillborns, and the individual birth weight and sex of all pigs born were recorded. The same measurements were taken at every subsequent parity during the experimental period and as long as the sow remained in the herd (1 to 5 consecutive litter measurements taken). Litter data were recorded irrespective of the litter sire (either a Line 3 boar for the production of L3 replacement gilts within the production nucleus, or Line 2 boars at the production multiplication level to produce potential Camborough replacement gilts for commercial production). Cross-fostering between litters was kept to a minimum and completed within 16 hours of birth. Day 1 care involved drying each piglet at birth and adherence to split-suckling protocol to ensure colostrum ingestion of piglets at birth. Litters were standardized managed according to standard herd operation procedures. The data collected over three consecutive farrowings were used to establish the sow’s LBWP.

Within 24 hours of the birth of the third or subsequent litters (at which time a sow LBWP had been established), all live potential Camborough replacement gilts were individually identified with an ear tag in both ears. Extensive protocols were implemented to enable tracking of individual gilts from birth to culling. From birth to the end of the nursery stage of the commercial replacement gilt production gilts were tracked within PICtraq® (PIC) and from nursery exit to culling with Porctec (Agritec Software, Barcelona, Spain). At the time of death or non-selection as a replacement female, ear tags were removed and the reason for culling or non-selection was recorded. Records were continually monitored to ensure all gilts were accounted for.

At weaning, agreed experimental protocols stipulated that all healthy gilts should be transferred to the nursery, irrespective of apparent differences in weaning weight. After weaning, selected gilts were relocated to the nursery facility and pen-housed groups of 16-20 gilts on plastic flooring in 2.7 x 5.5 m pens, providing 1.5 to 1.8 m² per animal, where they remained for approximately 6 to 7 weeks. All females were reared using industry standard protocols, and fed a developer diet ad libitum. At approximately 70 days of age gilts identified for this study were transferred to one of seven on-farm gilt rearing facilities. Again, acceptable criteria for culling or non-selection using visual appraisal at nursery exit (Pre-selection1) were: under condition, hairy, ruptures and extreme runts but not relative growth performance. During the rearing phase gilts were housed in group pens of 18 to 30 gilts on fully slatted floors until “Pre-selection 2” at approximately 170 days of age. Acceptable non-selection criteria at this stage included structural soundness and underline characteristics, in addition to criteria used at the Pre-select 1 stage. All pre-select gilts were then considered to be on inventory within their respective GDUs and received an HFI production ID tag that was cross-referenced to the birth ID. Gilt acclimation and vaccination programs followed standard HFI protocols and included vaccination against reproductive pathogens (porcine parvovirus, leptospirosis, and Erysipelothrix rhusiopathiae), porcine circovirus type 2, influenza A virus, and for specific farms may have included reproductive and respiratory syndrome virus.

Statistical analyses: Individual gilt birth weight (BWi), as a continuous variable, was used to determine the predicted probability for mortality at four days of age using logistic regression models in SAS (GLIMMIX procedure) and birth dam, parity of birth dam at birth and total number
born in the litter of origin, were used as random variables in the model. The predicted probabilities were used to obtain Receiver Operating Characteristic curves – ROC curves (LOGISTIC procedure). The optimal cut-off value for predicting mortality within 4 days of birth for BWi was determined. Model accuracy was assessed by calculating the area under the ROC curve (AUC) and interpreted as per Greiner et al. (2000). The optimal cut-off was used to create four classes according to average litter birth weight (ALBW).

Average litter birth weight (ALBW) was determined by averaging BWi for all pigs born in the litter (born live and stillborn). Litter sizes recorded in the experimental records and in the sow farm database were compared for consistency and litters were only designated for inclusion in any further analyses when the two records fell within 15% of each other. Taking account of the critical threshold for mortality described above, sows producing potential replacement gilts (n = 644: overall mean ALBW = 1.35 kg), and that had at least two successive litters with >10 total born, were retrospectively classified into four ALBW_Ps based on their successive litter records, viz: a low (L, < 1.18 kg, n=63), low-medium (LM, ≥1.18 to ≤ 1.35 kg, n=281), medium-high (MH, > 1.51 and ≤ 1.51 kg, n=254) or high (H, > 1.6 kg, n=53) ALBW_P. The extreme phenotypes represented approximately 15% of the total population.

Using additional data collected during the Preliminary Trial, a preliminary analysis of selection outcomes for pure-bred replacement gilts was completed.

**VIII.i Results:**

Overall, the individual BW of pigs born (n = 45,523) over 1 - 7 parities (n = 3,244 litters) were used to determine the birth weight phenotype in multiplication sows (n = 644; PIC) producing Camborough replacement gilts (n=7644) (Table 1).

**Table 1.** Summary statistics of measured traits of the birth sow used to determine phenotypic classifications.

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<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual piglet weight (kg)</td>
<td>45,523</td>
<td>1.34</td>
<td>0.34</td>
<td>0.23</td>
<td>2.80</td>
</tr>
<tr>
<td>Individual litter data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average litter birth weight (kg)</td>
<td>3,244</td>
<td>1.37</td>
<td>0.23</td>
<td>0.68</td>
<td>2.54</td>
</tr>
<tr>
<td>Average total born</td>
<td>3,244</td>
<td>14.5</td>
<td>3.5</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Sow litter phenotype¹,²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight phenotype (kg)</td>
<td>644</td>
<td>1.35</td>
<td>0.16</td>
<td>0.86</td>
<td>1.96</td>
</tr>
<tr>
<td>Average total born within phenotype</td>
<td>644</td>
<td>14.7</td>
<td>1.6</td>
<td>10.3</td>
<td>21.0</td>
</tr>
</tbody>
</table>
To calculate sow average litter birth weight phenotype, only sows that had at least two consecutive litter measurements with >10 total born were used.

To determine ALBW_P classifications, the best cut-off point estimation for individual gilt BW for mortality at 4 d after birth was 1.18 kg (AUC = 0.76%; P < 0.0001). ALBW for all litters weighed was 1.37 ± 0.23 kg (mean ± SD). Across all litter sizes born, there was a negative relationship between litter size (total pigs born) and ALBW (y = - 0.033x + 1.84, R² = 0.24, P<0.0001), representing a 600 g difference between the smallest and largest litters (Figure 1). In contrast, the variation in ALBW among litters with the same total born was greater (mean = 1200 g, range 900 to 1500 g). As litter size increases, there is an increasing lack of high birth weight litters due to increased prolificacy. As shown in Figure 1, the litter average birth weights of the most prolific sows with more than 20 total pigs born are lower than the population average litter birth weight of 1.37 kg. In contrast, across the entire range of litter sizes from 10 to more than 20 pigs total born, there is a population of sows that have low birth weight litters that cannot be attributed to prolificacy in the sense of total pigs born.

ALBW_P was established for a total of 644 sows with data from at least two successive parities and with litters with >10 total born (overall mean ALBW = 1.35 ± 0.16 kg (mean ± SD). These sows produced a total of 7,664 live replacement gilts that were individually tagged. Overall, L and H ALBW_P sows represented 13.4 and 14.6%, respectively, of overall population (Table 2).

![Figure 1. Relationship between litter size (as total number of pigs born) and litter average birth weight. The average litter birth weight over the population is 1.37 kg (dashed grey line). The solid grey line shows the critical breakpoint in individual birth weight (1.18 kg) for mortality at d4 after birth.](image)

<table>
<thead>
<tr>
<th>Average litter size (total born)</th>
<th>Average litter birth weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>1.0</td>
</tr>
<tr>
<td>15</td>
<td>1.5</td>
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<tr>
<td>20</td>
<td>2.0</td>
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<tr>
<td>25</td>
<td>2.5</td>
</tr>
<tr>
<td>30</td>
<td>3.0</td>
</tr>
</tbody>
</table>

![Table 2. Summary statistics of measured traits low (L), medium-low (ML), medium-high (MH) and high (H) birthweight phenotype sows.](image)
| Sow Birthweight Phenotype (ALBW_P) | L       | ML      | MH      | H       | P <  
|-----------------------------------|---------|---------|---------|---------|-------
| Sows                              |         |         |         |         |       
| n                                 | 85      | 250     | 209     | 100     | 644   
| % per category                    | 13.2    | 38.2    | 32.5    | 15.5    |       
| Total born                        | 15.3 ± 0.2 | 15.2 ± 0.1 | 14.5 ± 0.1 | 13.6 ± 0.1 | 0.001 
| Average litter weight             | 1.12 ± 0.01 | 1.28 ± 0.01 | 1.42 ± 0.01 | 1.62 ± 0.01 | 0.001 
| Gilts individually tagged        |         |         |         |         |       
| n                                 | 985     | 2882    | 2406    | 1075    |       
| % per category                    | 13.41%  | 39.22%  | 32.74%  | 14.63%  |       

When individual birth weight was classified by the same birth weight categories, greater than 49% of piglets born to sows with a L ALBW_P had an individual birth weight <1.15 kg and nearly 80% had a weight < 1.37 kg (Figure 2).
The preliminary analysis to determine selection outcomes for pure-bred L3 replacement gilts identified large variations in the proportion of gilts selected from particular litters (Figure 3). Sectors of the pie-chart show the percentage of total litters in which varying proportions of gilts born were not selected for transfer to the nucleus farm GDU. In about 10% of all litters, between 50 and 75% of gilts born (purple sector) were not selected for movement to the GDU. An even more extreme outcome was seen in 4% of the litters (light blue sector), with more than 75% of all gilt littermates born being considered “non-select”. Using existing selection criteria, a large proportion of gilts were considered “non-select” at weaning or around 140 days of age on the basis of relatively poor growth performance. Combined with the higher proportion of low birthweight pigs that die in the early post-natal period, our prediction (which will be confirmed in commercial replacement gilts) is that these high proportions of dead and non-select gilts are born to sows with a repeatable low birth weight phenotype.
**IX.i and ii. Discussion:**

Decades of selection for high-prolificacy sows and improvement in litter size has been successful in increasing the number of pigs weaned per sow per year. However, it has also resulted in an increase in the proportion of piglets with low birth-weights and an increase in within-litter variation in birth weight. In general, a low individual birth weight represents a greater risk of mortality, poor growth and poor retention of future replacement gilts (Almeida et al., 2014). A “low litter birth weight” carries all the same risks reported for individual low birth weight gilts, but as a “litter” trait. Sows that repeatedly farrow extreme low average litter birth weight litters, irrespective of litter size, are classified as displaying the low birth weight phenotype and considered to be a risk to good herd productivity. The incidence of the low birthweight phenotype is partially genetic (Da Silva et al., 2018). However, an important gene by (sow) environment (G x E) interaction also contributes to a low litter birth weight phenotype. An accumulation of data on the reproductive traits of contemporary commercial sows led to the hypothesis that a low litter birth weight phenotype is the result of poor placental development, driven by extreme intra-uterine crowding of embryos in early gestation, and involves an interaction of reproductive traits (ovulation rate and early embryonic survival) that are not responsive to current genetic selection practices (Foxcroft et al., 2007, Foxcroft 2012). This led to the proposal underlying the present large-scale, trial that “Measuring and managing this sow-dependent phenotype at production nucleus/multiplication level would improve overall breeding herd efficiency and the number of quality weaned pigs per sow lifetime”.

In the current study, when considered on the basis of individual pig birthweight, the critical cut-off for mortality in replacement gilts at 4 d of age was 1.18 kg and is similar to that reported previously. Gilts weighing less than 1.0 kg at birth have increased pre-weaning mortality rates and have little chance of surviving until weaning (Magnabosco et al., 2015). Those gilts that do survive past the nursery phase have poor growth until finishing and are significantly lighter than their higher birth weight littermates. Additionally, as future replacement females, low birth weights negatively impact their reproductive potential. Variation in gilt birth weight was negatively correlated to ovarian and uterine development (Deligeorgis et al., 1984) and Flowers (2015) suggested that below a minimum birth weight of 1.1 kg, gilts simply do not have the reproductive machinery to be efficient reproductively, no matter how well they are managed later in life. Magnabosco et al. (2016) reported that gilts weighing less than 1.0 kg at birth, and still selected as replacements at 170 days of age, produced fewer pigs over three parities and remained in the herd for less time. Furthermore, Almeida et al. (2014) reported that although low birthweight gilts were at risk for non-selection at breeding, there was no effect of birth weight on age at puberty.

A “low litter birth weight” carries all the same risks described above for individual low birth weight. In agreement with Smit et al. (2013), a negative relationship between total born (litter size) and litter average birth weight (average of all pigs in the litter) was reported in the current study. More importantly for the present approach to improving breeding herd performance, some 15% of sows can be identified within breeding herd populations that exhibit an extreme “low” average litter birth weight phenotype over consecutive parities, irrespective of the total
number of pigs born. Smit (2013) reported that sows giving birth to a low BW litter, again give birth to a low BW litter, or at best medium BW litter at the next farrowing, and that the correlation coefficient to determine the repeatability of average litter birth weight across successive parities is reasonably high ($r=0.49$ in later parities). Thus, litter average birth weight is repeatable, and thus predictable, within sows (see Figure 3).

**Figure 3.** Each of the colored lines represents a single sow where the average litter birth weight for three successive parities was measured. Sows that were classified as having a repeatable High (HBWT: brown, black and green lines) or Low (LBWT: circled) Birth Weight Phenotype are identified.

Overall, the data on birth weight phenotype collected was the critical first step in linking gilt litter of origin (birth weight phenotype) to SLP in a large commercial production system. From the perspective of the efficiency of gilt replacement production, gilt survival to weaning, retention though the pre-selection stages of production, and final selection in the GDU could be linked back to “litter of origin”. Moving forward, this characterization of birth weight phenotype provided additional opportunities to explore additional management strategies for improving SLP. From the perspective of the planned collaborative study with Dr. Flowers from NCSU, it was possible to target litters born to sows with the low or medium-low litter birth weight phenotype for a study of impact of litter size in lactation on weaning weight and subsequent gilt performance.

**IV.iii. Scientific Abstract:**

Validation of the use of exogenous gonadotropins (PG600) to increase the efficiency of gilt development programs without affecting lifetime productivity in the breeding herd\(^1\).
ABSTRACT: The objective of this study was to validate the use of exogenous gonadotropin (PG600) treatment for stimulating estrus in non-cyclic gilts and to compare lifetime productivity of gilts recorded as having natural (NAT) versus PG600-induced (PG600) first estrus in a commercial setting. Prepubertal Camborough gilts (n = 4,489) were delivered to a gilt development unit (GDU), with the goal of delivering known cyclic breeding eligible females to the sow farm (SF). A Boar Exposure Area (BEAR) was designed to facilitate stimulation and detection of puberty by providing fenceline and direct contact (15 min daily) with mature boars over an intensive 28-d period, starting at approximately d 160 (d 0). At d 14, non-pubertal gilts were mixed in new pen groups. At d 23, non-cyclic “opportunity” gilts with no record of vulval development and required to meet breeding targets, were eligible for treatment with PG600 to induce puberty. Overall, 77.6 % (n = 3,475) of gilts exhibited standing estrus (NAT = 2,654, PG600 = 821) and were eligible for shipping to the SF at approximately 35 d and 76.6 % of gilts administered PG600 exhibited the standing reflex within 13 d of treatment. Ultimately, 72.0 % of gilts entering the GDU were delivered to the SF as breeding eligible females. Considering gilts delivered, a greater proportion of NAT than PG600 gilts were successfully bred (P < 0.001) and farrowing rates to first service, and overall farrowing rates (including gilts that returned to estrus and were rebred) were greater for NAT compared to PG600 gilts (P < 0.001). Farrowing rate at second and third parity was similar between NAT and PG600 gilts; However, at fourth parity, a greater proportion of NAT gilts farrowed. In comparison, considering only gilts served, there was no difference (P > 0.05) in the proportion of NAT and PG600 gilts farrowing a third litter, but a greater proportion of NAT than PG600 gilts farrowed their fourth litter (P < 0.001). There was no difference between NAT and PG600 gilts for litter size at parity 1 through 4, or total pigs born over 4 parities (P > 0.05). A negative correlation (P < 0.0001) was detected between age at puberty and lifetime growth rate at puberty, and growth rate classification affected age and weight at puberty. However, retention rates and total sow productivity to parity 4 were not affected by growth rate classification at puberty.

V.iii. Introduction:

Key Risk Factors for Sow Longevity. As the basis for promoting a well-organized GDU as a critical component of breeding herd improvement, research that indicates the benefits of identifying “select” gilts at an early age (a critical part of a successful GDU program) and the positive effects this has on sow lifetime productivity becomes of interest. Improving sow longevity, herd stability and maximizing lifetime performance in the sow herd represents a significant challenge that is best addressed in the GDU, by maintaining a constant input of high quality gilts into the breeding herd (the “Push” concept of gilt replacement management). Meeting and maintaining breeding targets is often the primary goal of a GDU. However, there are two key risk factors which, if not addressed
by appropriate GDU management, will adversely affect lifetime productivity and overall profitability:

1) **Selection of gilts with the greatest reproductive potential, and**
2) **Inappropriate management for body state at sexual maturity.**

Invariably, sows will be culled or removed at each parity; and in general, industry standards for sow lifetime performance are suboptimal (Spörke, 2007). Therefore production benchmarks must be set and targets might include 86% of gilts selected to reach first farrowing, and no more than 10% gilt fallout in each subsequent farrowing (Kummer 2008: Figure 1).

**Selecting gilts with the greatest reproductive potential.** In one study of the relationship between age at puberty and lifetime performance (Patterson et al., 2010), pens of gilts were taken to a purpose built boar stimulation pen, and received 20 minutes direct exposure to mature boars daily as a pen group starting at approximately 140 days of age. Gilts were permitted up to 40 days of daily boar contact to exhibit pubertal estrus and “Select” gilts were recorded as cyclic by 180 days of age and were classified on the basis of age at puberty into three groups: 1) Early Puberty (EP) (< 153 d of age) n=87; 2) Intermediate Puberty (IP) (154 to 167 d of age) n = 146; or 3) Late Puberty (LP) (168 to < 180 d of age; n= 100). Gilts not exhibiting the standing reflex by 180 d of age were considered Non-responders (NR) or Non-Select (n = 107). At approximately day 18 of the 2nd estrous cycle, gilts were permitted fence-line contact with mature boars for detection of 3rd estrus. To determine sow lifetime performance, data were collected over three parities on sow body weight, loin and backfat depth at farrowing and weaning; total litter size born alive, dead and mummies; weaning-to-estrus interval; retention rate; and reason for culling.

The percentage of gilts bred was highest for those expressing puberty within in the 40 day experimental cutoff, and approximately 95% of “select” gilts were successfully bred at 3rd estrus. Non-select gilts were returned to the herd at 180 days of age and were stimulated to reach puberty by a number of means (continued boar exposure, pharmacological means), although the methods were not recorded. **Fewer Non-select gilts (37%) were eventually bred and produced a first litter compared to all categories of Select gilts (16%). This single measure of breeding herd inefficiency, linked to evidence that more “non-select” gilts were culled after weaning their first litter (see below), is representative of much of the data provided by large commercial units. In such data sets it is not unusual to see that up to 15% of gilts recorded as being on the breeding herd at the sow farm inventory never produce a first litter record.** Although no differences were detected in total born or born alive over three parities among gilt categories, an increase in 2.6 total born and 2.2 born alive by parity 3 in Select gilts, represents a significant economic gain to the producer.
Figure 1. a) Percent of gilts originally on inventory that never farrow a litter; b) Percent lifetime NPD (total number of herd days – total number of productive days (lactation and gestation) divided by herd days (Lucia et al., 2000)) of all gilts that farrow at least one litter (From Patterson et al., 2010).

Approximately 60 and 50% of Select and Non-select gilts, respectively, farrowed three litters, which is below the selected target of 75% (Figure 2). However, Kummer et al. (2005) showed that this target is achievable, with approximately 70% of select gilts in their study going on to farrow three litters. Considering Select versus Non-Select gilts initially served from the perspective of retention rate from first service to farrowing their third litter, the slope of the “target” regression line was similar to the for Select gilts, whilst the slope of Non-select gilts was the most negative ($P < 0.03$; Figure 1). On average 14.3% of Select gilts were removed at each parity, compared to 17.8% of Non-select gilts. **Culbertson (2007) reported that once sows make it to third parity the overall retention in the herd increases and the slopes of the retention curves beyond this point become very similar. He concluded that problems with young female retention are the driver of unacceptable replacement rates.** Lucia et al. (2000) also suggested that minimizing removals for reproductive failure is critical to optimizing lifetime reproductive efficiency. They suggested that reproductive management practices should be directed to reduction of NPD accumulation at early reproductive cycles, and that this could be achieved by implementing improved gilt management practices. Clearly, a key area for improvement is from gilt entry until farrowing the third litter, with a special focus on those gilts that never farrow a litter and that are 100% unproductive in their lifetime.
Of those gilts that farrowed at least one litter, the percent lifetime NPD decreased with increasing parity but at each parity, LP and Non-select gilts spent a higher percentage of their herd life non-productive and Non-select gilts were culled earlier (Table 1). Approximately 89, 94 and 90% of sows at Parity 1, 2 and 3 were recorded in estrus within in 7 days of weaning. Although WEI was acceptable, sows that did not return to heat within 7 days accumulated a large number of NPD. This was probably largely due to ineffective management practices, and as reported by Koketsu (2005), leads to unnecessary accumulation of NPD due to extended first-mating or weaning to culling intervals. On the positive side, Rodriguez-Zas et al. (2006) suggested that additional benefits of longer retention of sows in the breeding herd would be a greater opportunity to recuperate the initial costs of developing replacement gilts, greater acquired immunity to diseases, greater salvage value of sows culled and lower replacement costs.

Table 1. Parity at removal and reason for culling (± S.E.) by puberty group classification. (Patterson et al., 2010).

<table>
<thead>
<tr>
<th>Reasons for culling:</th>
<th>EP</th>
<th>IP</th>
<th>LP</th>
<th>Non-select</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parity at removal</td>
<td>1.7 ± 1.2</td>
<td>1.5 ± 1.0</td>
<td>1.6 ± 1.0</td>
<td>1.2 ± 1.0</td>
</tr>
<tr>
<td>Reproduction ¹</td>
<td>70.0</td>
<td>63.1</td>
<td>63.2</td>
<td>65.8</td>
</tr>
<tr>
<td>Litter performance ²</td>
<td>15.0</td>
<td>18.4</td>
<td>13.2</td>
<td>5.3</td>
</tr>
<tr>
<td>Locomotion ³</td>
<td>7.5</td>
<td>6.2</td>
<td>7.9</td>
<td>13.2</td>
</tr>
<tr>
<td>Disease/peripartum problems ⁴</td>
<td>7.5</td>
<td>12.3</td>
<td>15.8</td>
<td>15.8</td>
</tr>
</tbody>
</table>

¹ Conception failure, failure to farrow, no observed heat, abortion.
² Farrowing productivity, lactation-weaning productivity, difficult farrowing, smaller litter size,
retained pigs.

3 Lameness, unsoundness, injury, downer syndrome, body condition.
4 Rectal and uterine prolapse, vulvar discharge, hernia, gastrointestinal, urinary infection, abscess, mastitis, heart failure, behaviour, unknown.

Taken together, these data lead to the obvious suggestion that the response to a standardized protocol of boar stimulation can be used to identify the 75 to 80% of gilts that are likely to be most fertile over their productive lifetime in the breeding herd.

Inappropriate management of body state at maturity.

Age. Body condition of gilts at first mating has a significant effect on lifetime performance. Gilts that do not have sufficient body condition when they are first selected and introduced to the farm generally fail to achieve a reasonable number of parities (Close and Cole, 2001). Based on the data of Patterson et al. (2010), breeding on the basis of age alone was considered to be an inappropriate and inadequate benchmark, because 40 days of boar stimulation resulted in nearly 60 days variance in age at puberty, and a 75 kg variation in body weight at first estrus. This required gilts to be bred gilts at anywhere from 1st to 6th estrus if breeding weight targets of 130 to 150 kg (300 to 350 lbs) were to be met. In the study of Kummer et al. (2005) no difference in total born was observed between gilts inseminated at approximately the same weight but different ages. These authors concluded that breeding faster growing gilts at a younger age did not have repercussions for performance over three parities.

Weight. Results from experimental studies and cost/benefit analyses suggest that gilts should be bred at a target weight of 135 to 150 kg (300 to 350 lbs). According to Williams et al. (2005) gilts weighing less than 135 kg have less total pigs born over 3 parities than gilts weighing over 135 kg. There was also no advantage in breeding gilts heavier than 135 kg. Similarly, Kummer et al. (2005) reported no advantage in breeding gilts heavier than 140 kg. In addition, puberty stimulation should start about 30 days prior to gilts reaching the maximum allowable live market weight to avoid economic penalties for producers. In modern genotypes that have exceptional growth performance, the need to manage gilts to avoid excessive weights at breeding becomes an important emerging risk factor for sow retention. The collective studies from Brazil indicate that gilts bred at heavier weights have a lower retention in the herd and a higher percentage of heavy gilts are culled due to problems with locomotion (Table 2).

Table 2  Productive performance (born alive and retention rate over three parities) according to breeding weight categories of 130-150, 151-170 and 171-200 kg. (Amaral Filha, 2008)
An unexpected consequence of the considerable variability in growth performance and age at sexual maturity within the cohort of gilts studied by Patterson et al. (2010), linked to the decision in this study to use the standardize strategy of breeding all gilts at third estrus, was that the 75 kg weight difference between the lightest and heaviest gilts at first estrus was perpetuated until weaning the third litter, despite the fact that gilts and sows were fed to “condition” during gestation. Controlling body weight of the gilt at breeding mat therefore be the best guarantee that targets for body weight over successive parities in the sow will be met. Additionally, accumulated data indicate that a greater body mass after farrowing (>180kg) protects sows against the effects of excessive loss of lean mass during their first lactation if feed intake is low (Foxcroft et al., 2006a). This suggests a lower threshold of body weight at breeding and farrowing the first litter should be considered. As mentioned above, the current recommendation is to breed gilts between 135 and 150kg, at second or third estrus. Assuming a 35 to 40kg weight gain during gestation, this results in a weight of >180kg after farrowing the first litter.

Note: Adequate levels of back-fat are important to protect sows from physical injury, but there is no consistent evidence that increased back fat is an important factor in longevity and lifetime fertility of sows. This unanswered question is a key component of the NPB sponsored trial presently in progress within the Murphy Brown system.

The importance of measuring or estimating gilt weight, independent of gilt age and “body condition” (fatness), as a key factor in retention in the breeding herd pre-breeding management seems clear. As an alternative to capturing an actual weight, the application of established allometric growth curves that take advantage of the high correlation between two body measurements, heart girth circumference and body weight, to develop “weight tapes” has been validated. Given the accuracy of heart girth as a predictor of gilt weight it is an adequate substitution for determination of body weight during gilt stimulation (Pasternak et al., 2008). This estimation will allow producers to better manage gilt development for improved lifetime performance.
Figure 3. Relationship between Heart Girth (HG) and Body weight (BW) for two technicians separately. The linear regression equations for each data set over-lap one another and have similar slopes and intercepts (Pasternak et al., 2008).

**Estrus at mating.** More important than chronological age at mating (a function of management practices), is physiological age (known attainment of sexual maturity and number of estrous cycles). Early stimulation of gilts permits producers to take advantage of the increased productivity of gilts bred at second or third estrus. Generally, delaying breeding from 1st to 2nd estrus gives a 0.7 pig increase in first litter size. In contrast, delaying breeding from 2nd to 3rd estrus only increases litter size by 0.2 pigs for the same extra cost. Therefore, breeding should only be delayed to 3rd estrus in order to achieve acceptable breeding weights. Similar increases in productivity in gilts subjected to a “Heat-No-Serve” strategy were also reported in large commercial systems (Table 3).

Table 3. Effect of “Heat, no service (HNS)” on Sow Productivity* (Steve Pollmann – NPB workshop)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>No HNS</th>
<th>With HNS**</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farrowing rate, %</td>
<td>84.4</td>
<td>89.3</td>
<td>4.9</td>
</tr>
<tr>
<td>Total born/litter</td>
<td>12.76</td>
<td>13.20</td>
<td>0.44</td>
</tr>
<tr>
<td>Live born/litter</td>
<td>11.89</td>
<td>12.37</td>
<td>0.47</td>
</tr>
<tr>
<td>Stillborn/litter</td>
<td>0.57</td>
<td>0.52</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*One year of results from MFV, Nevada, MO from Apr 2009 to 2010; 15 sow farms

**Average HNS was 45% with a range 1.9 to 75.5%**

**Summary of gilt development aspects:** Successful introduction and retention through the early parities drives lifetime performance of the breeding herd and represents an important opportunity
to improve and enhance overall SLP. *Implementation of an effective GDU system (BEAR, Magic ‘42’) is considered absolutely necessary to select gilts with the greatest reproductive potential, and appropriate sexual maturity and body weight at breeding.*

**VI.iii. Objectives:**

The long term goal of the National Pork Board’s effort in Sow lifetime productivity is to increase the number of quality weaned piglets produced per sow lifetime by 30% over 7 years. As one part Preliminary, Phase 1, study, the efficiencies of using a purpose-designed BEAR system for puberty stimulation and heat detection, and the effectiveness of key intervention strategies (PG600) to reduce gilt NPD in the breeding herd, were re-examined. This component of the Preliminary Phase Trial met Objectives 3, 4, 6 and 7 described earlier.

**VII.iii. Materials & Methods:**

A database of approximately 6200 gilts was generated over nearly a two-year period for gilts entering the offsite “Bruce” GDU. Extensive records collected at the GDU using established management protocols and SLP data from production records were merged into a single database starting from approximately 160 days of age and continuing until at least 4th parity or culling.

*Animals.* This study was conducted at a 55,000 sow system located near Northfield, Minnesota (Holden Farms, Inc.). Within this system, a gilt development unit, supplying a 1,350 parity 1 sow farm was used. Between November 2010 and March 2013, 6208 prepubertal C42 (L3 dam X L2 sire) gilts (PIC, USA) born to multiparous sows were used in this study. Gilts arrived in the gilt development unit (GDU) at approximately 140 d of age in groups of 350 with the goal of 288 cyclic to be delivered to the sow farm every 4 weeks.

*Puberty Stimulation.* For the purpose of this study, within the existing GDU, a boar exposure area (BEAR) was designed to facilitate puberty stimulation and detection. The BEAR consisted of two gilt pens retrofitted to include a row of 8 boar stalls. At all times during the study, eight mature epidididectomized boars were continuously housed and used in the BEAR and a gilt:boar ratio of no greater than 15:1 was maintained during stimulation. New boars replaced older boars on a regular basis to ensure the boars did not get too large and to maintain boar libido.

A 28-day stimulation program was implemented (Appendix 3.1). Each day, starting at approximately 170 d of age, pens of gilts were taken to the BEAR and received at least 15 minutes of fence-line contact with boars in the stalls, as well as direct physical contact with a single boar as a pen group. Boars were not permitted to breed any gilts in standing estrus: However, to maintain libido, boars were routinely permitted to mount a gilt expressing the standing heat reflex and were “hand collected” by a technician. Physical signs of pending estrus in gilts, such as redness, degree of swelling and mucosal discharge from the vulva were recorded once daily during the stimulation period (Appendix 3.2 and 3.3). Puberty attainment was determined as the day gilts first exhibited the standing reflex in response to contact with a boar. On day 14 after initial contact to the boar any gilts remaining in the pen that had not exhibited the standing reflex were mixed and new pen groups established. On day 23 any “opportunity” gilts that had not exhibited the standing reflex, that had no
recorded physical signs of possible “silent” estrus, but were still needed to meet breeding targets, were treated using a combination dose of 400 IU eCG and 200 IU hCG (PG600; Intervet, USA, De Soto, KS). Boar stimulation in the BEAR continued for an additional 10 days. Gilts were retrospectively classified as “Select” gilts if they spontaneously expressed a pubertal estrus in response to boar stimuli (SEL, n=3276), or exhibited estrus after PG600 treatment (SELPG, n=1137). A number of “Non-select” gilts transferred to the sow farm either did not spontaneously show estrus (NOSEL, n=417), or did not exhibit puberty immediately after PG600 treatment (NOSELPG, n=150).

**Lifetime performance.** Standard herd performance data were routinely captured by using Porcitec software (Agritec, Barcelona, Spain) from 2009-2014. Lifetime performance of all gilts was monitored at breeding, farrowing and weaning for parities 1, 2, 3 and 4.

**VIII.iii. Results:**

**Puberty Stimulation.** Gilts began puberty stimulation at 166.2 ± 9.2 (mean ± stdev) days of age. Overall, 25.6% (range 14.0 – 46.5%) and 72.7% (range 40.0 – 91.2%) of gilts exhibited the standing reflex within 14 and 30 d of puberty stimulation, respectively (Figure 1). Overall, 72.3% of gilts treated with PG600 exhibited the standing reflex within 7 days. Large variation between cohorts of gilts (n=350) existed as a result of inherent biological differences between groups, health status and season. At the end of the GDU phase 75.1% of the gilts were considered “Select” (4561/6082) and eligible to be transferred to the sow farm with a recorded standing heat (Heat-no-Serve).

![Figure 1. Accumulative percent of gilts reaching puberty after daily exposure to boars in the BEAR (Boar Exposure Area). Each line represents a cohort of approximately 350 gilts.](image-url)
**Lifetime performance.** More SEL gilts (P ≤ 0.05) were served and farrowed to first service compared to PGSEL, NOSEL, and NOSELPG gilts (Figure 2). Although significantly lower than for SEL gilts, 96.6% and 90.0% of PGSEL gilts were served and farrowed to first service at the sow farm. More NOSELPG gilts that were delivered to the sow farm with no recorded standing heat after PG600 treatment were not bred or did not farrow to first service, accumulating greater non-productive days. At parity 3, >75% of SEL, PGSEL and NOSEL gilts remained in the herd, exceeding industry standards. Retention rate to 4th parity was higher for SEL gilts compared to PGSEL, NOSEL, or NOSELPG gilts.

Once gilts were successfully bred, the percent that farrowed at parity 4 (SEL: 73.0, SELPG: 70.2, NOSEL: 70.0, NOSELPG: 70.4%), and total numbers born (SEL: 55.2, SELPG: 55.0, NOSEL: 54.2, NOSELPG: 55.7) and weaned (SEL: 42.9, SELPG: 42.4, NOSEL: 43.7, NOSELPG: 43.0) were not different (P > 0.05) among gilt classifications.

**Figure 2.** Retention rate in gilts that were retrospectively classified as: “Select”, those that expressed a pubertal estrus and either exhibited standing heat without intervention (SEL), or exhibited estrus after PG600 treatment (SELPG), or “Non-select” gilts transferred to the sow farm either did not spontaneously show estrus (NOSEL or did not exhibit puberty immediately after PG600 treatment (NOSELPG).

**IX.ii. Discussion:**

The retrospective analysis of the large data set on GDU outcomes shows unequivocally that standardized management protocols and purpose designed GDU/BEAR facilities allow efficient gilt selection and pre-breeding programs to be implemented. The flow of HNS and weight controlled
gilts from the GDU provided a predictable flow of breeding eligible gilts within the 28 to 30 day window provided by this all-in/all-out offsite unit. Furthermore, the breeding performance of the gilts shipped to the sow farm met the highest industry benchmarks, both for first litter performance and for SLP and retention.

The use of PG600-induced puberty is still controversial, but this project illustrates the crucial role that PG600 treatment plays in meeting regular HNS targets within time and space allowances. This minimises gilt non-productive days (NPD) and allows the upper limits of body weight at breeding to be controlled. More importantly, although PG600-induced puberty slightly reduced the number of gilts bred and farrowed, performance of these gilts in later parities matched that of naturally cyclic gilts. Although a full economic analysis of these different management options has still to be completed, the use of PG600 as in this project will save at least 10 gilt NPD for every gilt not naturally cyclic at day 23 of the stimulation protocol, and either kept back at the GDU for further boar stimulation or shipped without a HNS record to the sow farm. As only 2 or 3 NPD will cover the cost of PG600 treatment, treatment would be cost effective. This approach also limits the size of the gilt pool needed to meet breeding targets, with associated savings in facility costs, extra labor and animal maintenance in the pre-breeding period.

During the period of GDU operation that this first set of data were collected, known HNS gilts could only be shipped to the sow farm at 4-week intervals. As there was a requirement for at least 14 days of crate acclimation before gilts could be bred, the longer shipping interval resulted in many gilts being bred at third estrus and at heavier body weights than targeted. Subsequently, weekly shipping of HNS gilts was implemented and the impacts of this change on the proportion of gilts bred at second estrus and within target body weights will be assessed in the extension of the GDU project in the Main (Phase 2) Trial. The variability in natural heat responses in successive groups of gilts is also clear from Figure 1. Other protocol changes have centred around a move to complete gilt vaccinations and intensive handling to the early period after first arrival at the GDU site, so that gilts are in a calmer and more stable environment at the time that boar stimulation commences. Preliminary results indicate that this has improved the natural heat response and will again be confirmed in further analysis of the GDU data.

Overall, the protocols established during the GDU and pre-breeding stages of production have already made a major contribution to the improvement in SLP targeted by the NPB SLP initiative. By standardizing these protocols and thus removing variability in SLP due to poor gilt selection and pre-breeding management, the Preliminary Trial has also set up a management program that will optimize the opportunity to study critical “litter of origin” effects on SLP. Our extension-based activities consistently identify inadequate boar stimuli as a key factor limiting puberty induction programs in the industry. This led to a modification in the original Objective 5 in consultation with Dr. Knox. Consequently, in the collaborative studies with the University of Illinois, confirmation of the impact of different intensities of boar stimuli on pubertal estrus attainment became the key goal.

Appendices:
Appendix 1 – Publications and Meetings:

November 2014 – presentation at Jornada Internacional de Actualizacion Porcina, Concepcion, Chile
March 2015 – ASAS Midwest Meeting, 2 abstracts were accepted.

Project Meetings & Trips to HFI:

March 2014 – Jenny Patterson spent several days at HFI to discuss the project prior to implementation.

July 2014 – George Foxcroft presented project summaries at the recent meeting of the NPB Animal Science Committee in Raleigh, NC.

September 2014 – Jenny and George travelled to HFI for meetings and protocol discussions. Chris Hostetler and Terry Prince were in attendance.

January 2015 - Jenny spent several days at HFI when litter tagging was implemented.

March 2015 - Jenny Patterson two days at HFI to collect 500+ tissue samples for DNA collection and meetings with the HFI team.

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Appendix 3: Management aids developed in the project

Implementation of a GDU Program

Pre-stimulation - 28 days

<table>
<thead>
<tr>
<th>Time Point</th>
<th>Action: group by group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1-4</td>
<td>Tagging, tattooing, vaccinations, etc.</td>
</tr>
</tbody>
</table>

Stimulation - 28 days

<table>
<thead>
<tr>
<th>Time Point</th>
<th>Action: group by group</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1-13</td>
<td>Direct (and fenceline) contact with vasectomized boars in BEAR</td>
</tr>
<tr>
<td>D14</td>
<td>Remix all non-cyclic gilts</td>
</tr>
<tr>
<td>D23</td>
<td>“Opportunity” (known non-cyclic) gilts without HNS receive PG600</td>
</tr>
<tr>
<td>D28</td>
<td>All eligible gilts are identified, Gilts without HNS are culled</td>
</tr>
</tbody>
</table>

** Puberty stimulation is initiated at a pen average of 170 days**

Appendix 3.1. A typical 28-day estrus induction program designed to reach a “heat-no-serve” decision with efficient use of labor and GDU facility space.

- Pre-stimulation management is critical if consistent responses to boar stimuli are to be achieved
- The stimulation program usually starts around 170 days of age
- Daily records are required for all gilts undergoing stimulation
- Remixed of non-cyclic gilts is used as an added stimulus to induce pubertal estrus.
- Depending on gilt breeding targets, PG600 may be used to elicit pubertal estrus in non-cyclic “opportunity gilts
- Gilts receiving PG600 must be clearly pre-pubertal at the time of treatment (i.e. can have no previous scores indicating possible silent estrus or other abnormalities)
Appendix 3.2. One version of a wall chart provided to GDU staff to help with accurate daily recording of events leading to pubertal estrus.

- Successive changes in vulval coloration and swelling are linked to distinct gilt behaviors in the presence of a mature, pheromone-producing, boar that ultimately lead to a record of a full standing heat within 3 to 5 days.
- A minority of gilts will show proceptive behavior and early vulval development but do not proceed to show a full standing heat: These are considered to be gilts with a “silent estrus” and the proportion of these gilts can vary over time within a farm, and between different farms.
Appendix 3.3. An example of a GDU record sheet showing daily records for one group of gilts over the first 21 days of stimulation.

- This sheet uses a 1 to 5 scale for recording pre-pubertal events
- The score of “5” is only given when a full standing heat is recorded when gilts are in good stall-front or direct contact with a mature boar
- The record of “5” is linked to a recorded weight, shown here in lbs in the brackets for each gilt in estrus
- Two gilts have no records of vulval development or proceptive behavior and would be eligible to be treated with PG600 at day 23 if additional “opportunity” gilts were needed
- Two gilts have several days with low scores but never show pubertal estrus: Experience suggests that these gilts actually ovulate and cycle but show “silent” heats
II. **Industry Summary: Main Trial (Projects 15-140, 16-148 and 17-139)**

1. **Objectives:** The principal objective of the Main Trail was to study associations among the established litter birth weight phenotype of nucleus/multiplication sows and the retention of their gilt progeny during development and selection, and the lifetime productivity and retention in the breeding herd. Collectively, these results were expected to inform decisions about how gilt selection programs affect efficiencies from the production nucleus/multiplication level to the level of terminal line production on commercial sow farms (Objective 1).

2. **How research was conducted:** Extensive data capture and data auditing was used to document the fate of over 7,500 potential Camborough replacement gilts born to sows with an established average litter birth weight phenotype (ALBW_P). Agreed protocols for Pre-selection of gilts at weaning (Pre-select 1), and for entry to both off-site and on-site GDU stimulation programs (Pre-select 2 at around 170 days), limited the non-selection of gilts on the basis of relatively low growth rates, thus allowing the impact of greatest range of preselection growth rates on selection rates and SLP to be determined. Gilts were stimulated to reach pubertal estrus using optimized GDU/BEAR facilities on the down-stream farms included in the study. Gilt flows were also directed at down-stream sow farms where the risks of disease-related effects on production performance during the Main Trail were thought to be minimal. Data were excluded from final analysis of birth weight phenotype effects when evidence of non-compliance with established management protocols was evident or when changes in health status clearly impacted the validity of the results. Notwithstanding these constraints analyses of lifetime performance in the breeding herd involved data from over 2,500 select gilts for which litter of origin data were available.

3. **Research findings:** Litter birthweight phenotype significantly affected the retention of gilts through post-natal development to Pre-selection at around 170 days of age. As in commercial line litters, higher peri-natal mortality and poor pre-weaning survival were significant risk factors in gilts born to sows with a low aALBW_P. However, non-selection at later stages of development continued to be an issue for gilts born to sows with a lower ALBW-P, resulting in a 10 to 15% lower selection rate in the gilt progeny born to the low compared to the medium-low, medium-high and high ALBW_P sows. In the gilts that were Pre-selected for entry to the off-site and on-farm GDUs involved in this study, ALBW_P was positively associated with growth rate to entry to the GDU: However, final selection rates for the pre-select gilts and the response to puberty induction protocols were not affected by ALBW_P. As a result, the lasting effects of ALBW_P were on weight at selection and breeding. Interestingly, the higher growth rates of gilts derived from dams with the medium-high and high ALBW_P were determined to be a risk factor for future retention in the breeding herd: With a mean estimated breeding weight of around 150 kg in this replacement gilt cohort, a substantial proportion of these gilts would exceed the upper target weight at breeding of 150 kg.

The lack of an effect of the ALBW_P of pre-select gilts on pubertal onset, was mirrored by a
lack of effect on the percentage of gilts bred, and on total litter size born over at least three parities. However, retention in the breeding herd was negatively associated with ALBW_P, and poor retention was intuitively linked to heavier weights at breeding and subsequent removal due to lameness and poor locomotion.

4. **What these findings mean for the industry:**

These findings indicate that poor survival to weaning, and lower gilt retention rates during development, are critical issues for low birth weight gilts and for gilts born to sows with a low ALBW_P. Therefore, retaining sows in the production genetic nucleus population if they exhibit a repeatable low ALBW_P negatively impacts the efficient production of replacement gilts and represents a poor return on the investment of their high genetic merit. Nucleus sow culling strategies aimed at the early removal of the 10 to 15% of sows with the extreme low ALBW_P, as well as non-selection at birth of the lower birth weight gilts from other litters, will improve the overall efficiency of the nucleus/multiplication farm.

Using current pre-selection criteria for gilts entering the GDU stage of production, lifetime growth performance and litter of origin traits have little impact on breeding performance. However, gilts born to the higher ALBW_P sows were heavier at breeding and their retention in the breeding herd was a risk factor for SLP. The risk of gilts being too heavy at breeding and negatively affecting subsequent retention in the breeding herd, emphasizes the importance of efficient GDU/BEAR programs that minimize entry to service intervals.

*The present study demonstrated that such programs can be implemented in large commercial systems and the success of these selection and pre-breeding programs makes a fundamental contribution to achieving acceptable SLP.*

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Jenny Patterson. E-mail: jennifer.patterson@ualberta.ca

III. **Key Words**

Gilts, Litter Birth Weight, Selection Efficiency, Lifetime Productivity

IV. **Scientific Abstract**

*A low litter birth weight phenotype reduces the retention rate of potential replacement gilts.*

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On the basis of data collected over at least two successive parities in the Preliminary Trial, nucleus/multiplication sows \( (n = 651) \) were classified as having either low \( (L, < 1.15 \text{ kg}, n=63) \), low-medium \( (LM, \geq 1.16 \text{ to } \leq 1.36 \text{ kg}, n=281) \), medium-high \( (MH, > 1.36 \text{ and } \leq 1.6 \text{ kg}, n=254) \) or high \( (H, > 1.6 \text{ kg}, n=53) \) average litter birth weight phenotype \( (ALBW_P) \). Within 12 h after birth, live gilts born to these sows \( (n = 7552) \) received a unique ear ID tag and retention rate \( (RR) \) was determined from birth until pre-selection to enter the breeding herd \( (pre-pubertal \text{ gilts at } 170 \text{ d of age}) \) having applied the standardized selection criteria. RR was analyzed as a Chi square using the PROC FREQ procedure of SAS. RR was lower \( (P \leq 0.05) \) for L than for LM, MH and H sows within 4 d after birth \( (91.4, 94.1, 95.4, \text{ and } 95.6 \%, \text{ respectively}) \), at 24 d of age \( (81.4, 84.5, 87.2, \text{ and } 86.9 \%, \text{ respectively}) \), at 70 d of age \( (66.7, 75.4, 78.7, \text{ and } 79.2 \%, \text{ respectively}) \) and at 170 d \( (42.6, 52.3, 55.3, \text{ and } 56.2 \%, \text{ respectively}) \). As has been reported for low individual pig birth weights, retention of gilts born to sows with the L ALBW_P was compromised. Effects of L ALBW_P on final selection and on sow lifetime productivity was then determined, using standard selection protocols in GDUs with purpose-built BEAR facilities. ALBW_P did not affect the days to recorded first estrus or the proportion of gilts recoded in estrus. However, ALBW_P was positively associated with pubertal weight and estimated breeding weight, and negatively associated with retention in the breeding herd. Higher pre-selection growth rates, and long entry to service intervals are therefore seen as important risk factors for retention in the breeding herd. In contrast, ALBW_P did not affect the proportion of gilts selected and initially bred, or total pigs born over four parities. Two key factors therefore seem to affect the overall production outcomes on large commercial swine operations. Firstly, a low ALBW_P has implications for inefficient genetic transfer to the level of terminal-line production and the high relative maintenance costs of nucleus sows that produce very few replacement gilts in their productive lifetime. At the level of the production nucleus/multiplication unit, the ability to predict a low ALBW_P can be directed at strategic culling decisions. Secondly, implementation of highly efficient GDU/BEAR selection programs are needed to minimize entry-to-service intervals and to mitigate the risk that overweight gilts at breeding will have poor retention in the breeding herd.

V. Introduction

The literature suggesting that a repeatable low litter birth weight phenotype in production nucleus/multiplication sows could have consequences for the efficiency of gilt replacement programs and for sow lifetime productivity \( (SLP) \) was presented as part of the Preliminary Trail sections above. The Preliminary Trial achieved a number of key objectives:

- Litter birth weight phenotypes were established for over 600 nucleus herd sows
- Objective criteria were used to allocate sows as having a low, low-medium, medium-high or high ALBW_P
- Existing gilt selection criteria were monitored and standardized for the Main Trial
- Benchmarks for effective final selection protocols using state-of-the-art BEAR/GDU facilities were established
In the Main Trial, live gilt progeny from nucleus/multiplication sows generating potential Camborough replacement gilts were provided with individual ID tags and their retention to final selection, and for select gilts their lifetime breeding performance, were monitored. Ultimately, the effects of litter birth weight phenotype on gilt selection rates and on SLP were determined.

VI. Objectives

The Main Trial essentially addressed the first and central Objective 1 described earlier, viz “Litter of origin as a key factor determining SLP”

VII. Materials and Methods

Within 24 hours of the birth of the third or subsequent litters (at which time a sow ALBW_P had been established, all live potential Camborough replacement gilts were individually identified with an ear tag in both ears. Extensive protocols were implemented to enable tracking of individual gilts from birth to culling. From birth to the end of the nursery stage of the commercial production gilts were tracked within PICtraq® (PIC) and from nursery exit to culling with Porcitec (Agritec Software, Barcelona, Spain) software. At the time of death or non-selection as a replacement female, ear tags were removed and the reason for culling or non-selection was recorded. Records were continually monitored to ensure that all tagged gilts were accounted for.

At weaning, agreed experimental protocols stipulated that all healthy gilts should be transferred to the nursery, irrespective of apparent differences in weaning weight. After weaning, selected gilts were relocated to the nursery facility and pen-housed groups of 16-20 gilts on plastic flooring in 2.7 x 5.5 m pens, providing 1.5 to 1.8 m² per animal, where they remained for approximately 6-7 weeks. All females were reared using industry standard protocols, and fed a developer diet ad libitum. At approximately 70 days of age gilts identified for this study were transferred to either on-farm or offsite gilt rearing facilities. Acceptable criteria for culling or non-selection using visual appraisal at nursery exit (Pre-selection1) were under condition, hairy, ruptures and extreme runts but not relative growth performance. During the rearing phase gilts were housed in group pens of 18 to 30 gilts on fully slatted floors until “Pre-selection 2” at approximately 140-170 days of age. Acceptable non-selection criteria at this stage included structural soundness and underline quality. All pre-select gilts were then considered to be on inventory within their respective GDUs and received an HFI production ID that was cross-referenced to the birth ID. Pre-select gilts were then either moved to an offsite GDU facility or entered the on-farm GDU facility. Gilt acclimation and vaccination programs followed standard HFI protocols and included vaccination against reproductive pathogens (porcine parvovirus, leptospirosis, and Erysipelothrix rhusiopathiae), porcine circovirus type 2, influenza A virus, and for specific farms may have included reproductive and respiratory syndrome virus.

Associations among gilt birth weight, retention rate and key developmental traits (pubertal age, growth rate, pubertal weight, and entry-to-estrus interval) and ultimately SLP in gilts bred, were explored using two different estimates of birth weight. Firstly, associations with individual gilt birth weight, irrespective of either litter or sow phenotype, were established. This initial analysis provided a direct comparison between the present results and results from similar large scale
studies reported in the recent literature. Secondly, associations using the established ALBW-P classifications were explored. In each case, birth weight was based on the four weight classifications used to establish ALBW_P. Collectively this approach provided a side by side comparisons of litter vs individual birth weight effects on gilt development, gilt retention and SLP.

**Statistical analyses:** Cumulative losses by death or removal at 4 days after birth, until weaning, at 70d of age, and selection into the breeding herd (>170 d of age), having applied standardized selection criteria, were first analysed using logistic regression models (GLIMMIX procedure). BiW class was considered a fixed effect and birth sow was included as random effects. PROC GLIMMIX used to determine effects of BiW and BiW class on developmental traits and on reproductive performance and retention of gilts bred until at least third parity (SLP). Birth sow and farm were used as random variables in the analyses. The analysis was limited to barns with BEAR systems.

**VIII. Results and Discussion:**

**Selection efficiency:** Retention rate at various stages of production for replacement gilts classified by the three different birth weight characteristics are shown in Table 1. As would be expected, relating retention rates to individual birth weight class resulted in greater variation in the retention results: However, even when analysed on the basis of the sow’s established ALBW-P, the trends were very similar. Gilts born to sows with the low ALBW_P have compromised retention at all stages of production compared to gilts born to sows with higher ALBW_Ps. A four percent difference in survival (retention) between the low and high ALBW-P sows was already evident at day 4 and by the Preselection-2 stage at day 170 had grown to nearly a 20% difference in retention rate.

**Table 1.** The effect of individual birth weight and sow birth weight phenotype on retention rate (%) from birth to “Pre-selection” at 170 d

<table>
<thead>
<tr>
<th></th>
<th>L</th>
<th>ML</th>
<th>MH</th>
<th>H</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 d after birth</td>
<td>93.0 ± 0.10a</td>
<td>94.2 ± 0.05a</td>
<td>95.5 ± 0.05b</td>
<td>96.0 ± 0.07b</td>
<td>0.0087</td>
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<tr>
<td>Weaning (~24d)</td>
<td>81.1 ± 2.2a</td>
<td>83.2 ± 1.5ab</td>
<td>84.7 ± 1.4b</td>
<td>86.4 ± 1.6c</td>
<td>0.0120</td>
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<td>Nursery Exit, (~70d)</td>
<td>70.3 ± 2.1a</td>
<td>75.3 ± 1.3b</td>
<td>77.4 ± 1.3bc</td>
<td>89.0 ± 1.7c</td>
<td>0.0011</td>
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<tr>
<td>Pre-Selection (170d+)</td>
<td>42.0 ± 2.9a</td>
<td>48.8 ± 2.4b</td>
<td>50.6 ± 2.5bc</td>
<td>53.8 ± 2.9c</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

a,b,c,d Differences within column are significantly different (P < 0.05)
Low birth weight, determined either on an individual pig basis, or on the sow’s average litter birth weight phenotype, is negative for pre-selection rate. Significant differences in survival are already present by day 4 and at weaning, reflecting the early crushing and poorer pre-weaning survival of low birth weight pigs and litters already reported at the commercial level of production (Smit et al., 2013). Also consistent with the present results, Magnabosco et al. (2015) reported that gilts weighing less than 1.0 kg at birth have increased pre-weaning morality and little chance of surviving until weaning and those gilts that do survive past the nursery phase have poor growth until finishing and are significantly lighter than their higher birth weight littermates. Results from the Preliminary Trial already indicate that a disproportionate number of low birth weight gilts are born to sows with the low and medium-low ALBW_P: Therefore, removing 10 to 15 % of nucleus sows with the low ALBW-P would substantially improve gilt retention rates of gilts born to the remaining sows. Additionally, very low birthweight gilts from sows with a higher ALBW-P would further improve the retention of gilts through the Pre-selection and Selection stages of production. In terms of the minimizing lifetime nucleus sows costs per replacement gilt produced, an early culling strategy for sows determined to exhibit the extremely low ALBW_P seems justified. If culling was based on litter birth weight data from the first two farrowings, even pure-bred nucleus replacement gilts could be removed as potential replacements at the Pre-selection 2 stage at around 170 days of age, at which time their birth dams would already have produced a second litter.

From a genetic transfer perspective, the production of very few replacement gilts in the productive lifetime of some sows in the production nucleus/multiplication herd represents a poor genetic investment. These sows only “earn” their genetic premium if their genetic potential is effectively passed on to their Camborough replacement gilts used for terminal line production. The disconnect between a high genetic merit for genetic traits included in the estimation of EBV and poor reproductive performance, and hence few offspring carrying these genes at the level of terminal line production, has an important impact on the efficiency of genetic transfer through the production nucleus herd. In many respects this situation is analogous to the problem of high EBV boars that are determined to have relatively low fertility when used for AI, either in single-sire or pooled semen doses, because these boars produce relatively few terminal-line progeny. In the larger production enterprises that manage their own boar studs and production nucleus/multiplication sow farms, the opportunity to optimize genetic transfer down to the level of terminal line production offers significant economic benefits. In both cases, the additional replacement costs of early culling of unproductive boars and sows is largely offset by the enhanced performance of the boars and nucleus sows remaining in production.

**Growth performance:** The associations among the different birth weight classifications and the growth performance of gilts to Pre-Selection at 170 days of age are shown in Table 2. Determined on an individual pig, birth weight had a highly significant effect on weights at 170 days. Comparable trends were seen when ALBW_P was used in these comparisons. The first and expected conclusion is that birth weight reflects post-natal growth potential, again reflecting results from studies at the terminal-line level of production (Smit et al., 2013) and in comparable replacement gilt studies (Amaral Filho et al., 2010; Magnabosco et al., 2015).
However, in all the birth weight classifications, gilts had adequate growth for achieving sexual maturity in response to stimulation with boars at the final Selection stage of gilt development. The study of Beltranena et al. (1991) defined a threshold growth rate to puberty of 0.55 kg/day below which the attainment of puberty was delayed. As with most recent surveys of gilt growth performance in systems that use feeding to appetite throughout gilt development, the data in Table 2 suggest that even the low birth weight gilts that are retained to the Pre-select 2 stage of development have sufficient growth performance to express their inherent sexual precocity. Therefore, little relationship would be expected between growth rate classification and the measured responses to stimulation with boars in the GDU/BEAR facilities. If the latter assumption is true, and the post-breeding performance of low ALBW_P progeny is not compromised, this raises questions about existing selection strategies that do not favor the retention of gilts with relatively low growth performance amongst their birth cohort. However, taking into account the cost of feed, non-productive days, numbers born alive and litter uniformity, Amaral Filha et al. (2010) recommended that at the time of breeding gilts should achieve a growth rates between 600 and 770 g/d for optimal performance. Again, most Pre-selected gilts in the present study would meet these growth requirements.

Table 2. The effect of individual birth weight (BWi) and sow average litter birth weight phenotype (BWP) on age, weight and growth rate at Pre-selection at 170 days of age.

<table>
<thead>
<tr>
<th>Individual Birthweight Phenotype (BWi)</th>
<th>L</th>
<th>ML</th>
<th>MH</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (d)</td>
<td>167.4 ± 4.6</td>
<td>167.4 ± 4.6</td>
<td>167.6 ± 4.6</td>
<td>168.2 ± 4.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>101.7 ± 6.0(^a)</td>
<td>107.6 ± 6.0(^b)</td>
<td>111.0 ± 6.0(^c)</td>
<td>115.0 ± 6.0(^d)</td>
</tr>
<tr>
<td>Growth rate (kg/d)</td>
<td>0.601 ± 0.02(^a)</td>
<td>0.635 ± 0.02(^b)</td>
<td>0.658 ± 0.02(^c)</td>
<td>0.679 ± 0.02(^d)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sow Birthweight Phenotype (BWP)</th>
<th>L</th>
<th>ML</th>
<th>MH</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (d)</td>
<td>167.8 ± 4.5</td>
<td>167.7 ± 4.5</td>
<td>167.4 ± 4.6</td>
<td>167.9 ± 4.6</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>103.5 ± 6.0(^a)</td>
<td>109.0 ± 6.0(^b)</td>
<td>111.6 ± 6.0(^c)</td>
<td>115.0 ± 6.0(^d)</td>
</tr>
<tr>
<td>Growth rate (kg/d)</td>
<td>0.612 ± 0.02(^a)</td>
<td>0.645 ± 0.02(^b)</td>
<td>0.660 ± 0.02(^c)</td>
<td>0.679 ± 0.02(^d)</td>
</tr>
</tbody>
</table>

a,b,c,d Differences within column are significantly different (P < 0.05)

At the other end of the growth rate spectrum, the excellent growth performance of gilts born to high ALBW_P sows may be an increasing problem for the industry, as individual gilts are achieving growth rates to puberty of > 0.7 kg/day. As there is no expected link between high growth rates and age at first estrus, some later maturing gilts achieve weights at HNS and at breeding that are above industry benchmarks. If the efficiency of inducing pubertal estrus is low, or the pre-stimulation management or health status of replacement gilts at the time of final selection is poor, over-weight gilts at breeding become a major risk factor for gilt retention in the breeding herd (Amaral Filha et al., 2010).

**Responses to puberty induction in the GDU:** The associations among birth weight classifications and responses to boar stimuli in the purpose built GDU/BEAR facilities used in the present trial are shown in Table 3. Collectively, the data confirm that, for those gilts retained beyond the Pre-
select 2 stage and moved to the GDU for stimulation with boars, there was little relationship between gilt birth weight and age at puberty when stimulation with boars commenced at around 182 days of age. However, because birth weight was positively associated with growth rate, there was also a positive association with weight at pubertal estrus, representing nearly a 10 kg difference in pubertal weight between gilts born to the low and high ALBW_P sows.

Table 3. The effect of individual birth weight (BWi) and sow average litter birth weight phenotype (BWP) on responses to standardized protocols for puberty induction.

<table>
<thead>
<tr>
<th>Individual Birthweight Phenotype (BWi)</th>
<th></th>
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<th></th>
<th></th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
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<td>n</td>
<td>L</td>
<td>ML</td>
<td>MH</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Age at boar stimulation</td>
<td>367</td>
<td>411</td>
<td>553</td>
<td>965</td>
<td>0.94</td>
</tr>
<tr>
<td>Days to recorded estrus</td>
<td>179.8 ± 2.0</td>
<td>179.5 ± 1.9</td>
<td>179.3 ± 1.9</td>
<td>179.6 ± 1.9</td>
<td>0.48</td>
</tr>
<tr>
<td>Gilts with HNS/gilts pre-selected (%)</td>
<td>85.6 ± 2.0</td>
<td>89.5 ± 1.6</td>
<td>90.6 ± 1.4</td>
<td>89.8 ± 1.1</td>
<td>0.08</td>
</tr>
<tr>
<td>Weight at recorded estrus</td>
<td>126.0 ± 2.5</td>
<td>130.1 ± 2.5</td>
<td>130.4 ± 2.5</td>
<td>132.5 ± 2.4</td>
<td>0.0001</td>
</tr>
<tr>
<td>Estimated weight at first service</td>
<td>141.6 ± 1.9</td>
<td>145.7 ± 1.9</td>
<td>146.4 ± 1.9</td>
<td>149.1 ± 1.8</td>
<td>0.0001</td>
</tr>
<tr>
<td>Gilts served/gilts pre-selected (%)</td>
<td>82.5 ± 2.1</td>
<td>86.5 ± 1.8</td>
<td>89.0 ± 1.4</td>
<td>87.8 ± 1.2</td>
<td>0.0266</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sow Birthweight Phenotype (BWP)</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>L</td>
<td>ML</td>
<td>MH</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Age at boar stimulation</td>
<td>210</td>
<td>798</td>
<td>687</td>
<td>307</td>
<td>0.24</td>
</tr>
<tr>
<td>Days to recorded estrus</td>
<td>180 ± 2.0</td>
<td>179.1 ± 1.9</td>
<td>179.5 ± 1.9</td>
<td>180.0 ± 2.0</td>
<td>0.28</td>
</tr>
<tr>
<td>Gilts with HNS/gilts pre-selected (%)</td>
<td>85.5 ± 2.5</td>
<td>89.6 ± 1.2</td>
<td>89.5 ± 1.3</td>
<td>90.7 ± 1.7</td>
<td>0.25</td>
</tr>
<tr>
<td>Weight at recorded estrus</td>
<td>129.2 ± 2.5</td>
<td>129.8 ± 2.4</td>
<td>131.0 ± 2.4</td>
<td>132.2 ± 2.5</td>
<td>0.01</td>
</tr>
<tr>
<td>Estimated weight at first service</td>
<td>144.8 ± 2.0</td>
<td>144.9 ± 1.8</td>
<td>147.1 ± 1.8</td>
<td>149.1 ± 1.9</td>
<td>0.003</td>
</tr>
<tr>
<td>Gilts served/gilts pre-selected (%)</td>
<td>84.5 ± 2.5</td>
<td>88.0 ± 1.3</td>
<td>86.6 ± 1.4</td>
<td>87.8 ± 1.9</td>
<td>0.49</td>
</tr>
</tbody>
</table>

a,b,c Differences within column are significantly different (P < 0.05)

The 15 to 17-day average response time from the start of stimulation in the BEAR systems to recorded HNS indicates effective application of the stimulation protocols. Although the on-farm GDU/BEAR systems can lapse into an almost continuous-flow style of management, early identification of a pubertal heat and early culling decisions for non-select gilts are essential if a gradual increase in entry-to-service intervals and overcrowding of GDU pens are to be avoided. As with the off-site GDU/BEAR sites that were part of this study, management of all GDUs on an all-in/all-out basis is important for maintaining breeding herd efficiency. The pubertal responses
shown in Table 3 are consistent with a 30 to 35-day puberty induction protocol as described in the Preliminary Phase Trial appendices.

Similarly, a comparison of mean age at puberty and mean age at service (a difference of around 27 days across all birth weight classes), suggests good compliance with a HNS protocol that provides known cyclic gilts to the breeding farm/breeding room for mating at second observed estrus. Again, given the good growth performance of contemporary commercial replacement gilts, implementation of an effective HNS program is critical if over-weight gilts at breeding are not to become a major risk factor for retention in the breeding herd.

**Post-selection performance:** Further analysis of litter birth weight effects on breeding performance, retention rate in the breeding herd and SLP was restricted to data from three sow farms, one of which received gilts from the same off-site GDU for which data were presented in the Preliminary Phase Trial, and two farms that maintained on-site GDU facilities. Substantial numbers of tagged “litter of origin” gilts were directed to these three sow farms which were largely free of any major disease breaks during the course of the Main Trail. The data therefore provide a “best-case” look at the impacts of gilt litter of origin on SLP. Although more restrictive, these analyses still included SLP data on over 2,000 select gilts whose performance could be linked back to their litter of origin.

Within this population of gilts, responses to puberty stimulation and key traits at selection were similar to those discussed above. The proportion of Pre-select gilts with a recorded HNS event was between 85 and 90 percent and provided an adequate flow of select gilts to meet gilt breeding targets. Better than 95% of the select gilts with a HNS record were eventually bred, matching the level of selection/breeding efficiency reported for the off-site GDU in the Preliminary Phase Trial. These results confirm our expectation that gilts that are induced into a recorded standing heat using effective combinations of boar stimuli will return to second estrus after a normal 21-day cycle and be available for breeding on a predictable basis. The reasons for industry problems with what are termed “hard-headed” gilts, that fail to show good standing heats or fail to show second estrus, suggests that important components of either the puberty induction or pre-breeding protocols are missing.

As observed for weight at pubertal estrus, the positive relationship between ALBW_P and growth rate resulted in significant differences in estimated breeding weight. For the high ALBW_P category, a mean estimated breeding weight of 150 kg indicates that a proportion of these gilts will have exceeded the upper targeted weight for breeding. Moreover, breeding weights for the other classes of ALBW_P fall in the upper range of target breeding weights of 135 to 150 kg. Even with an efficient gilt selection and HNS protocol, an increasing risk for SLP is the over-weight gilt at breeding.

**Litter size born over four successive parities** was not limited by a low ALBW-P. Total born Parity 0 (gilt) litter size met industry benchmarks, averaging over 14 pigs, and subsequent total born litter size was consistent with the reported genetic potential of the Camborough sow. The only significant difference in the data shown in Table 5 was a lower second litter size in the sows born
to the medium-high ALBW_P dams. Our earlier research on the associations between the metabolic state of weaned parity 1 sows and their subsequent reproductive performance (Patterson et al., 2011; Foxcroft, 2012) might suggest a negative impact of the higher maintenance costs of these heavier sows during lactation on the amount of tissue catabolism needed to meet their requirements for continued growth and milk production. However, the better performance of the sows from high ALBW_P dams seems to challenge such assumptions.

Table 5. The effect of sow litter birth weight phenotype on litter size to fourth parity.

<table>
<thead>
<tr>
<th>Individual Birthweight Phenotype (BWi)</th>
<th>L</th>
<th>ML</th>
<th>MH</th>
<th>H</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>259</td>
<td>323</td>
<td>446</td>
<td>752</td>
<td></td>
</tr>
<tr>
<td>Parity 1</td>
<td>14.4 ± 0.3</td>
<td>14.5 ± 0.3</td>
<td>14.5 ± 0.2</td>
<td>14.5 ± 0.2</td>
<td>0.88</td>
</tr>
<tr>
<td>Parity 2</td>
<td>14.7 ± 0.2</td>
<td>14.5 ± 0.2</td>
<td>14.4 ± 0.2</td>
<td>14.5 ± 0.2</td>
<td>0.71</td>
</tr>
<tr>
<td>Parity 3</td>
<td>15.4 ± 0.2</td>
<td>15.1 ± 0.2</td>
<td>15.1 ± 0.2</td>
<td>15.2 ± 0.2</td>
<td>0.62</td>
</tr>
<tr>
<td>Parity 4</td>
<td>15.4 ± 0.2</td>
<td>15.9 ± 0.2</td>
<td>15.4 ± 0.2</td>
<td>15.4 ± 0.2</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Table 6. The effect of individual gilt birth weight (BWi) and sow average litter birth weight phenotype (BWP) on retention rate (% of gilts bred) to rebreeding after weaning their third litter.

<table>
<thead>
<tr>
<th>Individual Birthweight Phenotype (BWi)</th>
<th>L</th>
<th>ML</th>
<th>MH</th>
<th>H</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>193</td>
<td>710</td>
<td>605</td>
<td>272</td>
<td></td>
</tr>
<tr>
<td>Parity 1</td>
<td>14.0 ± 0.3</td>
<td>14.2 ± 0.2</td>
<td>14.3 ± 0.2</td>
<td>13.8 ± 0.3</td>
<td>0.28</td>
</tr>
<tr>
<td>Parity 2</td>
<td>14.4 ± 0.4</td>
<td>14.6 ± 0.3</td>
<td>13.8 ± 0.3</td>
<td>14.4 ± 0.4</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Parity 3</td>
<td>15.2 ± 0.4</td>
<td>15.6 ± 0.3</td>
<td>15.2 ± 0.4</td>
<td>15.3 ± 0.4</td>
<td>0.44</td>
</tr>
<tr>
<td>Parity 4</td>
<td>16.0 ± 0.4</td>
<td>15.6 ± 0.2</td>
<td>15.3 ± 0.2</td>
<td>15.6 ± 0.3</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Retention of sows in the breeding herd over three parities met the industry benchmark of greater than 70%, irrespective of the ALBW_P of their dams. Retention was clearly not compromised in the gilts derived from dams with a low ALBW_P and in fact was optimal in these gilts (Table 6).
Indeed, as shown in Table 6, a higher ALBW_P represented an increasing risk for retention in the breeding herd, which is presumed to be linked to the higher weights of these sows when first bred. The trend for the rate of attrition of sows derived for the higher ALBW_P dams to increase with successive parities is consistent with the reported link between heavier weights at selection and breeding and removal due to lameness and locomotion problems (Amaral Filha et al., 2010). In ongoing analyses of the reported reasons for culling, it will be interesting to see if similar associations are apparent in the present study.
### Appendices:

#### Appendix 1 – Publications and Meetings:

<table>
<thead>
<tr>
<th>Event / Conference</th>
<th>Title / Description</th>
<th>Authors / Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 2015 – ASAS Midwest Meeting</td>
<td>Determining birth weight phenotype in a sow population.</td>
<td>George Foxcroft</td>
</tr>
<tr>
<td>March 2015 – ASAS Midwest Meeting</td>
<td>“Select” gilts have superior lifetime productivity.</td>
<td>Jenny Patterson</td>
</tr>
<tr>
<td>Leman Swine Conference 2015.</td>
<td>5 presentations</td>
<td>Jenny Patterson and George Foxcroft</td>
</tr>
<tr>
<td>J. Anim. Sci. 2016.94 doi:10.2527/jas2015-9705</td>
<td>Validation of the use of exogenous gonadotropins (PG600) to increase the efficiency of gilt development programs without affecting lifetime productivity in the breeding herd</td>
<td></td>
</tr>
<tr>
<td>AASV March 2016, New Orleans</td>
<td>Gilt management for improved performance</td>
<td>Jenny Patterson</td>
</tr>
<tr>
<td>AASV March 2016, New Orleans</td>
<td>Updates on sow longevity – Litter of Origin</td>
<td>Jenny Patterson</td>
</tr>
<tr>
<td>Nutritionist Round Table, World Pork Expo, June 2016</td>
<td>Impact of litter of origin on post-natal growth, subsequent performance and selection practices in the nucleus herd</td>
<td>Jenny Patterson</td>
</tr>
<tr>
<td>Leman Swine Conference: Reproduction Workshop Sept 17, 2016</td>
<td>Factors affecting nucleus gilt replacement programs, Origins of Sow Longevity and Productivity, Enhancing pre-weaning growth performance in replacement gilts by manipulating the litter size, Pubertal response of gilts with or without direct boar contact and with or without PG600</td>
<td>George Foxcroft, Jenny Patterson, Charlotte Meli, Ashley Daniel</td>
</tr>
<tr>
<td>Leman China, Xi’an, China, October 2016</td>
<td>Managing gilts for optimal lifetime performance</td>
<td>Jenny Patterson</td>
</tr>
<tr>
<td>Chilean Swine Congress, Concepcion, Chile, November 2016</td>
<td>Gilt management for improved performance</td>
<td>Jenny Patterson</td>
</tr>
<tr>
<td>Chilean Swine Congress, Concepcion, Chile, November 2016</td>
<td>Updates on sow longevity – Litter of Origin</td>
<td>Jenny Patterson</td>
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<tr>
<td>Event</td>
<td>Title</td>
<td>Presenter(s)</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>NHF Blue print article, October 2016</td>
<td>Large litter size vs. low average birth weight — it’s a production trade-off</td>
<td>Jenny Patterson and George Foxcroft</td>
</tr>
<tr>
<td>NHF Blue print article, November 2016</td>
<td>Effective selection of gilts is primary driver for sow herd productivity</td>
<td>George Foxcroft and Jenny Patterson</td>
</tr>
<tr>
<td>Banff Pork Seminar 2017</td>
<td>Pubertal Response of Gilts to Method of Boar Exposure and PG600 (Poster)</td>
<td>Ashley Daniel</td>
</tr>
<tr>
<td>ASAS Midwest Conference, Omaha, NE (March 2018)</td>
<td>A low litter birth weight phenotype reduces the retention rate of potential replacement gilts. (spoken paper)</td>
<td>Jenny Patterson</td>
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<tr>
<td>London Swine Conference London, ON (March 2018)</td>
<td>Troubleshooting reproductive issues</td>
<td>Jenny Patterson</td>
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<tr>
<td>NPC Pork Academy, WPE, Des Moines, IA (May 2018)</td>
<td>Gilt litter of origin, gilt management and sow lifetime productivity</td>
<td>George Foxcroft</td>
</tr>
</tbody>
</table>

**Project Meetings & Research-based Trips to HFI:**

January 2015 - Jenny spent several days at HFI when litter tagging was implemented.

March 2015 - Jenny Patterson two days at HFI to collect 500+ tissue samples for DNA collection and meetings with the HFI team.

June 2015 – Jenny Patterson, Julia Moroni, Billy Flowers and Charlotte Meli at Triagra to implement litter manipulation trial.

June, July, August 2015 – Charlotte and Julia to Triagra ~ 5 times for trial implementation.

September 2015 – Jenny Patterson, George Foxcroft, Robert Knox and Ashley Daniel to ProAg for implementation of gilt trial.

November 2015 – Jenny Patterson to ProAg to assist Ashley Daniel in the initiation of her trial

November 2015-January 2016 – Ashley Daniel based at ProAg.

December 2015 – Jenny Patterson and George Foxcroft to Triagra for implementation of Genome Canada trial and interactive discussions with the HFI Farm Management group.

February 2016 – Jenny Patterson, Mike Dyck, and 2 Phd students to Triagra twice for collection of samples associated with the Genome Canada trial

May 2016 – Jenny Patterson to ProAg for the implementation of the summer project.

May 2016-June 2016 – Brenna Clark and Stephanie Gartner (2 undergraduate students from the UofA) were at ProAg for 6 weeks to run the summer project.

July 2016 – Jenny Patterson and Stephanie Gartner to ProAg
July 2016 – Charlotte Meli and Ashley Daniel to ProAg

September 2017 – Jenny Patterson and George Foxcroft to HFI head office to discuss project outcomes and a new NPB-funded implementation project.

June 2018. George Foxcroft and Jenny Patterson. On-site project meetings (HFI head office, Northfiled, MN) and presentation (JP) to HFI Annual Shareholder Production meeting (Albert Lea, MN)

Appendix 2: References


