**Nutritional and Environmental Impact of Raising Breeding Swine on Pasture and Woodlot**

***"An Exploration of the role of Heritage Pigs in Local Food Systems"***

A Division Three Research Project By: April Nugent Livestock Management Major

Hampshire College Farm

Hampshire College, Amherst Massachusetts

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Natural Sciences Department Grants

**Experiment Summary**

In this project I aimed to research the nutritional and reproductive impact of environmental surroundings on a breeding population of heritage breed swine. The hope is that its findings will offer insight into the environmental impact of raising these animals under different management systems and provide producers with useful information about production efficiency in these settings. In order to explore this concept, data was collected on two separate groups of breeding females, one housed on pasture and one in a woodlot setting. Previously several studies have been done on the impact of nutrition on factors of swine production such as feed efficiency and carcass characteristics like back fat depth as well as reproductive success. However, many of these studies have been conducted on animals housed in confinement style management systems. Therefore there is a distinct lack of research on these topics that is actually applicable to small scale swine producers raising their pigs outside or in rotational grazing systems.

There are also a limited amount of studies that have explored the effects of pasture and woodlot on swine nutrition. One such study has suggested that animals eating grass and other woodlot forages like native tree nuts could be expected to have a higher back fat thickness than those fed a formulated diet (Rey, et al. 2006; Nilzen et al. 2001). Another Italian study on raising Iberian pigs in pasture based settings suggested that housing swine on pasture provides a chance to potentially increase nutrient intake and that swine reared on pasture exhibited longer breeding periods than those indoors (Fortina et al. 2011). Something which is extremely advantageous to producers who are trying to inseminate their animals through natural service or artificial insemination. Another study with similar methods revealed that “Ingestion of herbage and soil by pigs on pasture can make a substantial contribution to the energy, amino acid, mineral and micronutrient requirements of the dry sow" (Pg. 263 Edwards, 2003). In fact in an intensive nutritional study on the effects of environment and diet fortification in breeding gilts (breeding females who have yet to farrow their first litter) it was found that gilts raised on pasture did not express greater weight gain or loss during pregnancy and lactation than conventionally housed pigs; but they did express higher levels of selenium and vitamin E at weaning and that resulting weaned piglets were at more of an advantage if their dams had been housed on pasture than conventionally housed pigs (Mutettika et al. 1993).

## Introduction and Literature Review

In recent years there have been an increase in the number of studies investigating the impacts of nutrition on the reproductive success of sows. Despite this renewed excitement in swine reproductive efficiency the link between maternal nutrition and fetal development in mammals remains poorly understood. There is also a distinct absence of research about the effects of maternal nutrition of sows past the embryonic and nursing stages. This lack of definitive knowledge provides an avenue for the development of new research aiming to create a better understanding of the relationship between our prenatal and early developmental environments on our future biological successes. Many studies that have been done on the impact of nutrition on swine are performed under conventional and industrialized methods of production. However this creates a distinct lack of accessible information about the roles of nutrition in heritage breed varieties and the impact of natural forages on the performance of these animals as a whole. Therefore this lack of applicable swine research negatively affects small scale producers by in effect by lessening their ability to make informed management decisions that are grounded in science. In response to this lack of information I  made the decision to undertake a five month long research project that would examine the effects of nutrition on the reproductive success of heritage breed sows and their offspring.

Heritage varieties of livestock represent a subsector of the number of breeds of animals on farms today. These animals are often reminiscent of a simpler time and reflect the needs of the culture and in era in which they were developed; often uniquely adapted to the specific regional environments of their origins and providing products that were desirable to their handlers in that time. Heritage breeds can often prove to be an extremely beneficial addition to many small farms and homesteads because of their ability to extract nutrition from natural forages and sustain themselves on a less intensive diet than conventionally produced animals. However, -within the modern agricultural world there's very little attention paid to heritage breeds because these animals are often only well adapted to one specific climate type or task and therefore many of them do not perform well under standardized and regimented conventional growing conditions. Despite this these breeds are representative of a growing number of the animals that small scale producers are choosing to utilize in their own operations where these unique adaptations are beneficial. This is especially true in the case of the Gloucestershire Old Spots at the Hampshire College Farm as Spots are a breed traditionally raised to forage in orchard settings and much of the farm’s property is heavily wooded former orchard land.

**Groundwork Studies**

In one existing study on the relationship between nutrition and reproductive success in swine researchers specifically focused on the relationship between feed restriction on success factors such as embryo survival rates and the occurrence of estrus in the sow post weaning. This experiment utilized two groups of primiparous sows fed on prepartuition diets of a standard lactation diet containing 20% crude protein. One group received 5kg of feed a day while the other was limited to only 2.5kg per day during lactation before eventually being given access to feed ad libitum post weaning. These sows were then bred back and humanely slaughtered at 30 days of gestation in order to examine their reproductive tracts and embryo development. The results of this revealed that on day 30 of gestation “the number of live embryos were lower in restricted diet sows than in the control sows”. Additionally “ the sex ratios of embryos were 61% males for restrict sows and 54% males for controls”(Pg.350, M.D. Vinsky et al. 2006). These findings not only suggest that there is a clear link between good nutrition and sows abilities to produce viable litters but also show that there may be an association between a pregnant sow’s diet and the distribution of gender in her litter. Vinskey et al hypothesized that this phenomena was a result of the local resource competition theory that states animals with restricted access to resources may choose to prioritize male offspring who will disperse upon reaching sexual maturity and not stay in their birth territory as females will. Furthering studies of this phenomena could prove beneficial to the swine community by providing producers with the knowledge to produce uterine environments that are receptive to the production of female offspring which are much more valuable in the marketplace.

In R.N. Kirkwood's study on the influence of feeding level during lactation and its effects on the occurrence of estrus post weaning, researchers noted that almost one third of breeding sows are culled annually because of excessive anestrus or infertility issues; this an issue which costs pork producers thousands of dollars annually. This study revealed that sows "fed only 3kg daily took, on average, 38 hrs longer to return to estrus than those fed 6kg daily" and that "all high fed sows displayed estrus, but 15% of low fed sows were anestrus 25 days after weaning" (Pg. 411, R.N. Kirkwood et al.1986). The greater implication of this of course is that many potentially reproductively sound sows may be being unnecessarily culled due to reproductive issues such as a failure to return to estrus as a result of poor nutrition during previous lactations and periods of estrus. This further burdens producers financially and emotionally.

My study also attempted to examine the environmental impacts of swine production on various outdoor grazing systems. Many consumers tend to think about swine's interaction with the environment solely via the lens of commercialized indoor farming systems. In these systems many tons of manure and biological wastes are created annually. Without proper management plans these substances can run off into ground water sources or other nearby locations causing environmental pollution through nutrient leaching, antibiotic runoff or biological threats like the spreading of infectious diseases through direct exposure to these substances or through airborne contamination (Donham 2000). Even feral swine populations can prove detrimental to health of their environments if they are not managed properly; their ravenous appetites, rooting and rubbing behaviors can cause the destruction of natural plant species as well as cultivated crops (Campbell & Long 2009). There is also an existing public perception that swine are naturally filthy animals and that their rooting behaviors are extremely destructive to pastures and forest environments.

This study sought to fight that paradigm and analyze the effects of these animals on soil fertility and their surroundings in order to assess if it were possible with proper livestock management to have swine be minimally destructive to the environment. I would argue that swine can actually be used as a tool for improving soil fertility if care is taken to rotate them frequently. To assess all of these theories detailed records on soil fertility and the relative health of the study animals were obtained in order to synthesize a better understanding of these interacting factors and their effects on one another. The overall aim of this publication is to provide small scale producers and future scholars with the tools to make deeper inquiries into the interconnectedness of environments and their inhabitants as well as supply these producers with the tools to make informed production decisions that support improved animal health and environmental stewardship.

## Farm Facilities

The Hampshire College Farm Center is located in Amherst Massachusetts and acts as an extension of Hampshire College's hands on educational programs just a 10 minute walk from the main campus. The mission of the Farm Center is to "support teaching and research opportunities for faculty and students; serve as a model for land stewardship and ecological agricultural practices; and provides a "living lab" for Hampshire's values, particularly in the areas of sustainability, social justice, community-building, and experiential education" (Hampshire College Vision and Mission Statement 2017).

The farm currently utilizes about 80 acres of land in active agricultural production including 15 acres in organic vegetable production, another 65 in pasture and hay and rents several acres to local dairy farmers for feed corn production. The main property is located just a short walk from the main campus however many of the Hampshire College Farm's operations also take place on other relatively small plots of land surrounding the main campus. Additional acreage of native deciduous forests that are a home to a small sugarbush and lots of hiking trails, pastures and hay fields are also part of the property utilized by the Farm Center. The farm serves as a tool for hands on education in the fields of animal behavior, sustainable agriculture and many other interdisciplinary courses of study. Annually the farm employs almost fifty work-study students during the school year who assist in the care of the facility's livestock as well as the harvest, cleaning and packing of vegetables. Over the summer months the farm employs several full time student workers in addition to its four year round employees to assist in the management of the farm during its peak production season.

On this acreage the farm produces enough organic vegetables for an over 200 member CSA program and supplies many pounds of fresh produce to the school's only dining hall; over 65,000 lbs annually. A newly reformatted meat CSA program is also functioning at the farm and the livestock production of the facility feeds this and most of the demands of the dining hall. The livestock program utilizes a small flock of egg laying chickens, an annual herd of between 7 and

10 heritage breed beef cattle, 30 spring lambs and a breeding group of approximately 5 registered Gloucestershire Old Spot pigs to meet these production demands.

Farm facilities include several barns, storage sheds, greenhouses, converted farmhouses, a compost pad and a small irrigation pond. The everyday operations of the farm and farm staff offices are located on the side of the farm closest to the main campus. Thorpe Farm House is the hub of much of the activity and houses all the farm offices as well as one animal behavior lab accessible to students. This building exist as a relic of the original property owner's dairy farm. This side of the farm also has the Thorpe barn which houses machinery and small livestock, the CSA barn, Hampshire College Sugar Shack and several propagation greenhouses. The far side of the farm houses the main barn and attached washroom which formerly existed as a dairy parlor and processing space. This barn now serves as equipment storage. This section of the farm also includes a small chicken coop , the cattle loafing shed, a tractor storage shed, small livestock shed housing meat pigs, equipment workshop and another farmhouse with an attached garage that serves as extended machine repair workspace. The pastures, hay fields and vegetable production areas are scattered throughout the properties.

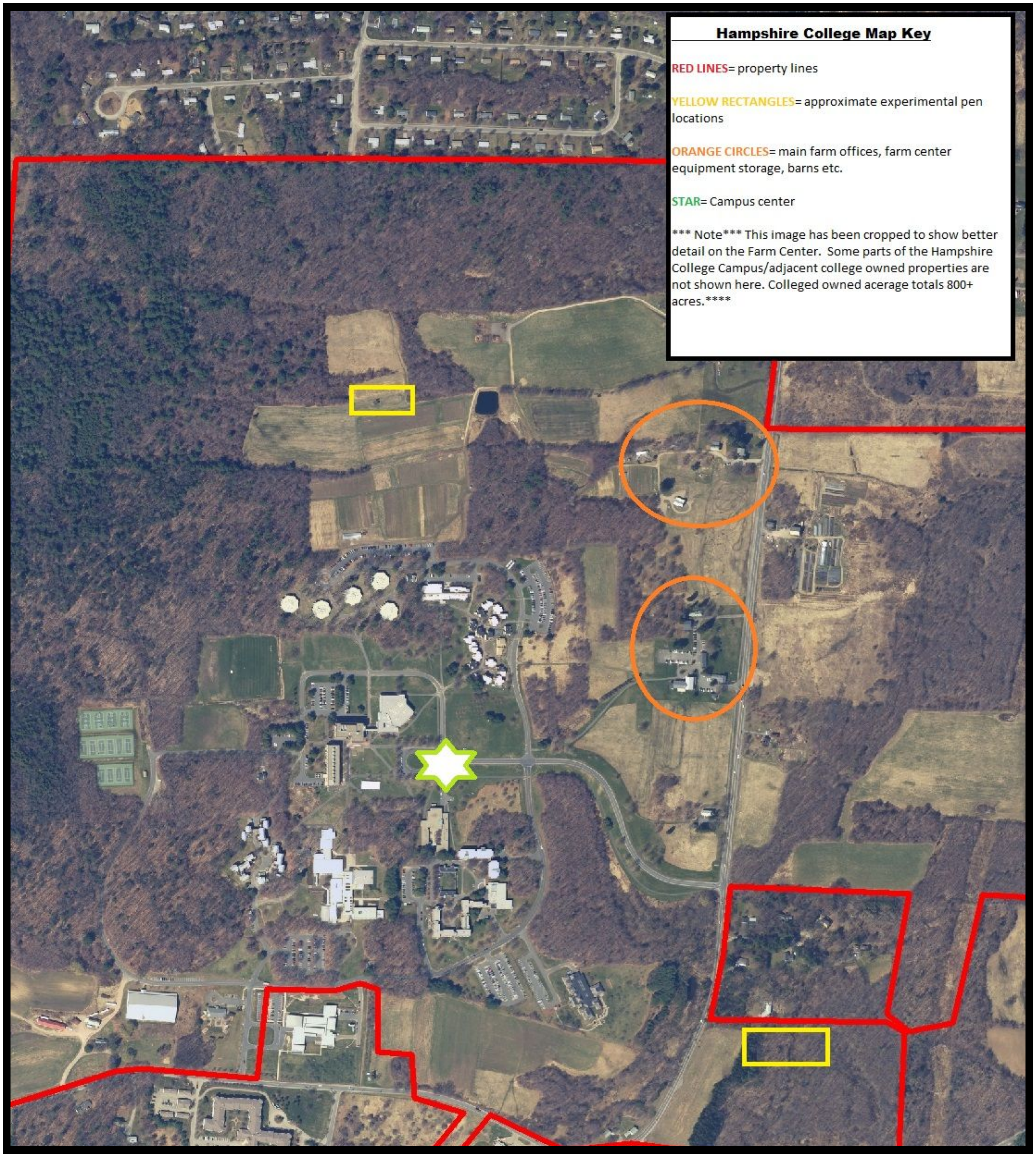



Figure 1: Satellite Image Map of Hampshire College Properties (Focus on farm facilities)

## Breed Characteristics and Study Animal Descriptions

### *Breed Characteristics*

The animals utilized in this study included four purebreed Gloucestershire Old Spots sows and gilts as well as their resulting offspring. Gloucestershire Old Spots are a heritage breed of swine originating from the Gloucestershire region of England. This breed is the oldest pedigreed spotted pig in the world so there is a very detailed record of registered animal's pedigrees going back to the early 19th century. This breed is also noted for its natural mothering ability and adaptability to a variety of forages including tree nuts, fruit drops, grasses and tuberous roots. As a result of these traits it is well suited for use on pastures or in woodland grazing situations. This breed was chosen to represent the sort of pigs many small scale farmers in New England might find suitable for their operations due to these characteristics. Old spots are also notoriously docile making them a great breed to utilize on hands-on educational farms like the one at Hampshire.

### *Study Animals*

The study animals consisted of four female Gloucestershire Old Spot pigs who were all individually identified by unique ear tag numbers. These animals were obtained from Hidden Nest Farm in Winchester, New Hampshire and included two older sows one six years of age (Phyllis ear tag: US/2/ROS), another of a year and a half of age (Mabel ear tag: 4-16-1) in the woodlot pen as well as a pair of littermate gilts of less than one year of age (ear tags: 3-16-1 Jane and 3-16-2 Roxy) that were housed in the pasture enclosure. Care was taken to select only females which shared genetic ties to one another in some respect somewhere on the maternal side of their pedigree. Each animal was bred to a boar of the same breed either during the duration of the experiment or immediately prior. Throughout the duration of the study each animal conceived one litter of live piglets and weight, sex ratio and mortality data was collected on the piglets until they were weaned at eight weeks of age.

Figure 2: Wood's Sow Phyllis; Ear tag: US/2/ROS on her first day at the farm with April Nugent and Pete Solis (Hampshire College Farm Livestock & Pasture Manager 2015-2018)

| Sow ID# | Name | Age | Sow Pedigree Line | Size of Birth Litter | Previous Litters | Experimental Pen |
|---|---|---|---|---|---|---|
| 3.16.1 | Roxy | <1 | Red Princess Mary | 7 | 0 | Pasture |
| 3.16.2 | Jane | <1 | Red Princess Mary | 7 | 0 | Pasture |
| 4.16.1 | Mabel | 1.5 | Green Princess | 5 | 1 | Woods |
| US/2/ROS | Phyllis | 6 | Red Princess Mary | 9 | 12 | Woods |

Table 1: Study Animal descriptions, pedigree and breeding information.

## Materials and Methods

### *Feed Rations and Medical Care*

Throughout this study data was collected on the weight changes of the study animals and their offspring as well as the relative reproductive success of the sows. Gloucestershire Old spots are known as lard variety of pig and are prone to becoming over conditioned on high protein diets, thus leading to reproductive issues. To avoid this issue sows were fed rations that were calculated based on their changes in body weight throughout the duration of the study. In addition to having access to natural forages the pigs were feed a supplemental ration of Green Mountain Organic Pig Grower pellets and cracked corn twice daily. Guaranteed analysis from Green Mountain certifies that their grower pellets contain a minimum of 16% crude protein (CP) and their organic cracked corn 7% CP. The pigs were feed on a ration of 3% of their live weight up until three weeks prior to their expected farrow date and from two weeks post farrowing through weaning they were fed 4% body weight. Exact ration values were equal to 25% corn and 75% grain by weight of the total ration required. This grain ration were divide into two daily feedings occurring each morning and evening. During the duration of the study the pigs were dewormed once but not given any other supplements such as iron injections or other vaccinations.

### *Data Collection*

Live weight of the pigs was accessed on a weekly basis and rations were altered to reflect that new live weight feed requirement every 19 days except for the period between 14 days prior to the expected farrow date until 14 days post parturition. The decision to do this was made in order to assure sows were not over conditioned going into labor, something which can prove detrimental to a healthy delivery.

Weight data on sows and their offspring were collected via the use of a swine weight tape. This measuring tape allows producers to assess the approximate live and carcass weights of animals based on measurements of length (L) and heart girth (Hg). These weights were determined by plugging the length and heart girth measurements of animals into one of two formulas. Heart girth measurements were taken around the circumference of the pig just behind the shoulder blades, length was measured along the midline of the back from the base of the ears to the base of the tail. The formula used to assess approximate live weight was Live Weight= $(Hg^2*L)/400$. The carcass weight formula was Carcass Weight = $((Hg^2 *L)/400)*0.72$. Swine weight tape is not as reliable as measuring weight via a livestock scale as it can be off by 5-10lbs in either direction but this equipment was unavailable during the duration of the study and weight tape is an easy tool for measuring animals housed outdoors without causing too much disruption in their normal routines.

## Location and Experiment Design

### *Experimental Pen Layout*

Each of the two experimental groups were housed in a pen setup that featured a three strand high electrified twine fence powered by marine batteries and electric fence charger.Within each experimental pen was a central pen that was the location of their twice daily feedings, farrowing huts and free choice water access. Off of this main pen were a series of four identically dimensioned laneways which the animals were given access to on a rotating basis (See Figure 3).

Dimensions of the laneways were as follows 270 ft x 27.5ft. Dimensions of the home pens were 50ft x 110ft . The total square footage of all four laneways was equal to 0.68 acres.

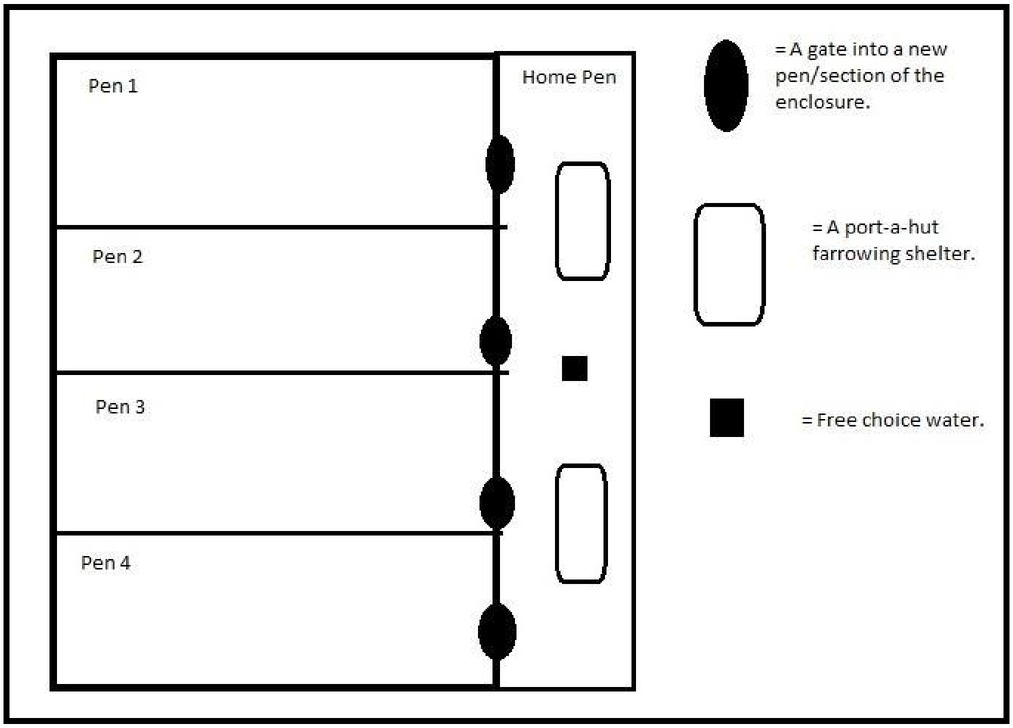



Figure 3: Experimental pen layout diagram

*Pasture Enclosure*

The pasture selected for use in this study was previously utilized as part of the fall rotational grazing acreage for the college's herd of beef cattle for several years and in the past two seasons as a hayfield. Because of these years of use, and a lack of limestone application in the past few years, this field was deficient in many nutrients. Forage sampling of the site revealed that despite these deficiencies the pasture is home to several forage species varieties including orchard grass, various clover species, tall fescue and other species of pasture plants. This pasture was also affected by several patches of multiflora rose and blackberries growing around a dead tree in the middle of this field. This pasture was located on the far end of the farm adjacent to a large portion of college owned wooded property. This field was secluded and received little noise pollution from campus and nearby roadways. However these animals were more often exposed to farm machinery, tour groups and local visitors walking along the farm trails. The total dimensions of this pasture were 35,200 sq ft (0.8 acres).

### *Woodlot Enclosure*

The woodlot used in this study was located on a property down the road from the main farm property. This patch of woods is located directly behind an old farm house that once housed the original land owner’s family. As far as college records indicate this patch of forest was never used for agricultural purposes however its history before it came into possession by the college is still largely unknown. This patch of land is home to a small brook and bog like area where runoff containing animal manures and mowing remnants from the pastures uphill collects. Plant species in this plot included maples, chestnuts, walnuts, hemlocks, and ash trees in addition to other understory species found in that environment. This location was located directly adjacent to route 116 in Amherst so these animals were exposed to more noise pollution from campus and the road then their pasture raised counterparts. These animals also received more attention from the public traveling along this roadway and received many visits from locals driving by. Total dimensions of this location were also 35,200 sq ft (0.8 acres).

## Results and Discussion

### *Soil and Forage Analysis*

Prior to the arrival of the pigs on the pasture and woodlot plots soil samples were taken and sent off to be analyzed through the University of Massachusetts (Umass) Soil and Plant Nutrient Testing Laboratory. Soil samples taken after the removal of the pigs were also performed through this same laboratory. Preliminary soil analysis taken on the study pens before the pigs arrived indicated that the pasture pen had a baseline pH of 6.4, below optimum levels of phosphorus, potassium and calcium (see Table 2). Analysis of the woodlot sample revealed that this soil had a lower pH level (5.8), and shared a similar lack of adequate macronutrients (see Table 4). Plant forage species information was also collected by sampling the species of grasses, legumes and herbage found in each pen. These most common plant species present were identified and included in the study pen descriptions.

Upon analysis of the soil sampling results it was determined that in all experimental pens many of both micro and macro nutrient levels improved overtime (Tables 3, 5; Figure 5) as a result of the swine turning over soil and depositing manure thus improving the soil's fertility. Professor of Soil Sciences Masoud Hashemi (Umass Amherst) was consulted when determining the results of these tests and he noted that he saw a significant improvement in soil organic matter in the pasture paddock and a slight improvement of the CEC (cation exchange capacity; a measure of soil fertility) were also noted (see Figure 4). Both of these findings were not of much surprise when compared to the original hypothesis of increased fertility and soil health occuring after the introduction of rotationally grazed pigs. Another observation of note is that all the paddocks became more acidic over time; however this cannot be attributed to the presence of swine as it is instead likely is a result of acidic rainfall notoriously attributed to New England. Because of the nature of this acidic rainfall it is highly recommended that producers relime agricultural fields and pasturelands in this area with frequency.

**Results**

| *Analysis* | *Value Found* | *Optimum Range* | *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|---|---|---|
| **Soil pH (1:1, H2O)** | 6.4 | | **Cation Exch. Capacity, meq/100g** | 7.6 | |
| **Modified Morgan extractable, ppm** | | | **Exch. Acidity, meq/100g** | 1.5 | |
| *Macronutrients* | | | **Base Saturation, %** | | |
| Phosphorus (P) | 3.8 | 4-14 | Calcium Base Saturation | 59 | 50-80 |
| Potassium (K) | 28 | 100-160 | Magnesium Base Saturation | 21 | 10-30 |
| Calcium (Ca) | 891 | 1000-1500 | Potassium Base Saturation | 1 | 2.0-7.0 |
| Magnesium (Mg) | 190 | 50-120 | **Scoop Density, g/cc** | 1.06 | |
| Sulfur (S) | 10.1 | >10 | | | |
| *Micronutrients* * | | | | | |
| Boron (B) | 0.0 | 0.1-0.5 | | | |
| Manganese (Mn) | 3.3 | 1.1-6.3 | | | |
| Zinc (Zn) | 0.7 | 1.0-7.6 | | | |
| Copper (Cu) | 0.7 | 0.3-0.6 | | | |
| Iron (Fe) | 2.8 | 2.7-9.4 | | | |
| Aluminum (Al) | 32 | <75 | | | |
| Lead (Pb) | 0.9 | <22 | | | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

**Results**

| *Analysis* | *Value Found* | *Optimum Range* | *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|---|---|---|
| **Soil pH (1:1, H2O)** | 6.2 | | **Cation Exch. Capacity, meq/100g** | 10.5 | |
| **Modified Morgan extractable, ppm** | | | **Exch. Acidity, meq/100g** | 3.5 | |
| *Macronutrients* | | | **Base Saturation, %** | | |
| Phosphorus (P) | 4.7 | 4-14 | Calcium Base Saturation | 48 | 50-80 |
| Potassium (K) | 69 | 100-160 | Magnesium Base Saturation | 17 | 10-30 |
| Calcium (Ca) | 1005 | 1000-1500 | Potassium Base Saturation | 2 | 2.0-7.0 |
| Magnesium (Mg) | 221 | 50-120 | **Scoop Density, g/cc** | 1.01 | |
| Sulfur (S) | 12.9 | >10 | | | |
| *Micronutrients* * | | | | | |
| Boron (B) | 0.1 | 0.1-0.5 | | | |
| Manganese (Mn) | 5.2 | 1.1-6.3 | | | |
| Zinc (Zn) | 0.8 | 1.0-7.6 | | | |
| Copper (Cu) | 0.1 | 0.3-0.6 | | | |
| Iron (Fe) | 3.5 | 2.7-9.4 | | | |
| Aluminum (Al) | 45 | <75 | | | |
| Lead (Pb) | 0.5 | <22 | | | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

Tables 2-3: Pasture Soil Samples pre (top) and post (bottom) the introduction of pigs. Samples were taken 5/1/17 and 10/31/17 respectively. Analysis done courtesy of Umass Soil and Plant Nutrient Testing Lab.

**Results**

| *Analysis* | *Value Found* | *Optimum Range* | *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|---|---|---|
| **Soil pH (1:1, H2O)** | 5.8 | | **Cation Exch. Capacity, meq/100g** | 11.8 | |
| **Modified Morgan extractable, ppm** | | | **Exch. Acidity, meq/100g** | 4.8 | |
| *Macronutrients* | | | **Base Saturation, %** | | |
| Phosphorus (P) | 1.1 | 4-14 | Calcium Base Saturation | 50 | 50-80 |
| Potassium (K) | 61 | 100-160 | Magnesium Base Saturation | 8 | 10-30 |
| Calcium (Ca) | 1188 | 1000-1500 | Potassium Base Saturation | 1 | 2.0-7.0 |
| Magnesium (Mg) | 109 | 50-120 | **Scoop Density, g/cc** | 0.97 | |
| Sulfur (S) | 14.8 | >10 | | | |
| *Micronutrients* * | | | | | |
| Boron (B) | 0.1 | 0.1-0.5 | | | |
| Manganese (Mn) | 10.7 | 1.1-6.3 | | | |
| Zinc (Zn) | 2.3 | 1.0-7.6 | | | |
| Copper (Cu) | 0.9 | 0.3-0.6 | | | |
| Iron (Fe) | 8.2 | 2.7-9.4 | | | |
| Aluminum (Al) | 55 | <75 | | | |
| Lead (Pb) | 1.5 | <22 | | | |

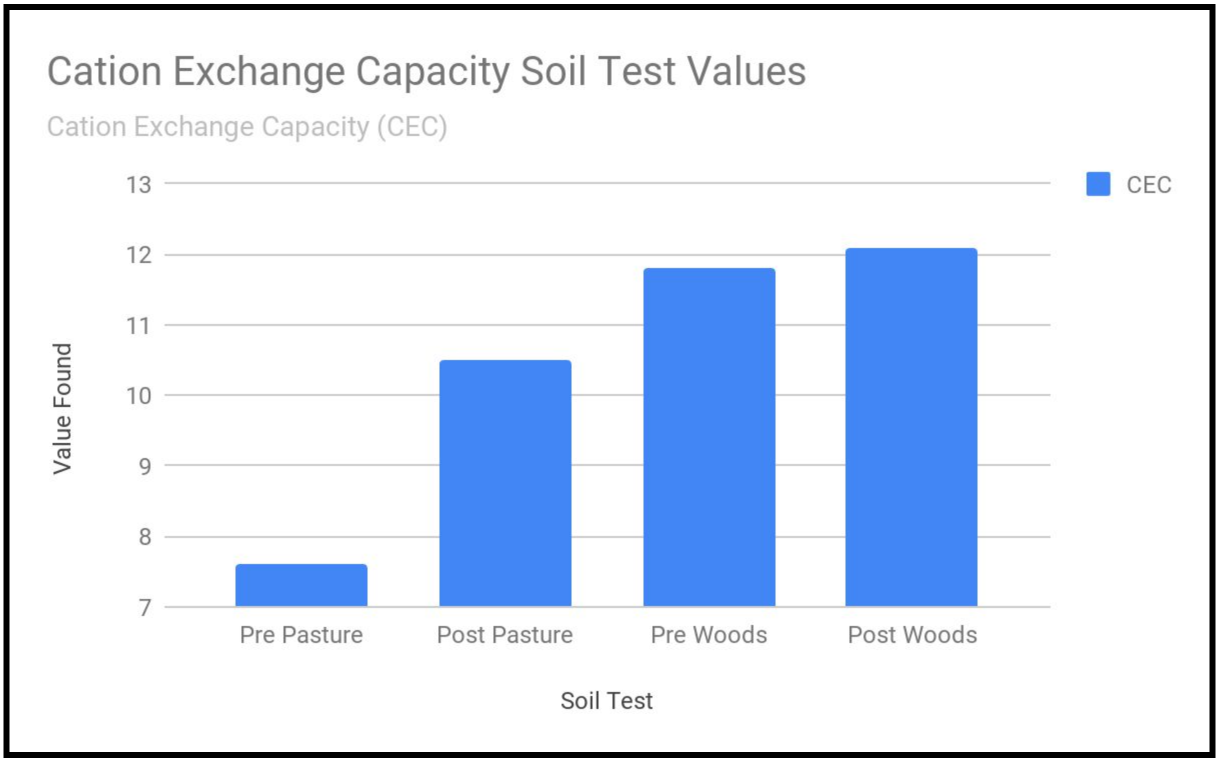
* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

**Results**

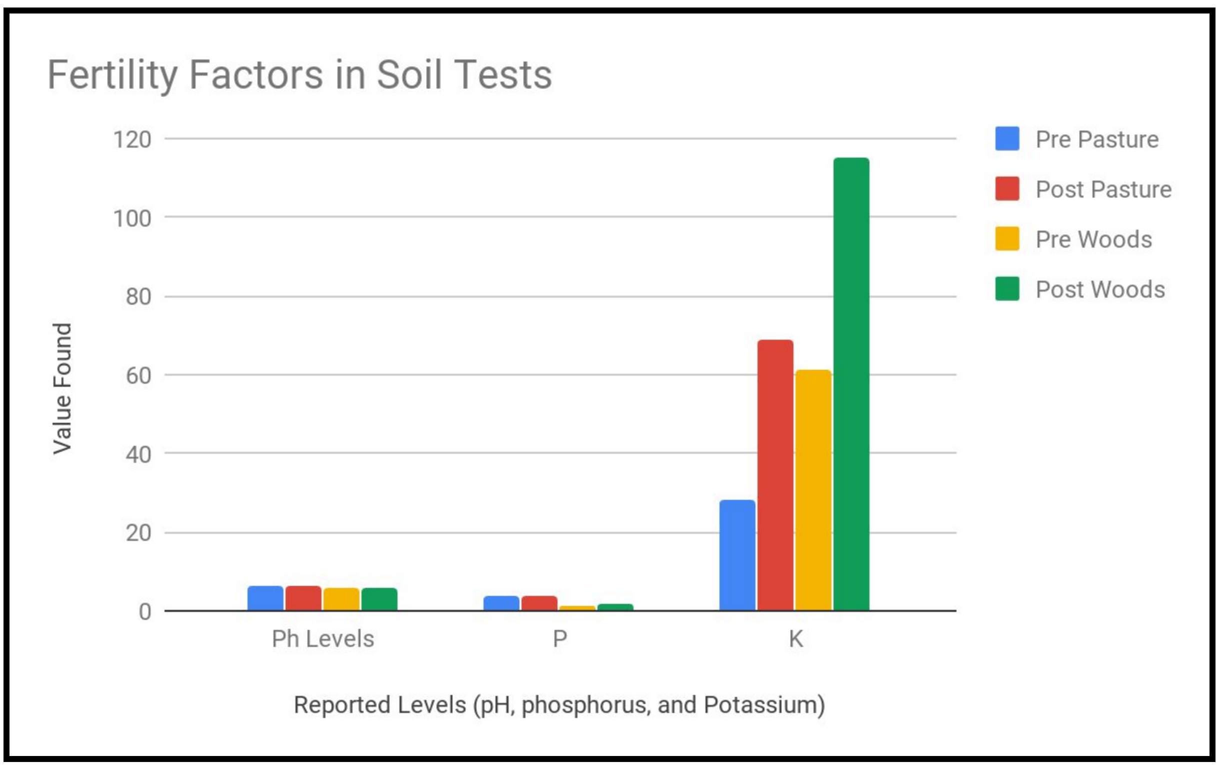
| *Analysis* | *Value Found* | *Optimum Range* | *Analysis* | *Value Found* | *Optimum Range* |
|---|---|---|---|---|---|
| **Soil pH (1:1, H2O)** | 5.6 | | **Cation Exch. Capacity, meq/100g** | 12.1 | |
| **Modified Morgan extractable, ppm** | | | **Exch. Acidity, meq/100g** | 6.9 | |
| *Macronutrients* | | | **Base Saturation, %** | | |
| Phosphorus (P) | 1.5 | 4-14 | Calcium Base Saturation | 34 | 50-80 |
| Potassium (K) | 115 | 100-160 | Magnesium Base Saturation | 6 | 10-30 |
| Calcium (Ca) | 830 | 1000-1500 | Potassium Base Saturation | 2 | 2.0-7.0 |
| Magnesium (Mg) | 95 | 50-120 | **Scoop Density, g/cc** | 0.90 | |
| Sulfur (S) | 17.8 | >10 | | | |
| *Micronutrients* * | | | | | |
| Boron (B) | 0.1 | 0.1-0.5 | | | |
| Manganese (Mn) | 12.5 | 1.1-6.3 | | | |
| Zinc (Zn) | 1.3 | 1.0-7.6 | | | |
| Copper (Cu) | 0.2 | 0.3-0.6 | | | |
| Iron (Fe) | 17.9 | 2.7-9.4 | | | |
| Aluminum (Al) | 109 | <75 | | | |
| Lead (Pb) | 1.5 | <22 | | | |

* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

Tables 4-5: Woods Soil Samples pre (top) and post (bottom) the introduction of pigs. Samples were taken 5/1/17 and 10/31/17 respectively. Analysis done courtesy of Umass Soil and Plant Nutrient Testing Lab.




<u>Figure 4:</u> Cation Exchange Capacity (CEC) levels found in each soil sample.




<u>Figure 5:</u> Fertility Factors found in all soil samples.

*Reproductive Values*

Collecting reproductive data on the sows revealed some interesting information about the relationship between nutrition and reproductive success in swine. Reproductive data collected included litter size and sex distribution figures. Table six below lays out the details of each study animal's reproductive success in terms of factors such as number of stillborns and number of piglets weaned. The average litter size for the woods group pigs was 10.5 piglets with an average of 5.5 females. In the pasture group the average litter size was 8 with an average of 5 females. This seemed to suggest that there may have be a connection between nutrition and sex ratios as well as litter size as suggested in previous studies.

| **Reproductive Data: Litters** | | | | | M:F | | |
|---|---|---|---|---|---|---|---|
| *Sow* | *GOSA Litter ID #* | *Farrow Date* | *Litter Size* | *Born Alive* | *Gender Ratio (All Piglets)* | Piglets Weaned | Study Pen |
| Roxy | *117* | *7/31* | *7* | *6* | *4M:3F* | 5 | Pasture |
| Jane | *217* | *8/251* | *9* | *9* | *2M:7F* | 8 | Pasture |
| *Mabel* | *417* | *10/18* | *12* | *12* | *7M:5F* | 9 | Woods |
| *Phyllis* | *217* | *8/17* | *9* | *6* | *3M:6F* | 3 | Woods |

Table 6: Reproductive success factors of study animals.

Previous studies on sex distribution in litters have suggested that sows with more access to food may have more female dominated litters. Theories on this sort of sex selective behavior include the idea that selective pressure against females offspring in sows with restricted feed access may be a result of a need to reduce future drain on resources. This theory relies on the notion that sows may selectively prioritize males fetuses over females when resources are limited, because unlike females males naturally leave their home territory once they reach the age of sexual maturity and therefore are less of a drain on resources in their birth environment. It has also been shown that males typically require a greater maternal investment as measured by piglet weight, and uterine space at day 35 of pregnancy. It has been theorized that sow's displaying male biased litters as seen in feed restricted sows may result from an effect of maternal nutrition on oocyte development and quality as well as early post zygotic development (M.D. Vinsky et al. 2006).

*Polling Breeders*

In order to get a better handle on how accurate my findings on litter size and sex ratios were I decided I needed a larger sample size to compare this data to. To acquire this information I sent a multiple choice style questionnaire out to Gloucestershire Old Spot Breeders via the GOSA members network and on social media platforms about swine farming. Participants were asked to choose the best answer/s representing their experience with the breed to a variety of questions about topics such as liter size, sex ratios, pedigree, diet and environment. This questionnaire yielded a large data set with over 20 participants from across the US and UK participating and providing useful data on the purebred GOS litters they had born between the spring of 2017 and the fall of 2018 a similar timeframe of this study A complete version of the questionnaire can be found in the appendix section of this paper. The results of this poll were then sorted by generalized environment (woods or pasture) and diet of the subject sows in order to create sample groups to compare my own data on litter size and sex ratios to.

Comparing these two different sources of data sets allowed me to better examine trends in reproductive efficiency based on environment and diet in pregnant sows. For example in the charts below (see figure 6) I was able to compare the sexes of piglets born in pasture and in the woods for my study animals and the GOS community as a whole. Even with the larger sample size (scaling) of my poll it is clearly displayed in the graphs below that despite my initial assessment of seemingly larger instances of a majority of the offspring being born oh pasture being female; this ratio was not large enough to be statistically significant.

Figure 7 depicts the frequency of each litter size averages reported for GOS pigs during the year of the study. This information gives us an idea the range of liter sizes most common in GOS pigs. When I sorted this data by pedigree line it became clear that certain pedigree lines seemed to be much more productive than others, producing higher frequencies of larger than average litters. Many of the sows in my study delivered piglets that fell into the most commonly reported litter size ranges for their pedigree lines as revealed by this poll (see figure 8). The only exception to this trend. The only exceptions to this were 3.16.1 and US/2/ROS who each delivered litters of nine piglets which was above average for reported performance from their pedigree line. However this excellent litter size performance can't be tied to exclusively to environment as they were housed in opposite enclosures. Another theory that might initially explain this is that US/2/ROS is actually the maternal grandmother of both 3.16.1 and 3.16.2 and therefore may have passed along genes for increased litter size to these grandoffspring. However as illustrated earlier in this study 3.16.2 farrowed the smallest litter of the group so litter size can also not be totally regarded as only affected by maternal genes. After further analysis of weight data of the sows during the last two months of their pregnancies it became apparent to me that both US/2/ROS and 3.16.1 were the heaviest sows in their respective study enclosures and therefore the most competitive for grain at feeding times. It is my theory that both of these sows were able to farrow larger than average litters reported for their pedigree in part of the superb genetic potentials available to them as well as their more dominant roles in their respective pens which allowed them to control more feed resources than their penmates. Additionally figure 9 further breaks down this litter size and sex ratio data by depicting the frequency of reported average sex distribution per litter in the breeders poll.

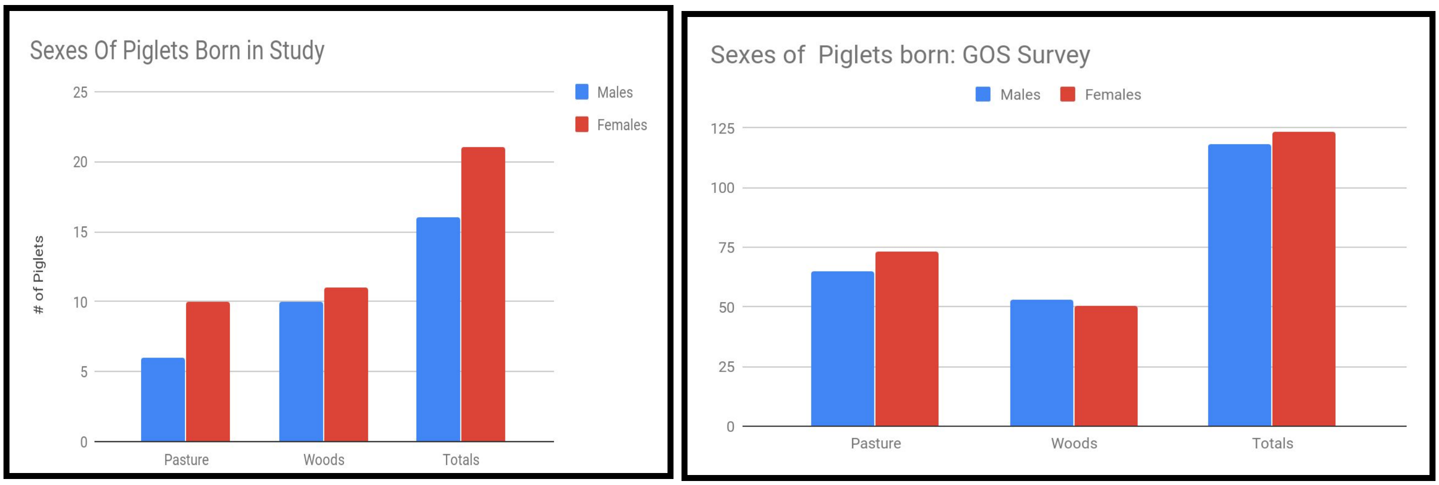



Figure 6: Comparison of sexes reported in woods and pasture for my study animals and GOS Breed Poll responses.

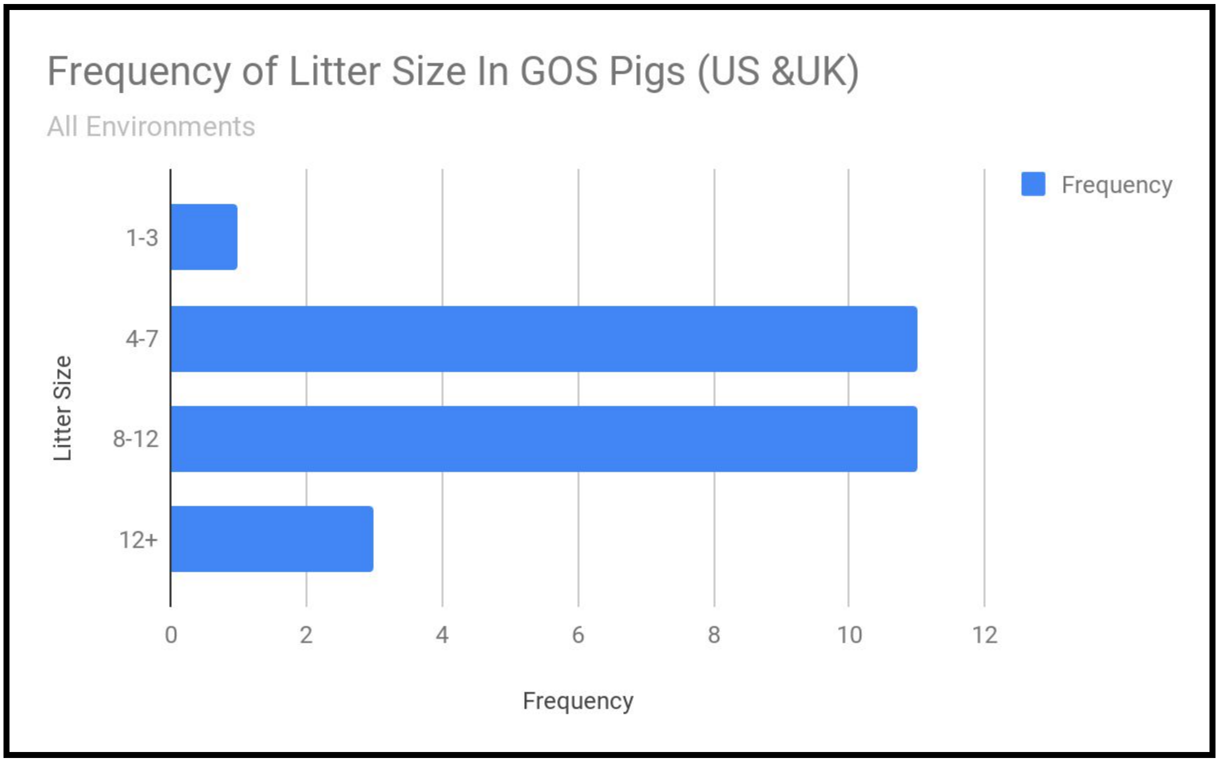



Figure 7: Graph of Reported Litter Size in GOS pigs. All study sows delivered litters that fell into the most commonly reported ranges.

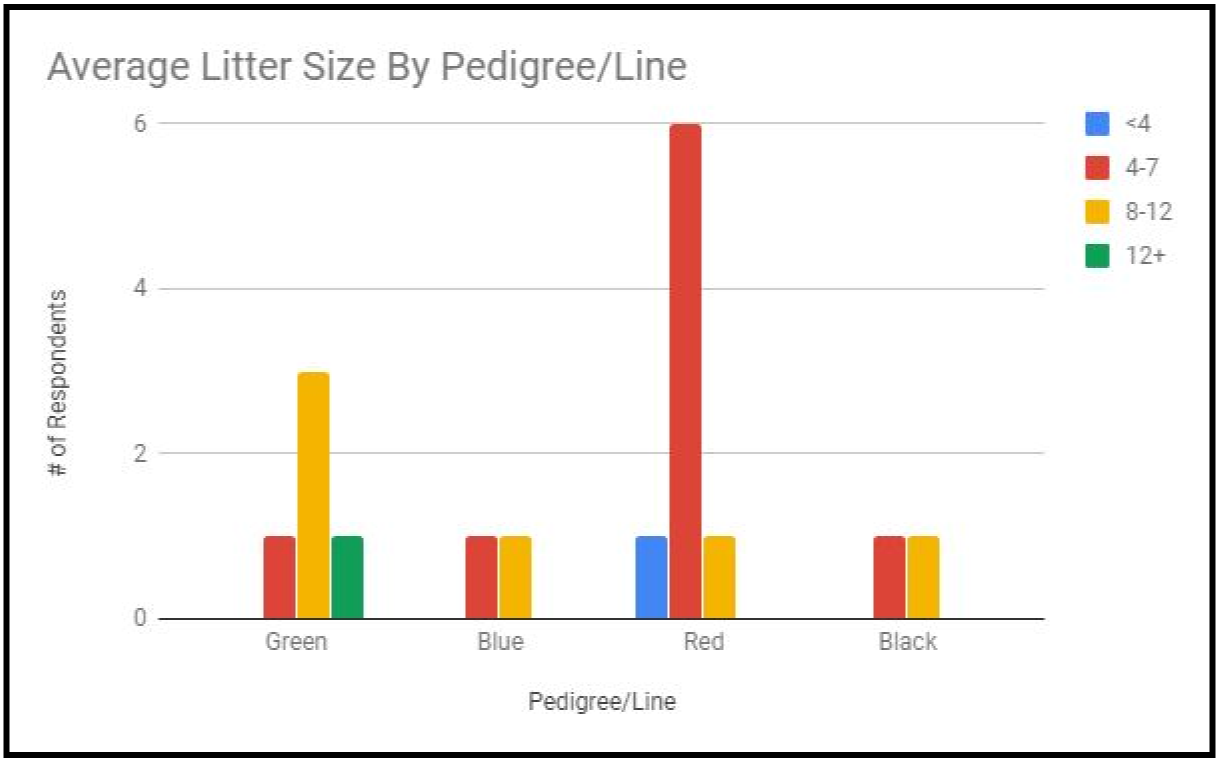



Figure 8: GOS Poll Results for average litter sizes reported by sow pedigree line

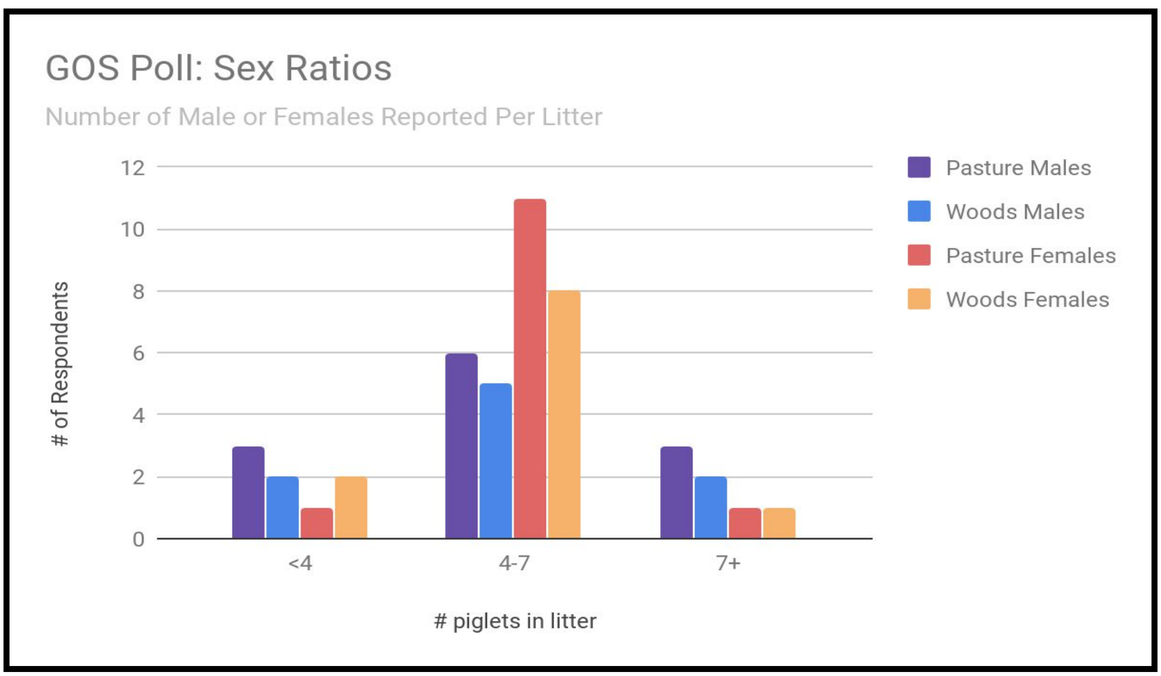



Figure 9: GOS Poll Results for sex distribution in pasture and woods sorted by indicated number of reported piglets of that sex in the litter.

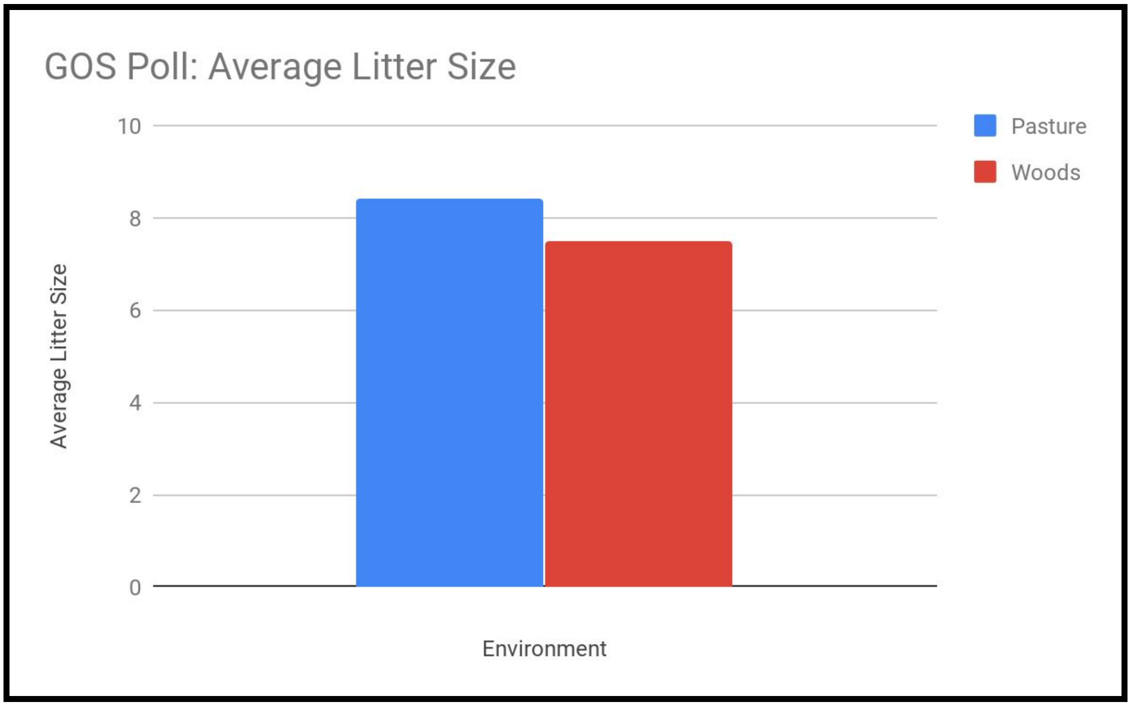



Figure 10: GOS Poll results for average litter size broken down by environment compared to Study Results- for the same data. Chi Square Analysis of Sex Ratios reported in Poll Responses revealed that x^2=0.04 ,df=1, and p value of 0.83, not statistically significant.

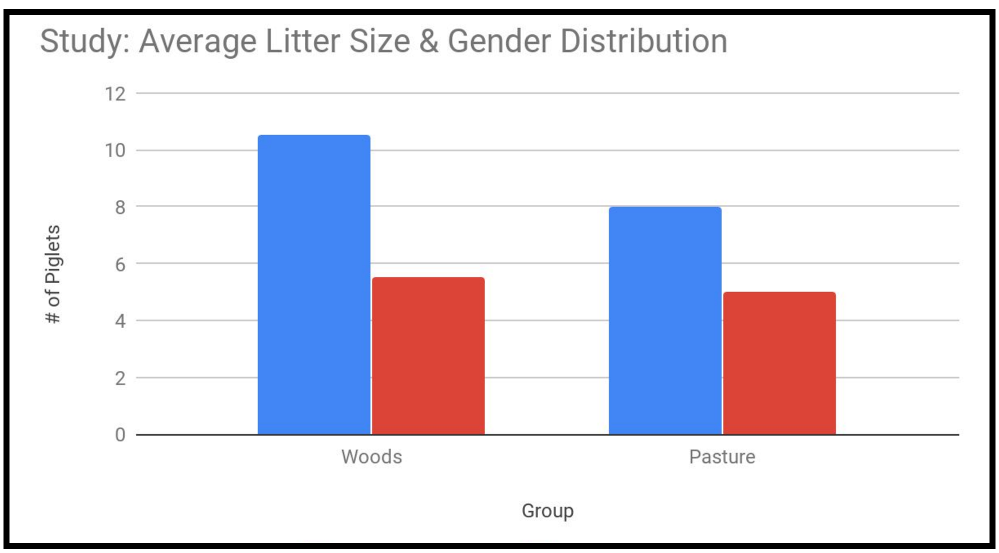



Figure 11: This same analysis of the Sex Ratios in the Study Animals indicated Chi values of x^2= 0.21, df=1,and a p value p=0.64, non significant. As above blue indicates litter size (this graph also includes the number of females born in each environment; red column).

Litter size data was also collected based upon the housing environment of the sow. When these results are compared (Figures 10 and 11) it can be see that the average number of piglets born on pasture in both environments was about eight (8.5 in poll results, 8 in study data) and the large litter sizes produced by this study's animals was not representative of the litter sizes being reported by other breeders farrowing sows out in the woods. The poll results showed average woods litter sizes of less than eight more than two points lower than what this study initially suggested. I think this poll was a good tool for analyzing these trends on a larger scale however to get more reliable results from it I would have to look further into the exact CP content of the supplemental rations feed to these sampled sows and compare it to my own feed rations.

*Study Animal Growth (Sows)*

During the duration of this study live weight data was collected weekly on all its reproductively mature study subjects. The sows and gilts that made up this group had their live weights collected from the first month of pregnancy (Approximately 4 weeks from their first successful breeding) through the weaning of the resulting litter (approximately 8 weeks post farrow). Significant milestone dates in the pregnancy (28 days, 48 days, 84 days, farrow date approximately 115 days, wean date 56 days post farrow) were noted at weigh in and later used to analyze the growth of the females in each stage of production. As indicated in figure 12 below; females in both experimental groups experienced a similar growth curve throughout their pregnancies from 28 days to farrow date.

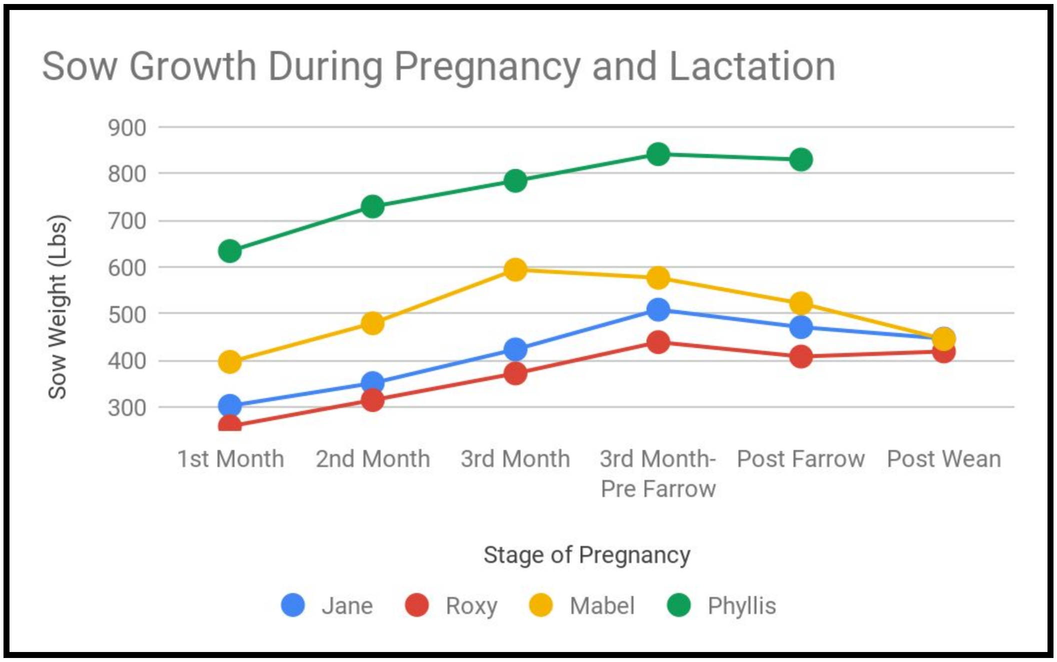



Figure 12: Growth of study sows over time. Key milestones are marked on each line.

One exception to this is a woods housed sow 4.16.1. This individual actually lost weight between 84 days and farrow to the note of 61.68lbs. This finding was unexpected and quite unusual given that all the other animals continued to gain weight during this time period. After tedious review of all the other weight data, litter data and weather conditions present at the time I have hypothesized that this extreme weight loss may be due to the fact that this sow successfully farrowed a very large litter and was carrying this heavy reproductive load during the hottest part of that summer; the late days of August. It can be theorized that the added stress of maintaining and appropriate body temperature in addition to sustaining a large number of fetuses must have taken a lot of resource utilization on her part. Therefore this sow probably choose to allocate more resources to maintaining a low body temperature and the current size of the fetuses rather than utilizing those extra calories for further developing them and giving herself a much heavier physical burden to carry.

Weight loss during the lactation period also followed a similar curve in the animals with the exceptions again of 4.16.1 and additionally US/2/ROS. Sow 4.16.1 displayed a much more rapid and significant weight loss than either of the pastured sows in this timeframe. It is my belief that this again can be attributed to the fact that this sow had to nurse a large group of piglets in an environment which soil samples proved was providing her with less accessible levels of both macro and micronutrients to be utilized in milk production. In the case of US/2/ROS weight data ceases post its initial post farrow collection. This lack of applicable data is the result of an emergency transfer of her litter that occured on 8/24/2017 just a week post farrow. The decision was made to pull her remaining piglets from her care at this early age as a result of several instances of her crushing the majority of her litter to death (three of the six liveborn piglets). These surviving piglets were bottle fed formula supplement for one day before being transferred to a pasture sow 3.16.1 to nurse amongst her litter until natural weaning. Upon examination of US/2/ROS post transfer it was determined that this sow came into farrowing slightly over conditioned and had also lost much of her hearing between her purchase for this study and delivery of her piglets. This hearing loss could be probably be attributed to her advanced age (most producers don’t breed sows past six years) and as a result would have rendered her unable to hear distress calls from the piglets and properly respond to these signals by standing up and moving out of the nest area as to not crush them.

Despite this unfortunate circumstance it is interesting to note that even with the added burden of nursing three surrogate piglets in addition to her own offspring 3.16.1 managed to actually to better maintain her weight,and loss less overall during the lactation period showing that she must have had access to higher quality nutritive inputs that allowed her to perform at this exceptional level. Her pen mate 3.16.2's weight also followed a similar pattern during the lactation period supporting the hypothesis that this may well be a result of better nutrition access. Soil Sample results from the pasture enclosure also support this by showing that this pen contained higher levels of soil nutrients such as calcium and increased levels of CEC which would prove beneficial to lactating sows. In fact on the topic of neonatal piglet survival and milk production it was found that sows fed high fiber diets in the later portion of gestation showed increased colostrum and transient milk production (P.K. Theil et al 2014).

In one particular review paper about sow nutrition studies it was suggested that the within litter birth weight variation in swine could be reduced with increased sow nutrition and access to important nutrients. This paper suggested that increased access to these nutrients during early and mid gestation could increase fetal muscular development via myofiber development (and therefore increase piglet birth weight). This paper also recommended increasing the amount of fiber available dietarily in the estrus cycle preceding mating because this was found to "increased embryo survival and reduced intrauterine growth retardation at day 27." In addition to this it was revealed that "higher amounts of feed fed to sows (3.63kg/day of gestation diet) from 30 to 50 days of gestation resulted in fewer total piglets born" and these sows tended to "have lower numbers of piglets born alive when compared with sows feed a control diet" (Pgs. 801, 802,P.H.R.F. Campos, B.A.A. Silva, J.L. Donzele, R.F.M. Olivera and E.F. Knol 2011). This suggests that an excessive amount of nutrition can actually prove detrimental to sow reproductive ability as which may have been demonstrated in this study with US/2/ROS/ having a large number of stillborns and coming into delivery over-conditioned. In another one of the studies reviewed in this paper it was reported that dams had the ability to mobilize maternal nutrient reserves when they were subsisting on a restricted energy diet and could use these reserves to support the development of fetuses as well as the placenta during gestation (P.H.R.F. Campos, B.A.A. Silva, J.L. Donzele, R.F.M. Olivera and E.F. Knol 2011). This phenomenon could support the theory of increased weight loss due to large litter size and restricted access to adequate energy and micronutrients as demonstrated by 4.16.1 during the later months of her gestation.

In order to further examine the influence of litter size and nutritional access on sow weight changes I graphed the amount of live weight lost per piglet she was carrying in each of the months of pregnancy. These values can be seen in the chart below (see figure 13) and represent the sows changes in weight divided by the total number of fetuses (live and dead) she farrowed for months one to three. The weight change for the sow from farrow to weaning at eight weeks post farrow is also indicated in figure 14 and these values are based on weight changes of the sow divided by the total number of piglets weaned. Once this data was graphed out it became clear that there wasn't an obvious trend in how much weight a sow gained or lost based on her environment. This graph also makes it clear that there weren't any trends based on litter size either, as both sows who farrowed nine piglets didn't show similar trends in amounts gained or lost during the study. Therefore, I can conclude that at least in this research there didn't seem to be any correlation between littersize or environment and weightloss.

However, the data on sow weight gain or loss per weaned piglet is much more interesting. When this was graphed out as in figure 14 it can be seen that 3.16.2 (Roxy) lost the most weight per piglet than either of the others do to hear small litter size. When 4.16.1 (Mabel) and 3.16.1(Jane) data points were compared it can be seen that Jane lost more weight per weaned piglet than Mabel despite initially nursing similarly sized litters. This proves very interesting when examined alongside the weaning weight data (see figure 17) which showed that Jane's piglets also weighed out heavier than Mabel's (despite the fact they weaned 11 and 9 respectively). This finding suggests that nutrition available to 3.16.1 may have been of higher value and therefore allowed her to nurse more piglets and get them to a higher weaning weight than her woods counterparts.

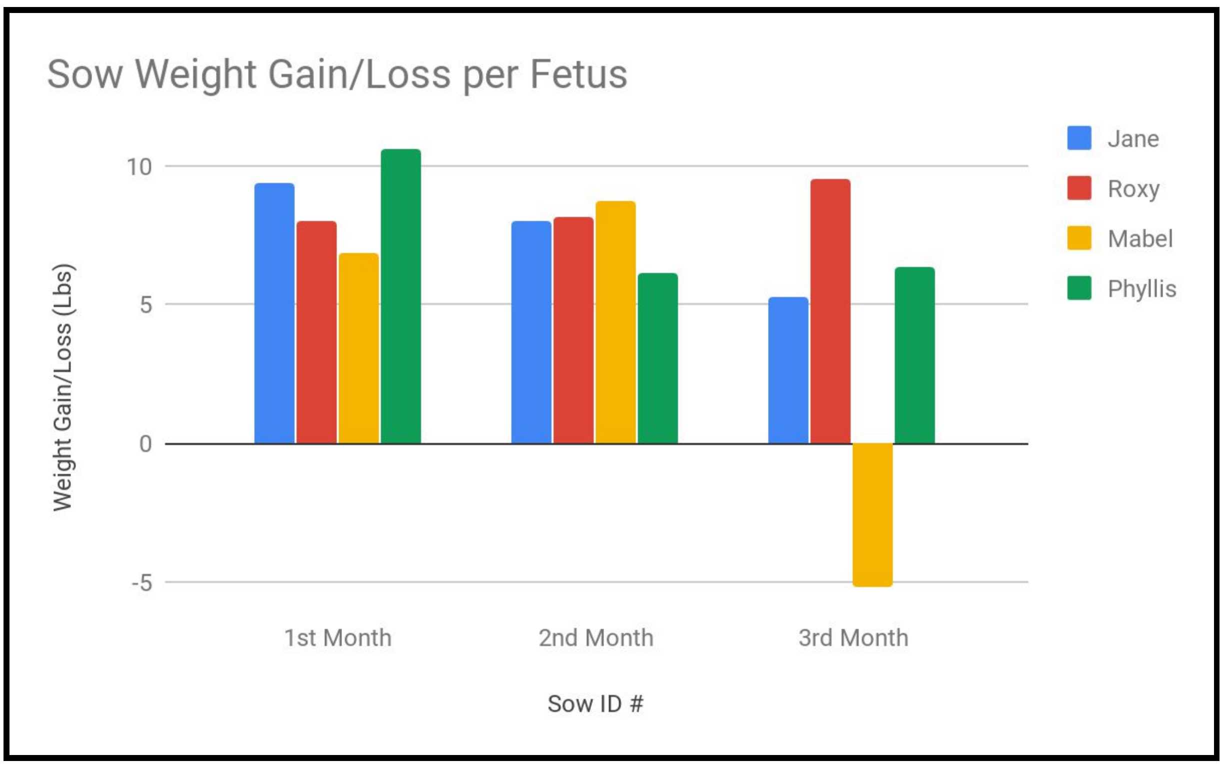



Figure 13: Sow weight gain or loss per fetus broken down by stage of pregnancy.


Figure 14: Sow weight loss from farrow to wean per piglet weaned. This chart factors in the three surgote piglets nursed by Jane into her total number of piglets weaned. It should be noted that weaned piglets totals were as follows Jane 11, Roxy 5, Mabel 9.

*Study Animal Growth (Piglets)*

Weight data was kept on this study's resulting piglets throughout their first eight weeks of life. After eight weeks piglets were weaned from the sow's and no more data was collected on them. Piglets were weighed in the same manner as the sows and weigh ins happened three times during the nursing period at approximately three, six and eight weeks of age(on weaning day). Average piglet growth was then graphed in the charts below (figure 15) by taking the average piglet weight for each litter at a particular milestone age. Figures 16 and 17 reflect the average piglet weight at their last weigh ins on weaning day (approximately 56 days) for both experiment pens as well as broken down by individual sow. Only two penmate sows farrowed in close enough proximity to one another to co nurse their offspring however these sows (3.16.1 and 3.16.2) did display co-nursing behavior with one another's litters allowing them to share resources and lessen the burden of excessive nursing. Towards the end of the nursing period for 3.16.2's litter her offspring began to nurse almost exclusively off of 3.16.1 as their mother began the weaning process. It should be noted that these additional feedings for pasture piglets may have had a significant effect on their rapid growth during the study period. It should also be mentioned that despite farrowing several months earlier than her penmate US/2/ROS displayed nesting behaviors along with 4.16.1 in the days before she farrowed. These sows cooperated in a collective nest building experience and once 4.16.1's piglets arrived US/2/ROS often mimicked maternal grunts and nursing rumbles to them while allowing them to join her in the nest and suckle on her teats despite the lack of active milk production. That being said had these two woods sows farrowed in closer succession to one another I would have been interested to see the effects co nursing may have had on the weaned weights of their piglets.

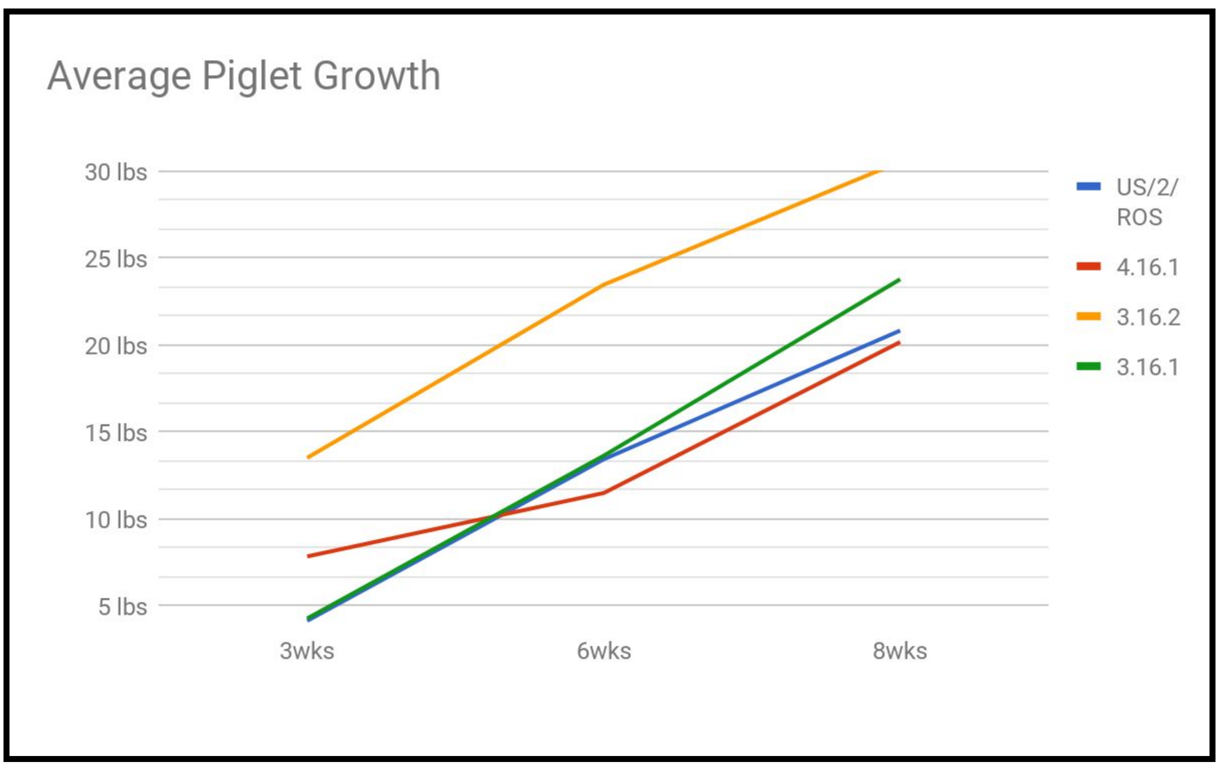


Figure 15: Average Piglet Growth from farrow to wean (8wks) organized by dam (origin sow). US/2/ROS piglets were surrogated to 3.16.1 but their growth data has been graphed here separately from their adopted littermates.

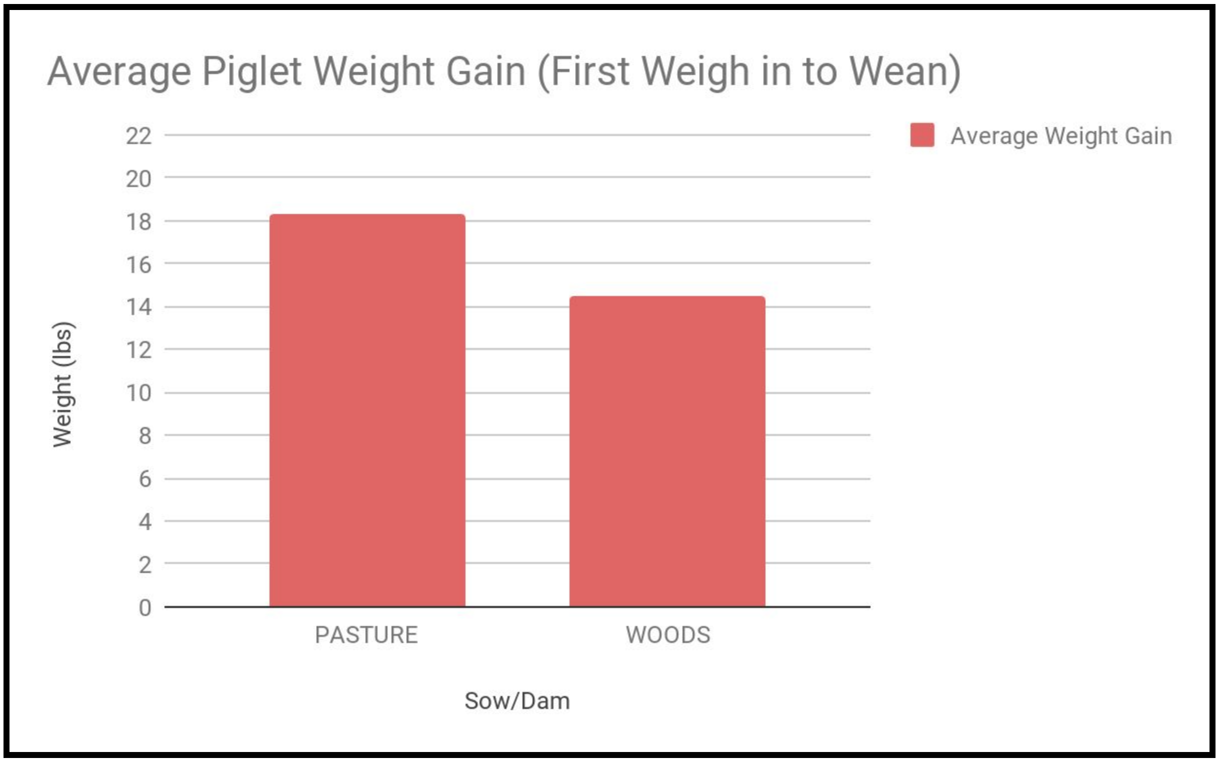



Figure 16: Average piglet weight gain from first weigh in approximately 3wks to weaning at 8wks sorted by experimental pen location.

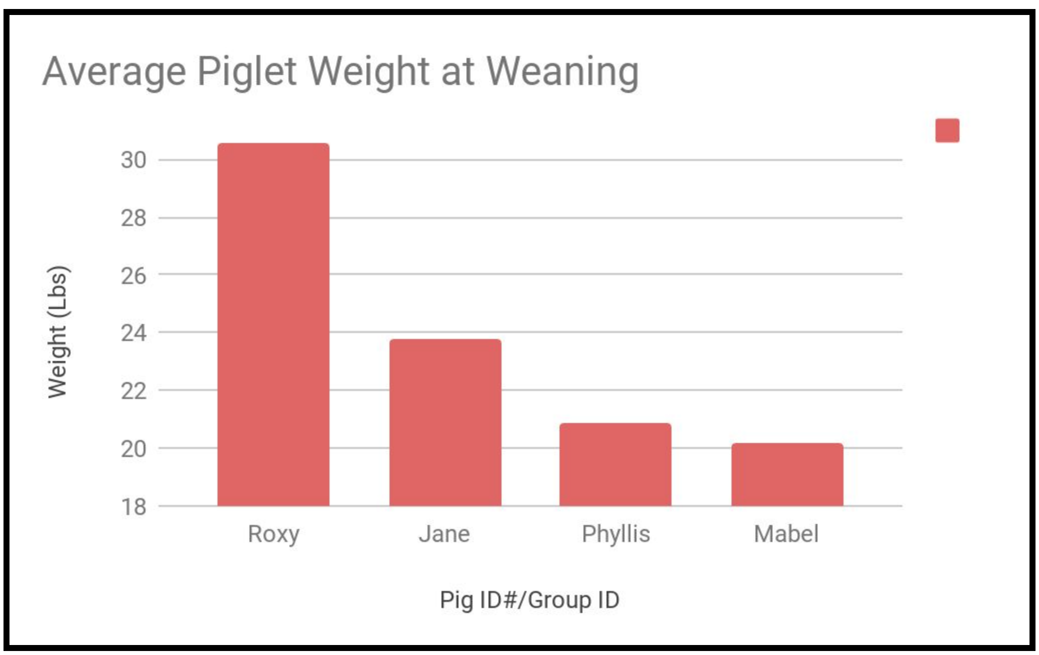



Figure 17: Average piglet weight at weaning (8wks) sorted by dam.

As can be seen in this figure 15 sow 3.16.2's litter started out at a higher average weight at their first weigh in at approximately 3wks old (13.508lbs) than any other and continued this trend over time; weaning piglets that averaged 30.553lbs. This is likely a result of her smaller litter size and increased ability to put input more calories per piglet. Her penmate 3.16.1 started out with an average piglet weight of 4.262lbs; one of the lowest starting weights. However this sow still managed to wean out piglets at an average of 23.786lbs quite a feat considering that in addition to nursing her own large litter she also took on three surrogattes from US/2/ROS. These three transferred piglets had a first weigh in of 4.128lbs but managed to wean out at 20.833lbs due to a successful bonding with 3.16.1. When we look at 3.16.1's success in this situation it serves to reiterate that despite nursing one of the largest batches of piglets in the study she still managed to wean out average sized piglets that weighed more than woods sow 4.16.1 who also nursed 12 piglets for some duration of the study. Sow 4.16.1 weaned out the lightest batch of piglets in the study averaging a weaned weight of 11.483lbs.

## Conclusion

This study sought to examine factors relating to reproductive success in swine in relation to the environment these breeding sows were housed in. I carried it out under the hypothesis that breeding sows raised in forest environments would be at an advantage to their pasture-raised counterparts because of increased access to higher-calorie forages during gestation and this would allow them to farrow larger litters which would grow more rapidly than pasture born piglets and potentially display a gender bias towards more female offspring as result of this increased access to nutrition. Additionally, I believed that breeding sows and their offspring would be far less destructive to a forest environment than previously suggested in other studies, again as a response to this increased nutrition and lack of a need to forage as rigorously to access it. However upon a thorough examination of the resulting data I have been able to determine that my hypothesis didn't necessarily hold true in all its predictions. As a result of my findings I have nethertheless come to some conclusions.

Although environment seemed to have an impact on littersize and sex distribution in my small sample size, this evidence didn't seem to reflect the true role of these reproductive factors when my samples were compared to the whole of the GOS population in the UK and US Poll. In fact it seemed to reveal opposing information, namely that the overall GOS population respondents indicated slightly smaller than average litters in the woods (7.5) when compared to an average litter size of 8.4 in the pasture sows. In order to get a better handle on average sex distribution and litter-size, I believe it would be a great benefit to the heritage breed community to do annual or semi-annual polls on these sorts of reproductive factors housing environments, feed styles (specifically ration weights anc CP contents) and individual mortality to better understand how many of these rare breeds are out there, how they are being utilized and how their production is when compared to other livestock breeds. The other half of my hypothesis that suggested that these woods-born piglets would grow more rapidly than their pasture counterparts and be a heavier weight at weaning was also proven false. Woods-born and nursed piglets still weighed out nicely at eight weeks of age (an average of around 20 pounds each) but they were considerably smaller than the pasture piglets (weighing an average of around 27 pounds each). This evidence showed me that despite the nice weight gain of the woods sows throughout most of their pregnancies this environment didn't benefit them in the lactation phase of production.

My final hypothesis, that sows are less detrimental to the soil health and fertility of forest environments than swine are traditionally thought to be was proven correct by soil analysis that showed increased fertility after the sows were introduced to that environment.

Conducting this five-month long research project proved an amazing opportunity to learn more about the role of environment on productivity of heritage breed swine and their offspring. Overall despite not getting all the results I was hoping for I do believe this study was a great tool for exploring these topics and allowing people to come to a better understanding of how to better support sow nutrition for increased productivity during gestation and lactation. I highly recommend continued research on this topic with similar methods as this study. It would be my suggestion that in any future attempts to replicate this study, a hybrid group of sows that spend the first three months of pregnancy foraging in the woods, then moving to a pasture environment for the last few weeks before farrowing and nursing should be included. I suggest this because based on the data I gathered and several other nutritional studies I read about lactating sows it is now my belief that the initial rush of high density food like roots and tree nuts can benefit sow weight gain and weight maintenance during gestation. I also believe that a more high fiber diet of the grasses and legumes found in pasture was a much better feed source for providing lactating sows, with the nutrients they needed to produce ample milk to feed their piglets. Future replications would also benefit from a more unified study group of sows of exactly the same age (or of equal sized groups of various ages) that were all bred by the same boar as well as slightly altered rations that would max out at a predetermined weight to prevent some of the over conditioning that happened in the older sows. I hope to see further research on these topics in heritage breeds in the future.

## Appendix

*GOS Breeders Questionnaire*

1) How do you house your sows/breeders?
a. On pasture
b. In the woods
c. Confined
2) What breed are your sows/breeders?
a. GOS purebred
b. GOS mix
3) What do you feed?
a. Grain/supplements only
b. Grass/pasture/forage only
c. Grass/pasture/forage and grain/supplements
d. Other (describe please)
4) In the Past year or so (approximately March 2017-September 2018) how many GOS/mix litters have been born on your farm?
a. <4
b. 4+
5) Tell me about this past year's litters. *(Record for each sow/litter you had of GOS/GOS mix you had in the last year)*
a. How old is this sow/gilt?
    i. <3yrs
    ii. 3yrs+
b. Is she registered? If so what is her color group/line? (ex. Red Princess Mary)
    i. Red line
    ii. Green line
    iii. Blue Line
    iv. Black Line
c. How many piglets did she farrow total?
    i. 1-4
    ii. 4-7
    iii. 8-12
    iv. 12+
d. How many still borns did she have?
    i. <2
    ii. 2-6
    iii. 6+

e. How many males v.s. females in the litter? (Note if this number is based of total piglets or just live births)

i. <4 males
ii. 4-7 male
iii. 7+male
iv. <4 female
v. 4-7 female
vi. 7+female

f. What color group/line of boar was she breed to?

i. Blue Rufus
ii. Red Sambo
iii. Black Patrick
iv. Green Gerald

g. How many previous litters has she had? Any idea how many she usually farrows?

i. <3 litters
ii. 3+ litters
iii. Previous litters are <4
iv. Previous litters are 4-7
v. Previous litters are 8-12
vi. Previous litters are 12+

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