# OPTIMIZING ANIMAL WELFARE IN COMMERCIAL LAYING HENS THROUGH NOVEL MANAGEMENT PRACTICES AND FARM MANAGER EVALUATION

John R. Brunnquell
*University of Kentucky*, brunnquelljohn@gmail.com
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John R. Brunnquell, Student

Dr. Anthony Pescatore, Major Professor

Dr. David Harmon, Director of Graduate Studies

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DISSERTATION

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A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Agriculture, Food and Environment
at the University of Kentucky

By
John Richard Brunnquell
Lexington, Kentucky
Director: Dr. Anthony Pescatore, Professor of Animal Sciences
Lexington, Kentucky
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# ABSTRACT OF DISSERATION


## OPTIMIZING ANIMAL WELFARE IN COMMERCIAL LAYING HENS THROUGH NOVEL MANAGEMENT PRACTICES AND FARM MANAGER EVALUATION

The commercial production of pasture and free-range eggs in the United States is expanding rapidly. According to the United States Department of Agriculture Agricultural Management Assistance, in May of 2019 there were 2.6M pasture hens and 4.5M free-range hens representing 1.9% of the nation's laying flock. There is little industry and/or academic experience with this style of production in the United States. Programs such as the European Layer Training Initiative (ELTI), which emerged in 2019, have tried to fill this void but participation from the US was low. The principal sources for guidance of commercial free-range egg production in the United States are Non-Government Organizations (NGOs) such as the American Humane, Humane Farm Animal Care, Global Animal Partnership, a limited number of dedicated academic faculty, industry associations such as United Egg Producers, and/or trial and error of individual egg companies and farms.

To provide a baseline from which humane poultry husbandry can be planned and put into action, three experiments were developed and executed with goals of examining the performance of the poultry and the production economics of an integrated approach to free-range egg production. Within these three experiments interactions among genotype, environment and management, in a commercial setting were evaluated.

The first experiment assessed whether movements of free-range laying hens were influenced by changing the locations of movable habitat enrichments, such as shade coverings, the research demonstrated moving shade in a range affected laying hen movement and location within the range. This ability to move laying hens around a range is critical to avoid overgrazing and denuding of areas within the range and giving areas of the range a chance to rest and rejuvenate. The second experiment assessed the correlation between stockman personality assessment and flock performance. Research identified a correlation between personality attributes of a stockman and flock productivity and developed a regression using production and personality parameters that yielded an 81.85% predictability of expected results. Key personality traits were emotional control and the relationship between detail orientation and assertiveness. This information is important to better identify ideal stockpeople that will optimize flock productivity. The third experiment assessed the effect of blue light compared to white light on the tonic immobility of 16-wk old female pullets during nighttime move-outs (depopulation) and transfers from a commercial pullet barn to a commercial layer barn. Tonic immobility (TI) did not differ between light treatments. Reducing TI scores at the pullet move concurrently will reduce other stress related challenges to the pullet during the move.

The research clarified aspects about humane poultry husbandry that will advance the industry and contribute to the ability of the U.S. free range egg producers to compete in a national marketplace in development, training, and application of the humane commercial production of eggs.

KEYWORDS: Pasture, Free-range, European Layer Training Institute, Mobility, Enrichments, Personality Profile, Versatility Level, Emotional Control, Assertiveness, Detail Orientation

John Richard Brunnquell

*(Name of Student)*

May 15, 2020

Date

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By
John Richard Brunnquell

Dr. Anthony Pescatore

Director of Dissertation

Dr. David Harmon

Director of Graduate Studies

May 15, 2020

Date

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# Chapter 1 - Literature Review

## 1.1 Introduction

A changing consumer mind-set, a rise in the farm to table movement and increased consciousness about food origins, and animal welfare have all contributed to an increased focus on humane farming practices. These practices are not new but are experiencing a resurgence after decades of focus on low cost production and less focus on animal welfare. Relative to laying hen welfare, the United States table egg industry is striving to make a comeback from 80 years of suppressing the native behaviors of laying hens *(Gallus domesticus)* such as of dustbathing, foraging, perching, scratching, and socialization, and the associated stress of confined laying hen production. Managers are re-thinking laying hen housing and striving to reconnect laying hen production to the basics of these natural behaviors. This is a novel concept though, and there is still a great lack of understanding of the best way accomplish this shift within the industry. Accomplishing a humane yet productive, efficient, and economical outcome will likely require changes in how facilities are managed, and in the personalities of those who do the management. Similar to any large industry, there is considerable inertia working against large-scale change. In the egg industry change can be very slow and market opportunities lost primarily because there is little research on how to incorporate such practices and innovations into commercial husbandry while maintaining productivity and economic visibility.

The literature review focused on the use of range by laying hens and the proper animal welfare practices (or lack thereof) associated with such. Existing literature regarding general animal welfare was quite available and accessible, however when narrowing down to laying hen range usage, the amount available drastically declined. I examined 235 papers covering research from 1931 – 2019. I used Google Scholar to find articles using the search terms hens, laying hens, poultry, pasture, laying hens, free-range, range, range, animal welfare, allostasis, and laying hen behavior. Through the research, five themes emerged:

1) Enriched ranges (i.e., including shade, distractions, etc.) that engage laying hens promote wider use of such.

2) Proactive and detailed management of the physical aspects of the range, as well as the way that the laying hens use it, are imperative for range health.

3) The environment (cages, enriched cages, cage-free or free-range) alone does not guarantee good laying hen welfare.

4) Providing laying hens range is good for laying hen health, management and production; and

5) Most research has been conducted on small non-commercial flocks (100-1500 laying hens).

Whether results from these flocks are applicable to larger commercial operations of 10,000-20,000 laying hens is unknown, so there is some trepidation about adopting suggested practices at a large scale. I summarize the information from these papers that form the current state of research regarding laying hen welfare on a commercial farming scale.

## 1.2 The definition of animal welfare

There are multiple definitions for animal welfare (Sherwin et al., 2010) but most are based on the idea that animals are sentient (i.e., have the capacity to feel and perceive what is happening around them) (D'Silva, 2006; Hovi et al., 2003; Korte et al., 2007; Webster, 2001). Animal welfare can be assessed via a measurement of allostasis, which is the process by which the body responds to stressors to regain homeostasis (Ohl & Van der Staay, 2012).

Two main definitions of what is considered “good” animal welfare are:

1) Good animal welfare provides captive animals with the five freedoms (Brambell, 1965; Webster, 2001).

1) Freedom from hunger and thirst;

2) Freedom from discomfort;

3) Freedom from pain, injury or disease,

4) Freedom to express normal behavior; and

5) Freedom from fear and distress.

2) Good animal welfare provides captive animals with the opportunity to express natural behavior (Pettersson et al., 2016).

The first definition is more specific, but it ignores adaptability of behavior. The second definition focuses on behavior and although provided or offered, every animal will not express the same behavior or take advantage of all opportunities. There are other definitions (Webster, 2001) but animal welfare is interpreted by society and what society sees as acceptable changes over time (Fraser et al., 2001, Ohl & Van der Staay, 2012). Individuals with different agendas often write their own definitions of animal welfare (Fraser et al., 2001) making the general perception even more complex. For example, a zookeeper, an animal rights advocate, a wildlife biologist, and large-scale stockman, all practicing within the same geographic location, have different definitions of what animal welfare means.

Examples of changes in animal welfare through time are stark. In the late 1800s and 1900s, the display of trained elephants was accepted and expected in traveling circuses (Fraser et al., 2013). Societal expectations have changed drastically since the heyday of Ringling Brothers and Barnum and Bailey Circuses to the extent that Ringling Brothers has completely shut down their circuses (Allen, 2017). Sea World is a similar example, where captured Orcas were trained and displayed to a supportive public. As societal understanding and expectations changed, Sea World was forced by public outcry and a poor safety record, to abandon their killer whale program (Martin, 2016). Elephants and Orcas are not viewed as food, nor do they produce food products – at least not in the US, but there are interesting parallels in terms of the evolution of society's perspective regarding animal welfare. For large animals being shown as curiosities, the interest in animal welfare has been linear, very little in the early days, when elephants were shackled individually and Orcas were kept in solitary pens, to avid animal welfare protagonists today insisting on humane treatment or no captivity at all.

For purpose of this paper, "good" animal welfare is defined as:

1. The avoidance or lack of negative stimuli;
2. Animals can and are allowed adapt to the environment;
3. Understanding that animals have emotions; and
4. Offering an environment where animals can adapt to a point, they perceive positivity.

The science of animal welfare is a two-step process: first Society must set the vision, and then science must set the parameters (Fraser et al, 2013). The concept and focus of welfare has also broadened from a focus on veterinary and production metrics to a more holistic approach that considers animal behavior, physiology, psychology, housing and husbandry (Powell & Watters, 2017).

## 1.3 Prevalence of animal welfare in the poultry industry

Despite some parallels, for laying hens, the path has been less linear. In the United States in the last 80 years, the industry has gone from virtually 100% cage free/free-range production prior to World War II, to the highly confined, efficient, and highly engineered egg production of today (Fraser et al., 2013). This means that in the 1800s, there was little thought about animal welfare for laying hens because first, they were food, and second, they were outside anyway, so there were few concerns (Ohl & Van der Staay, 2012). Mid-century, "factory farming" appeared and laying hens were managed solely with an eye to production. These practices laid the groundwork for an upsurge of animal welfare activity and it became a hot button topic in the 1960s (Ohl & Van der Staay, 2012). Dramatic changes to the housing practices of laying hens in the United States is now under way. This is rooted partly as backlash from the animal rights movement started in the 1960s and 1970s (Ohl & Van der Staay, 2012), and partly as a result of the movement towards sustainability and organic farming and consumption in the 2000s (Ohl & Van der Staay, 2012). The laying hen industry in the United States is currently convulsing through a projected 70% conversion back to cage free or free-range and pasture egg production, projected to be completed by 2025 (Taylor et al., n.d.). In addition to changes in housing, there is a strong trend in the United States table egg industry to incorporate more natural behavior of laying hens into future production. To do this concurrent with housing changes, at minimal expense and with little disruption to supply, a greater understanding of what type of environment promotes the expression of natural behaviors in laying hens is needed.

## 1.4 The influence of conscious consumerism

Today's consumers are demanding more choices in all industries of purchasing, and eggs are no exception. There is a wide variety of what people are willing to pay per dozen, as well as what factors are important to them while purchasing. When deciding what product is best for them to put forth, there are four management styles for stockmen to decide upon and ultimately make a large investment in – cages, enriched cages, cage free, and free range. Prior to 2017 in the United States, 13% of eggs were from uncaged operations (Ibarburu, 2019). However, in 2017, three of the top 60 egg production companies in the United States are 100% free-range (Alonzo, 2017), with clear statements of and commitments to this need in the marketplace. A general shift in consumer social conscious has driven this change, which is supported by research indicating natural behaviors are good for production (Harper, 2002; Hegelund et al., 2005; Pettersson et al., 2016).

The egg market is supported by the producers' investments regardless of what management practices they follow. Those that choose a more intensive management style can typically produce lower cost eggs that sell to consumers less concerned about the details of how eggs are produced. Free-range eggs (less intensive management) typically sell to a more affluent demographic. Despite this generality, conscience consumerism is changing how people view the food they purchase and will have a significant effect on the return on both intensive and free-range management styles (Croney et al., 2015).

### 1.5 Determining if range use is good for laying hen health and productivity

When reviewing laying hens, providing them opportunity to range (go outside on range) would be considered a good animal welfare practice. It is known that some laying hens will access the range (outdoor range) frequently while others may never go outside (Richards et al., 2011). However, they do have certain indigenous behaviors and given an opportunity to express those behaviors in the correct environment, they will perch, scratch, forage, dustbathe and socialize (Broom, 1988; Leone & Estevez, 2008). Of these five, foraging and dustbathing typically require a range.

While range provides the opportunity for laying hens to express natural behavior, it also exposes them to risk factors that do not exist in a caged environment (Humphrey, 2006; Lay et al., 2011; Van Oers et al., 2004). These risks include exposure to predation, fluctuating temperatures, and parasites, and have the potential to offset the benefits of range opportunities (Evans et al., 1993; Korteet al., 2007). Notably, environment alone (e.g., cage versus range) does not ensure good animal welfare (Duncan, 2001; Moura et al., 2006). Rather, the application of high-quality management within any environment is critical to provide an optimal situation for laying hens (Hilimire, 2012; Von Borell & Sørensen, 2004).

Good animal welfare practices historically depended on constant human monitoring, as well as an intimate knowledge of the state of the facility and individual laying hens (Moura et al., 2006). Now, technology can significantly assist the manager in achieving good animal welfare and access to data (=information) provided by monitors, computerized controls, and computer applications to track laying hen physiology and production, assisting in flock management. When data are collected remotely less time is likely to be spent at the facility or in contact with the animals, which can lead to an increased fear of humans and therefore a poor animal welfare situation (Daigle, 2013).

Specifically, researchers have identified benefits to time spent on range that include increased plumage (full feathers) (Zeltner & Hirt, 2008), Additional benefits include less aggression due to reduced density (Estevez et al., 2002), reduced feather picking (Bestman & Wagenaar, 2003; Lambton et al., 2010), and increased leg health (Bizeray et al. 2002). Further, general measures such as vitality increased with increased time spent on range (Van de Weerd et al., 2009) and laying hens visually exhibited less fear with regular access to range (Grigor et al., 1995).

Despite evidence that suggests that free-range status benefits laying hen health, 57 of the largest egg companies in the United States produced eggs from caged, enriched caged, or cage-free hens. Companies often use a mixture of these scenarios (Haroon, 2018) and few incorporate only one method of egg layer production system (Haroon, 2018). Concerns include a high level of keel bone damage in free-range environments (Richards et al., 2012; Tarlton et al., 2012), and predation and exposure to wild bird species that could cause an epornitic event (Evans et al., 1993; Richards et al., 2012; Singh & Cowieson, 2013; Tarlton et al., 2012).

Existing research results are equivocal about the provision of range for laying hens, advantages as well as disadvantages are documented (Humphrey, 2006; Lay et al., 2011; Sherwin et al., 2010).

## 1.6 Factors that impact range use

Managing a free-range environment is different from managing a caged environment. In addition to an awareness of interactions among laying hens based on age, health, productivity and general social behavior, an awareness of the outside environment is critical (Fanatico & Born, 2002; Sossidou et al., 2011; Von Borell & Sørensen, 2004). Achieving proper management of a free-range environment requires a multi-factorial approach. Management of the flock and associated living area will have a direct effect on flock performance (Lay et al., 2011).

### *1.6.1 Management of the range*

The physical environment of laying hens in a free-range setting is important and there are several factors that influence the laying hens' desire to express natural behavior on range. These factors include the means and convenience of access to the range (i.e., opening size and location within the indoor enclosure) (Pettersson et al. 2016), temperature and complexity of the range (i.e., availability of shade and enrichments) (Singh & Cowieson, 2013), and the familiarity of the range to the hen (Singh & Cowieson, 2013). The management of the flock and associated living area will have a direct effect on flock performance (Lay et al., 2011).

While many factors are out of the control of the stockman, there are several areas that remain under their control. For example, where and when laying hens forage and graze on the range can be completely controlled by a stockman using rotating fences. Healthy range management is critical to maintain a balance between laying hens using the range, but not over grazing and damaging the range (Breitsameter et al, 2013; Singh & Cowieson, 2013). A healthy range provides health benefits to the laying hens, such as reduced feather picking (Bestman & Wagenaar, 2003; Grigor et al., 1995; Knierim, 2006). Another aspect of management is imprinting pullets at a young age to use range, which increases the use of range when they become laying hens (Grigor et al., 1995; Lay et al., 2011).

### *1.6.2 Weather/environment*

The laying hen may go outside under a variety of weather conditions and range environments (Spencer, 2013), it is not a specific temperature or level of sunlight that determines the range usage. The continuity or consistency of that outdoor environment also affect whether the laying hen takes advantage of the opportunity to be outdoors (Heckendorn et al., 2009). For example, at a consistent daily temperature of $35^0$ Fahrenheit the laying hen will acclimate to that environment and have potential to range consistently. However, when temperatures and conditions are inconsistent, (75 $^0$ Fahrenheit and one day, then $35^0$ windy and rainy the next) the laying hen will reduce its use of range (Rault et al., 2015).

Other climatic conditions that influence laying hens range use are extreme temperatures (hot or cold), high winds, and strong rains, which all reduce the probability of a laying hen venturing outside and the consequently the amount of time spent outside (Gebhardt-Henrich et al., 2013; Pettersson et al., 2016; Richards et al., 2011; Singh & Cowieson, 2013;

Hegelund et al., 2005). Weather also has an impact on how range behavior is exhibited (e.g., warmer temperatures increase dust bathing) (Duncan et al., 1998).

#### *1.6.3 Light Intensity*

Sunlight intensity is another significant factor in range use by laying hens. Laying hens are more likely to use range in morning hours, then again in late afternoon through dusk (Chielo et al., 2016). Full sunlight, especially at midday, is avoided (Bubier, 1998; Chielo et al., 2016; Miao et al., 2005; Van de Weerd et al., 2009). This is likely because laying hens have tetrachromatic vision and see a broader spectrum of light, therefore full sunlight is hard on their eyes (Daigle, 2013). Further, Moura et al (2006) reviewed the difference in light intensity in the middle of the day both inside and outside of a barn and found that a greater number of laying hens were inside the barn at midday, suggesting that they prefer lower light intensities. These observations suggest an alternative to high temperatures as the mechanism behind laying hen avoidance of ranges in mid-day. Laying hens may be photorefractive, influencing their decisions to be on range at high light levels (Moura et al., 2006), but there are no definitive studies.

Specific to range management, light duration and intensity can play different roles (*FeatherWel*, 2013). It can raise and lower production, raise and lower levels of fear, and provide general health benefits to the laying hens. Lower light intensity is associated with less fear, which correlates with more range use in the early morning and later evening (Van de Weerd et al., 2009). Lower light intensity is also associated with reduced feather picking (Zimmerman et al., 2006). The range use by laying hens also allows the absorption of Vitamin D through natural sunlight (Spencer, 2013). Intriguingly, range usage increase after dark for broilers (chickens raised for meat production) which is opposite of laying hens (Dawkins et al., 2003). In addition to influencing range use by physically deterring outside use (i.e., too bright or too hot), light also affects general laying hen behavior. For example, in the spring, increases in photoperiod light promote increased production (Hy-Line International, 2016).

Reduced light in evening is a cue for laying hens to begin roosting activity (Olsson & Keeling, 2000; Sharp, 1993). Light has been a used as a management tool for years in commercial egg production. Light intensity in the hen house is generally lower than natural sunlight intensity at mid-day depending on time of year (Bailie & O'Connell, 2014; Richards et al., 2011). The dominant role of light manipulation has been to recreate springtime by increasing photoperiod regardless of natural day length to stimulate production in young laying hens (Sharp, 1993). However, the manipulation of light in free-range systems can be challenging. Most free-range laying hen barns, in addition to providing access to outside range and natural daylight, have windows allowing considerable natural light into the barn. Natural light can interfere with manipulated light regimes, potentially canceling or amplifying the behavioral effects of artificial light (Bailie & O'Connell, 2014).

#### *1.6.4 Fear*

In addition to conditions on the range, the laying hen's perception of the range is relevant. Fear is one of the strongest expressed behaviors in laying hens (Campbell et al., 2016; Gebhardt-Henrich et al., 2014; Grigor et al., 1995) and the fear response to the physical attributes of the range at multiple levels. One is protection – is it free from predators (mammalian, avian, reptilian) (Bright et al., 2011)? The second - are there opportunities to rapidly hide or find cover, rather than running back to the barn (Richards et al., 2011)? The fear factor or lack of fear related to range use is conveyed among the flocks through vocalizations (Manteuffel et al., 2004; Rodenburg et al., 2013).

### *1.6.5 Shade*

Laying hens show a high propensity to seek shade (Nagle & Glatz, 2012) a behavior related to light intensity (see section 1.5.3), need for protection (section 1.5.4) or some combination thereof (Nagle & Glatz, 2012). Reflecting this behavior, laying hens typically remain near buildings (in shade) when on range (Lay et al., 2011). Therefore, additional shade away from the building can be an effective tool for dispersing them around the range (Knierim, 2006, Lay et al., 2011). A minimum of 5% of the range in shade is recommended (Bright et al., 2011).

Shade can be achieved different ways. Stockmen can provide shade and cover by allowing existent vegetation to grow tall or by adding vegetation, for example, rapidly growing crops such as hemp  (Knierim, 2006; Singh & Cowieson, 2013; Sossidou et al., 2011). Trees are effective, if they are mature (Jones et al., 2007; Miao et al., 2005; Van de Weerd et al., 2009). Shrubbery and wind breaks (e.g., shelter belts) are also effective (Chielo et al., 2016; Nagle & Glatz, 2012). Moveable shade such as wagons can be used as a unique tool to encourage laying hens to move around the range (Zeltner & Hirt, 2003). As free-range commercial production increases, more innovative ways have been developed to address two issues simultaneously, such as solar panels being used for shade and energy production (Zeltner & Hirt, 2003). An additional attribute of shade is the ability to keep outdoor water sources cool and provide a transition from the indoor environment to the outdoor range (Bright et al., 2011).

### *1.6.6 Dustbathing*

Dustbathing is an indigenous behavior of laying hens (Pettersson et al., 2016) and the strength of this behavior in an individual laying hen can influence its desire to spend time on range (Costa et al., 2012). It is known that early exposure to dust bathing type activity in the pullet barn will increase dust bathing activity of the mature flock (Nicol et al., 2001). The purpose of dust bathing is believed to maintain quality and amount of feather lipids as well as reduce ectoparasites (Lundberg & Keeling, 2003). This is a synchronized activity, and once one laying hen starts dust bathing on range, more laying hens will follow (Olsson et al., 2002). Laying hens also tend to use the range in search of fresh areas to dustbathe, avoiding areas of higher ammonia concentrations in the laying barn (Knierim, 2006).

### *1.6.7 Access*

While there is a body of research on what an ideal range might look like, there is very little information on best practices for providing access to the range. The most typical method in commercial free-range production is access openings (Pettersson et al., 2016; Singh & Cowieson, 2013). Access openings need to be of adequate height and width to allow traffic in both directions (FeatherWel, 2013). They must also be distributed evenly around the building to ensure reasonable access to all laying hens inside (Gebhardt-Henrich et al., 2014) and have dry, friable litter near the opening (FeatherWel, 2013) to encourage laying hens in the direction of the popholes

While there appears to be a minimum width necessary, there is little evidence that use increases as the access opening gets wider (Harlander-Matauschek et al, 2006). The height of the bottom of the opening from the barn floor is also important. Access openings that are too high inhibit use and can cause keel bone damage (Richards et al., 2012). As keel bone damage scores go up, access opening usage goes down (Richards et al., 2012). Richards et al (2012) reported at 45 weeks of age, as keel scores went from zero to two, the percent of laying hens using the access openings dropped from 53.9% to 10.8%. Access openings that are too low, such as those at ground level, are potential access points for field mice and other disease vectors (Haroon, 2018; Laing, 1988).

The microenvironment around the access opening should begin at a reasonable height below the opening, and be protected (e.g., no wind, temperatures not significantly different from the building) (Pettersson et al., 2016). Access openings should also be free of barriers such as commercial training wires. One way to achieve this buffered area is through use of a winter garden, a management practice prevalent in European countries but rare in the United States. Winter gardens are structures between the barn wall and the range that are at ambient temperature but protect laying hens from precipitation and direct sunlight with cover (Tauson, 2005). The role of the winter garden is to create a transitional environment between the barn and range to reduce transitional stress (Thuy Diep et al., 2018) and encourage laying hens to use the range.

### *1.6.8 Enrichments*

Range enrichments are additions to the environment that are designed to engage hen behavior, reduce anxiety and facilitate interaction. Range enrichments have proven important to laying hens (Bizeray et al., 2002; Gebhardt-Henrich et al., 2014; Lay et al., 2011; Leone & Estevez, 2008; Lund & Algers, 2003; Mason et al., 2007), with a complex three-dimensional environment being optimal (Rodenburg et al., 2013). Research into range enrichments and management relative to laying hens was first published by Bailey and Mayton (1931) who assessed the utilization of Kudzu as a shade provider on the range. Range enrichments can include the earlier mentioned examples of natural vegetation (trees, shrubs, tall grass [Singh & Coweison, 2013]) and shade structures (shelters, solar panels or wagons, [Bubier, 1998; Nicol et al., 2003]), but are not limited to these. “Attractive” range (Van de Weerd et al., 2009) and ranges richer in quantity and variety of plant life are positively correlated to range use by laying hens (Breitsameter et al., 2013; FeatherWel, 2013).

### *1.6.9 Communication*

Laying hens are social. Pettersson et al (2016) noted that once one laying hen used the range, others followed. In addition to physical cues and enticements to encourage range use, laying hens use auditory communication to relay information and influence the use of the range (Evans et al., 1993; Manteuffel et al., 2004; Tefera, 2012). Up to 30 separate vocalizations have been identified in laying hens with 19 of these being distinctly defined (Tefera, 2012). One of the most understood vocalizations is the gakel call, indicating a desire to find a nest prior to oviposition (Manteuffel et al., 2004). Other vocalizations convey fear or presence of raptors and vary in volume and pitch (Jones & Waddington, 1992). Alarm calls get louder if the predator is moving faster or is larger (Tefera, 2012). Calls vary if it is a ground attack versus an aerial attack. Laying hens use all these calls to communicate about the status and safety of using the range. Vocalizations are relevant to stockmen and may contribute to an overall welfare assessment strategy (Gilani et al., 2013; Nicol et al., 2003). For example, unfamiliar enrichments increase vocalizations as do frustrated non-rewards (Zimmerman & Koene, 1998). Frustrated non-rewards occur when a laying hen is expecting an outcome and the desired outcome does not occur, for example, a laying hen unable to get outside when it hears the sound associated with the access opening. Additionally, because laying hens associate audio cues with automated feeder systems, reduced feeding during the day can improve range use (FeatherWel, 2013).

#### *1.6.10 Genetics*

Laying hen behavior and the effects of different management actions follow from the provenance of commercial laying hens being descended from jungle fowl (Dawkins, 1989). Until recently, the principle focus of a breeding program was production (Fraser et al., 2013) with selective breeding improving productive characteristics of the laying hen dramatically (Kjaer & Sørensen, 2002). Characteristics selected for include percentage egg lay, shell quality, mortality, and feed conversion. Little emphasis was given to traits reflecting natural instincts useful in a free-range environment such as perching and foraging (Flock et al., 2005). Despite this, such innate behaviors remain intact (Van de Weerd et al., 2009). There is strain variation within laying hens for most traits, including the expression of fear, egg production, and the five behaviors previously referenced (Miao et al., 2005). The simplest example is the obvious differences in performance in range behavior between brown and white feathered laying hens (Gebhardt-Henrich et al., 2014; Pettersson et al., 2016). For example, brown hybrids spend more time on range whereas white laying hens move more frequently on range. This suggests that there may be differences in ranging behaviour between genetic strains. However, these results are from small groups of 50 laying hens and cannot be easily generalized to commercial conditions (Pettersson et al. 2016).

The ideal free-range laying hen genotype when compared to the caged genotype will differ in multiple traits. Traits are manipulated through directed breeding with selections including resilience to keel bone damage, susceptibility to fear, and durability to a wide changing climatic environment while retaining production attributes of feed conversion, low mortality and other traditional production parameters (Bishop et al., 2000; Sossidou et al., 2011).

### 1.7 Length of time on range

The literature review yielded no research detailing the amount of time laying hens spend on the range. This is notable, as consumers of free-range eggs expect laying hens to use the range frequently (Fraser et al., 2001; Pettersson et al., 2016). Reported metrics of use focused on the percentage of the flock that used the range and what influences increased or decreased aggregate flock participation in range behavior (Pettersson et al., 2016). However, there is an inverse correlation between flock size and percentage of flock using the range (Gebhardt-Henrich et al., 2014; Pettersson et al., 2016). There were also studies showing that high use of range was correlated to more active laying hens (physically and socially) (Campbell et al., 2016) and a positive correlation between good flock and range management and high use of range (Castellini et al., 2006; Van de Weerd et al, 2009). Additional studies illustrated that factors such as wind speed, laying hen age, precipitation, and volume of cover all can influence how long a laying hen will stay on the range (Hegelund et al., 2005). Genetics also affect the duration of range use. White laying hen strains used the range more frequently and for shorter durations than brown laying hens (Mahboub et al., 2004); broilers come out more commonly at nighttime, which is an inverse of laying hens (Dawkins et al., 2003).

There is variability within flocks on time spent on the range. Some laying hens will never go out even given the opportunity and the fact that their flock mates do (Pettersson et al., 2016). There is also variability within individual laying hens, who will use the range on some days but not others (Campbell et al., 2016). The variability in this behavior is influenced by many factors. Older laying hens use the range less than younger laying hens (Marıa et al., 2004). The more enriched and complex the range is, the greater the percentage of the flock the uses the range (Gebhardt-Henrich et al., 2014; Singh & Cowieson, 2013; Taylor et al., n.d.). Winter gardens also serve to prolong range usage (Hegelund et al., 2005). The variability in a flock can be reduced by exposing the flock to the range (imprinting) at a younger age (Daigle, 2013).

In general, the same factors that influenced range use (section 1.5) correlated with bimodality (Gebhardt-Henrich et al., 2014; Singh & Cowieson, 2013), suggesting that bimodality can be influenced by management. Bimodality occurs in both broilers and laying hens (Lima & Nääs, 2005). This can lead to nutritional variation within the flock if not properly managed, depending on how much nutrition the laying hen acquires from the forage on the range (Van de Weerd et al., 2009).

In the process of selecting for feed conversion, especially in broilers, there is a selection against movement and activity (Weeks et al., 2000). Cover, shade and enrichments all serve to keep the laying hen on range longer (Taylor et al., n.d.), as well as mobile housing which introduces the laying hen to different parts of the range (Plamondon, 2003).

## 1.8 Distance traveled on range

There is little published research about the distance laying hens will travel on range. More is known about the spatial distribution of laying hens on the range – it is not uniform and is affected primarily by social interaction (Febrer et al., 2006; Pettersson et al., 2016), but can also be motivated by fear and foraging availability (Leone & Estevez, 2008). Nearest neighbor distance is influenced by the social nature of laying hens (Bizeray et al., 2002) and increases the further the laying hens move from the barn (Chielo et al., 2016). Shade and cover influence travel distance. Most laying hens travel very little and tend to stay near the shade of the building (Miao et al., 2005; Pettersson et al., 2016; Taylor et al., n.d.). Laying hens can be influenced to move further from the building by environmental complexity (Bizeray, 2002). Enclosure size (i.e., cages) and density contribute the most to the extent of animal mobility (Leone & Estevez, 2008). Larger enclosures also encourage more exploratory behavior (Leone & Estevez, 2008) and animals in larger enclosures tend to have greater nearest neighbor distances. The distance of enrichments from the building is positively correlated to the distance laying hens move away from the building (Heckendorn et al., 2009; Leone & Estevez, 2008; *Range Poultry Industry*, 2000). Increased distance from the barn is beneficial in management of round worms and other helminths on laying hens by reducing the number of laying hens (i.e., host density) and potential helminth load near the building (Heckendorn et al., 2009; Höglund & Jansson, 2011).

## 1.9 Conclusions

Much is known of what stimulates a laying hen to use a range. However, there is minimal research on the activity of laying hens once they are on range and what currently exists is generally focused on smaller non-commercial settings. What is known is that the definition of animal welfare is ever evolving and influenced by religion and societal expectation. The issue of animal welfare specific to commercial egg production is a growing issue. Some consumers are consciously altering spending habits based on concern for animal welfare. Properly managed free-range commercial egg operations allow the laying hen to express more of their natural behaviors. Range use is influenced by a variety of factors including strain of genetics, weather, enrichments and access from the barn. Time spent on the range is influenced by the multiple factors, but little is known about how far laying hens travel on range, but this is a growing area of research using radio frequency identification (RFID) and global positioning systems (GPS). There is limited research conducted exclusively on commercial facilities and thus limited data available to determine how these behaviors and modifications to management can improve husbandry in large-scale operations. This information gap provides the impetus for the research embodied in this thesis

Chapter 2 - Influencing movement of free-range laying hens by moving enrichments

## 2. 1 Abstract

A range can be over grazed if laying hens continuously forage in the same location, therefore rotating foraging locations for flocks is a key to good range management. Laying hens are preferentially neutral to range health and can either improve or damage the range dependent on routine movement (Spencer, 2013). Different strategies include moving laying hens to new paddocks, called rotational grazing, or moving their barn if possible, to relocate the laying hens to fresh forage (Sossidou et al., 2011). Although sometimes labor intensive, influencing the movement of laying hens on a range can be very straightforward by providing shade and cover (Hegelund et al., 2005), which promotes more frequent use and further travel from the laying barn. This also provides consistent new influence in order to disperse laying hens from continually returning to the same spot (Haroon, 2018). A study was conducted to explore new options to motivate laying hens to change forage locations within range. Rather than moving the barn or herding laying hens into subset paddocks of the range, the study used movable enrichments (shade sleds) to alter laying hen behavior. The hypothesis was laying hens would move to new locations on the range in response to the shade being moved and tested this by observing their behavior. The target behavior was volunteer movement by laying hens to shade after shade was moved to a new location. Data analyzed using $CHi^2$ analysis results indicated that the location of laying hens on range can be influenced by shade enrichment. Portable shade is an effective tool to alter laying hen range patterns.

Key words: Shade, portable enrichment, precipitation, temperature, solar radiation

## 2.2 Introduction

A specific component of free-range egg production is giving laying hens the opportunity to access the outdoors (*"Egg Laying Hens",* 2018). By providing laying hens free access to the range, good welfare can be achieved due to availability of different environments, increased space allowance per laying hen and diversity of stimuli (Knierim, 2006). However, Knierim (2006) also noted that providing outside access does not guarantee a utopian experience for laying hens. Free range management on a commercial egg farm is a more complex management challenge than simply providing a pophole on the side of a barn. There is greater difficulty maintaining bio-security standards. Laying hens with outside access may experience increased contact with infectious agents, imbalanced diets, and predators (Knierim, 2006).

In addition to the difficulties of managing the range to keep hens safe (Knierim, 2006), laying hens themselves can improve or damage the range depending on their movements (Spencer, 2013), with most damage occurring near the barn (Hughes & Dun, 1983). Singh (2013) observed few studies on the use of the range area have been carried out on larger (commercial-sized) flocks, even though flock size has been shown to significantly influence the average percentage of laying hens outside (Appleby & Hughes, 1991; Bubier, 1998; Grigor & Hughes, 1993; Harlander-Matauschek et al., 2006; Hegelund et al., 2005; Whay, 2007). Traditional methods to move laying hens on range include daily movement of pens, machine portable housing, and fixed housing with paddocks (Plamondon, 2003). The first two methods do not lend to commercial flocks of 15,000 to 20,000 laying hens because the labor intensity and fixed housing with paddocks does not encourage dispersion over the entire range at any one time.

To address the above issues, a means to influence laying hen movement inexpensively and efficiently, was developed and tested. The hypothesis was that laying hens in permanent commercial housing would alter their range usage behaviors if shade enrichments were moved on a periodic basis. The project was designed to understand laying hen movement as it is influenced by behavior (fear and social), using environment enrichment as a motivator in order to impact range usage.

### *2.2.1 Impact of minimal or no enrichments on fear in laying hens*

When encountering alarming stimuli, fear can overtake and inhibit other normal behavior in laying hens (Jones, 1996), while good animal husbandry and environment can minimize such (Dawkins et al., 2003). Fear especially, increases when laying hens are left in a large open area with no protected areas or cover (Jones, 1996). In free-range flocks, this can be resolved by providing ample shade and cover (whether natural or man-made), which encourages the laying hens to use the range and travel a further distance from the laying barn (Hegelund et al., 2005). Shade and cover also influence the distribution of laying hens on a range and the number that are outside at any given time (Pettersson et al., 2016). Despite the general positive influence of shade and cover, fear can still outweigh them. For example, the further away the enrichments are from the barn and the more open space a laying hen must travel, the less likely they will be used (Sonaiya, 2004).

### *2.2.2 Social nature of laying hens influences use of range*

The social behavior of laying hens influences their range use. While shade enrichments can draw them further from the barn, the social nature of laying hens (desire to stay near flock mates inside the barn) will always compete and cause some to resist the opportunity to utilize the more distant enrichments (Appleby & Hughes, 1989). The acclimation process for laying hens to range can occur in as little as 10 days (Rault, 2013; Zeltner & Hirt, 2003). The habituation process is perpetual whether it is short term, such as a helicopter flying overhead, or long term, such as adjusting to a new range for the first time (Jones, 1996). Over time however, repetition and experience will show an increase in foraging (Spencer, 2013). Use has been reported as 10-

50% of the flock out on the range at any one time (Pettersson et al., 2016; Gebhardt-Henrich et al., 2014). Whether many laying hens are using the range a small percentage of time, or a small number are using the range a large percentage of time though is unresolved (Pettersson et al., 2016; Sossidou et al., 2011). Some research indicates that as flock size grows, the percent of the flock using range diminishes (Gebhardt-Henrich, 2014; Sonaiya, 2004; Zeltner & Hirt, 2003). Other research, using RFID data, disputes this and indicates no correlation between flock size and outside use (Pettersson et al., 2016). Pecking order among laying hens is well understood in dense settings that occur inside barns. The degree of victimization of smaller laying hens, ranges from none to high (Freire et al., 2003), but victimization rates are lower in range settings (Grigor et al., 1995). Higher use of range correlates with lower feather picking (Zeltner & Hirt, 2008) but may not always be the case because the distribution of laying hens on the range is not uniform and when gathered in denser clusters, social interactions such as feather picking may still occur even outside (Pettersson et al., 2016). These phenomena further support the research to develop wider use of range through shade enrichments.

#### *2.2.3 Other motivations for range use by laying hens*

The use of range and the extent of use is motivated by a laying hen's ability to get outside (access), and internal and external motivators (Pettersson et al., 2016). Enrichments can be motivating to the laying hen and have been shown to decrease the density of laying hens near the barn and influence the location of laying hens on the range (Breitsameter et al., 2013; Hegelund et al., 2005; Nagle & Glatz, 2012; Pettersson et al., 2016; Rault et al., 2013). These enrichments are equally effective whether they are manmade or natural, but they must be meaningful to the laying hen as evaluated by their usage (Hegelund et al., 2005; Rivera-Ferre et al., 2007; Zeltner & Hirt, 2003). Small enrichments such as feeders seemed to have limited impact, as did young trees (<2yr) (Grigor et al., 1995; Jones et al., 2007). Age also has an impact on range use, with data showing older laying hens using the range less (Hegelund et al., 2005).

All these factors weigh into the experimental design of movable enrichments and the potential influence they may have on the flock.

A multitude of environmental factors influence the laying hen's motivation to use the range. Laying hens may use the range less if there is a significant variation in density between the indoor and outdoor environment (Grigor et al., 1995). This phenomenon is related to extreme novelty causing fear and moderate novelty leading to exploration. Weather can have a large impact on range usage (Sonaiya, 2004). Wind speed, precipitation, season, and temperature have all shown influence (Dawkins, 2003; Hegelund et al., 2005). Range behavior is also diurnal, with morning and evening times being the most popular for laying hens to be outdoors (Pettersson et al., 2016; Spencer, 2013). Other factors impacting range use include range design, development of range, and interior facility design, including the design and size of popholes (Dawkins, 2003; Pettersson et al., 2016; Richards et al., 2011). The research in this paper focuses on the development of range enrichment and range design.

### *2.2.4 Impact of laying hen movement on range quality*

Social behaviour, emotion and motivation affect how laying hens use range and thus directly affect the quality of the range. Stocking density of the flock and the amount of time laying hens spend on the range affect range quality and productivity. Higher range laying hen density and more time on range lead to lowered vegetation quality (Breitsameter et al., 2013). Laying hens tend to forage (i.e., digging root zones, catching insects) on the range as opposed to eating the vegetation, which still damages it (Breitsameter et al., 2013). This behavior creates a conflict in free-range management: The more time and further distance a laying hen spends on the range, the better off it will be (Chiello et al., 2016), however, the more time a laying hen spends outside, the more the vegetation suffers and therefore the quality of the range reduced (Bubier, 1998). Good management practices will keep track of how range areas are faring with laying hen use and move the laying hens frequently to new paddocks or barns, to minimize range degradation (Sossidou et al., 2011). This requirement is straightforward, but not easily implemented. Novel (i.e., simple) and economical ways to manage range to achieve durability are needed. To address this need, a system of portable shade enrichments was developed to motivate laying hens to graze in different areas of a range. The hypothesis was range behavior could be influenced by movement of shade enrichments. This was tested by observing laying hen behavior.

## 2.3 Materials and Methods

### *2.3.1 Experimental Design*

Six commercial flocks of ~ 20,000 Hy-Line Brown laying hens were used for the two seasons of this trial. There were three flock replications (N=3) during each season. All flocks were on the same property and managed using third party Humane Farm Animal Care (HFAC) free range and pasture certification protocols. The property had two attached, but individual, barns with a common egg room in the middle. The third barn was separate but also on the same farm. The three barns were located on ~70 acres of land. The single barn had a 50-acre range and the attached barns shared the remaining 20 acres. Two of the flocks in each season were genetic sisters and housed in the attached barns. The third flock, in each season trial, were seven and five weeks older than the other two flocks respectively and housed in the single barn for both seasons. In the first season, two flocks were 73 weeks old at the onset of the treatment and one flock was 80 weeks old. The treatment was shade sled present or shade sled absent. Season one occurred in November and December of 2017 over a six-week window of time. In the second season, two flocks were 42 weeks old and one flock was 47 weeks old at the onset of the season. Season two occurred in August and September of 2018 over a six-week window of time. Given the two seasons, data were collected both in the cooler temperatures of fall/winter and the warmer temperatures of summer/fall. Field cameras were mounted true North and true South to the barn for each season. The cameras were aimed at a defined area where shade was present or absent. The shade sled was moved every two weeks from the "present" location to the "absent" location and vice versa. Photos were taken hourly during the day and the data were measured as presence or no presence of laying hens in each photo.

*2.3.2 Housing and range*

Schematics of the integrator barns can be found in Appendix A. The living area of each barn is 480 feet long and 50 feet wide yielding 24,000 $ft^2$ or 1.2$ft^2$/laying hen housed. There are 14 popholes on each side of each layer house. They were opened daily at 9:00am and closed at dusk. Laying hens were free to access the entire range for ~8-12 hours per day depending on the season and time of sunset.

The interior laying hen area of each barn was as identical in layout as possible in commercial barns. The Big Dutchman Colony nesting system was used in each barn. Laying hens had 1.2$ft^2$ interior living area and were able to move freely through the entire barn. The building was designed to allow 10 laying hens per water nipple, six linear inches of perch space per laying hen housed and four linear inches of chain feeder space per laying hen housed. The barn used Munters ventilation equipment with a Farm Premium XL controller. The barn was 50 feet wide with a concrete floor. Scratch areas on either side of the interior of the building were 10 feet wide and the remaining 30 feet in the center of the barn was an elevated slat area with a center row of colony nests. Slats were 36" above the floor. Feeders, waterers and perches hung from the ceiling on a pulley system and could be raised or lowered with winches.

Exterior range fencing varied between 75-1,058 feet away from the nearest point of the barn. Variation was dictated by fence lines of the property. The property is rolling with an elevation change of ~120 feet from the lowest point on the property to the highest. The lowest point was a valley that ran parallel to and in between the barns. The barns were built on the ridges of the property.

### *2.3.3 Range enrichment and portability*

In Figure 2.1, the red lines seen define all fence lines for all ranges on the experiment property. Enclosed fence line is fence around a pond on the property. Purple dots indicate the location of the six pairs of cameras.

A shade sled was used as the movable enrichment for each barn as a source of shade and cover for laying hens. The shade sleds were wood construction 10 feet wide by five feet deep. They had three-foot front legs to create a “lean to” structure. A photo of one of these sheds can be seen in Appendix B. The shade sleds were not visible to each other nor could a flock from one barn see more than one shade sled.  Shade sleds were stationed ~100 feet from the layer house either due North or due South. A second location 100 yards lateral to the sled and equidistant from the building was staked out and shade sleds were moved every two weeks for six weeks between the original location and the staked location. The sleds were moved in an ABA pattern spending two weeks in location A, while data were being collected at both sites A and B. The sled was then moved to location B for two weeks, while data were collected for both locations A and B.  The sled was then returned to location A for the remaining two weeks, while data were collected at both locations A and B. Enrichments were moved three times during each season, providing three sets of observations per location, per season.

### *2.3.4 Diets*

The two genetic sister flocks were fed a commercial NGMO diet and the older flock in the third barn was fed a commercial organic diet both seasons (Appendix C).  This variation was based on management decisions of the integrator made independent of this research (Note: For the purpose of this paper, an integrator is defined as an animal agriculture company that owns the livestock and provides the feed and transportation related to the animals. The counterpart is the stockperson who provides the facilities, the utilities and the labor to manage the animals.) The diets were nutritionally balanced.

### *2.3.5 Age*

The laying hens were 16 weeks old when housed at the farm the experiment was conducted at. When season one began in the Winter of 2017, two flocks were 73 weeks old and one flock 80 weeks old. When season two began in the Fall of 2018, two flocks were 42 weeks old and one flock was 47 weeks old. There were different flocks used for each season.

### *2.3.6 Seasonality*

Two seasons were monitored. The purpose was to gather data on possible temperature and season influence as a variable in the shade trial study. Season one began in November 2017. It ran for six weeks and was completed in December of 2017. Season two began in August 2018. It ran for six weeks and was completed in September 2018. A Davis Vantage Pro2™ Plus including UV & Solar Radiation Sensors weather station was placed on the property and hourly data were collected for temperature, solar radiation, and precipitation.

### *2.3.7 Location*

The research occurred on a farm located in Owenton, Kentucky 40359 owned by Kentucky Pasture Poultry, LLC. An aerial view of this property can be seen in Figure 2.1.

### *2.3.8 Data Collection*

Two PlotWatcher PRO cameras (model TLC -200-C) were mounted on each layer barn to take photos of the area surrounding the enrichment and the area surrounding the alternate site. Photos were taken once per hour from 9:00am to dusk. Shade sleds were moved between the two locations every two weeks in an ABA model. At the end of the trial photos were assessed to analyze presence or lack of presence of laying hens with and without the enrichment.

The original intent was to count the number of laying hens present under the enrichment in each photo, however due to the quality of photography, this was replaced with counting the number of photos that had laying hens present in the photo in the defined area.

### *2.3.9 Statistical analysis:2 sample T test - Chi$^2$*

This research was conducted to determine the influence of and preference for shade by laying hens. Data were analyzed with that single variable as well as multivariate interactions with environmental parameters. Actual counts of laying hens in both the shade and no shade photos was difficult and subject to interpretation. As an alternate data were measured as presence or no presence of laying hens in either treatment (shade/no shade) in using photos. The data gathered was not continuous but discrete over a six-week, daily sampling regimen. Chi$^2$ analysis for association was used to compare the presence of laying hens in either option (shade/no shade) against five variables: observation camera, time of day, precipitation, air temperature, and solar radiation. This analysis can be found in Appendix D.

A question arose whether there was a statistical difference in shade sled usage between Southern or Northern exposure of the shade sled. A 2-sample T-test was used to determine if there was a difference (Table 2.1). The original data were accumulated during season one of the experiments and the second set was accumulated during season two.

The data from this study was discrete (present or not present) rather than continuous (some number of laying hens present) and analyses factored in that limitation. This limitation reduces the confidence in conclusions. The nature of Chi$^2$ data is it is used to analyze discreet data rather than continuous data. As such it is difficult to make strong statements of conclusion. An example is “more laying hens used shade in Summer than in Winter”. It cannot be fully determined from the data if this is a temperature phenomenon, an age of flock phenomenon or is it because younger hens have potentially better feathering and that influences shade usage. The time series plots provide directional but not 100% conclusive interpretation of the data.

Inter observer accuracy and analysis was tested using techniques published by Landis and Koch (1977). When large populations of data are reviewed observer fatigue can provide incorrect interpretation of the data. This was reconciled by the measurement of Kappa scores where a second observer reviews subsets of the same data and an evaluation was made of consistency of data review by both observers. Kappa scores between 0.81 and 1.00 are viewed as "almost perfect" (Landis & Koch, 1977). All Kappa scores for observer agreement fell into the "almost perfect" category.

## 2.4 Results and discussion

### *2.4.1 Shade/no shade*

The primary investigation was whether shade had an influence on laying hen behavior and movement on range. This was measured by the presence or lack of presence of laying hens, in photos, with and without shade present in the identical location. Free-range laying hens are bi-modal relative to the laying house they live in. Some will use the range under a variety of conditions, and some will never leave the laying house regardless of conditions. It should be expected to see similar population variation relative to laying hen behavior and movement on range where shade is present and not present. The evaluation is on 20,000 potential individual behaviors, not one flock.

Using $Chi^2$ analysis (Appendix D), in season one there were 582 photos with laying hens present. Of those 582, 188 photos had no shade present and 394 photos had shade present. In season two there were 732 photos with laying hens present. Of those 732, 134 photos had no shade present and 598 photos had shade present. Results of this can be seen in Figures 2.2 and 2.3.

In this trial there appeared to be a clear influence of shade on laying hen ranging behavior. When shade was present at a specific location an increased number of laying hens were viewed in photos. When shade was removed there was a significant decrease in the number of photos with laying hens present. The conclusion is that shade presence influences laying hen behavior in a positive way on commercial egg production farms on range.

### *2.4.2 Shade/time of day*

The data were further parsed apart, and a series of additional parameters were analyzed in conjunction with shade/no shade to measure influence on behavior. The first additional parameter was time of day. Popholes opened at 9:00am and remained open until dusk. Feeders ran at scheduled times throughout the day. There was little presence of the laying hens on range early in the day. The morning peak was at 11:00am. It then declined until 3:00pm and peaked at 5:00pm. This reflects only data from laying hens caught on camera. It cannot be stated with certainty from the data but there is no reason to assume the remaining laying hens on range exhibited different behavioral trends.

Figures 2.4 and 2.5 show the identical camera angle at two points in the day. Figure 2.4 is a photo is taken at 9:00 in the morning and Figure 2.5 is a photo taken at 7:00 in the evening. The behavior of more laying hens on range during late afternoon hours was seen consistently in the data. Data were charted for both seasons of the experiment and showed similar results. This is consistent with prior published research that laying hens will use the range most dominantly in the late afternoon and early evening hours.

The analysis then pulled apart the influence of shade present or not present along with time of day, with the results being seen in Figures 2.6 and 2.7. In all results other than 9:00am and 10:00am in season one, there were always more laying hens present under shade than in the open no shade photos. The data begins to clarify a deeper understanding of the general trend of more laying hens outside in the afternoons and a greater amount of these laying hens using the shade structure than out in the open (while keeping in mind that the areas being photographed represent only a small part of the total range). While it may be reasonable to assume the same type of activity is occurring across the entire range, the data in this trial would not be able to confirm that thesis. Follow-up research using a combination of RFID and GPS technology would further our understanding of the broad flock behavior that is occurring in commercial settings.

The influence of shade on time of day presence was confirmed using time series plotting. In Figure 2.8 (season one), at 9:00am and 10:00am there were more laying hens in photos that did not have shade structures than in photos with shade. The sample size for this period was very low (n<10) and the activity of two or three laying hens out of 20,000 can skew the data. This could also simply be a randomness issue and is an example of not being able to make 100% conclusive statements. In Figure 2.9 (season two) there are more laying hens under shade at every time of day. This continues to support the hypothesis that shade has an influential impact on laying hen behavior. Laying hens exhibited normal presence outside by time of day from a global perspective and was consistent with prior published data (Pettersson et al.2016; Spencer, 2013).

*2.4.3 Shade/temperature*

Data were analyzed by looking at the interaction of shade and temperature (degrees $F^0$). With seasonality of temperature between the two seasons, data overlapped in temperature range between 50 and 70 degrees $F^0$. Across the two seasons, laying hens were present between 30-90 degrees $F^0$, regardless of the absence/presence of shade. This was expected as laying hens will use the range over a wide range of temperature (Sonaiya, 2004).

Presence on range, relative to temperature, mirrored a bell curve with the apex at 50 degrees $F^0$ for season one and 80 degrees $F^0$for season two. This can be seen in Figures 2.10 and 2.11. This showed an excellent example of acclimation. Acclimation is the process of adjusting to a localized environment. Using 50 degrees $F^0$ as a discreet data point this represented a relatively warm day in December and a relatively cool day in September. The laying hens had acclimated to the adjusting external temperature relative to the season and based on behavior viewed the discreet 50 degrees $F^0$ with entirely different activity.

At every temperature there were more laying hens present when shade was present than when shade was absent. This observation once again reinforces the hypothesis that shade has a strong influence on laying hen ranging behavior. While laying hens experienced a range of temperature from 30 degrees $F^0$ to 90 degrees $F^0$, across all temperatures they were more often found under shade than in non-shade areas.

Box plot data of temperature influence on shade usage (Figure 2.12) suggests there could be a minimum temperature where laying hens simply no longer prefer to be outside thus mitigating the shade /no shade conversation. In season one (Figure 2.12), there appears the possibility that below a certain temperature laying hens simply do not go outside or use shade. In season two (Figure 2.13), there does not appear a correlating upper end of temperature where shade is no longer influential.

*2.4.4 Shade/precipitation*

Precipitation has the potential impact to reduce range activity. In this study, laying hen activity was analyzed with shade present or absent during measured precipitation. In analyzing the shade charts in Figures 2.14 and 2.15, I uncovered two findings:

1) When there is no precipitation present the hypothesis holds that shade is an influence of laying hen behavior on range activity.

2) When even very small amounts of precipitation occur (<0.10 inches per day) range usage essentially ceases.

There was inconsistency and no trend of laying hens present on range during precipitation events regardless of shade being present or absent. The amount of data points with laying hens present during precipitation dropped significantly (0 < N <55). The time series plots (Figures 2.16 and 2.17) appears to show completely random behaviors. This is true for both seasonal treatments. The plot would suggest that precipitation appears to disrupt normal conventions of shade use. This could occur through normal flock variability or possibly that the few laying hens that venture outside view precipitation is an inviting attribute, more so than shade. There are so few data points that no firm analysis can be arrived at.

### *2.4.5 Shade/solar radiation*

Laying hens tend to be on range less during bright sunlight (Grigor et al., 1995). There is more activity in the dawn and dusk hours on range than there is in the middle of the day (Hegelund et. al, 2005; Nagle & Glatz, 2012). Research suggests one influencer is the brightness and intensity of sunlight that inhibits laying hens from being on range during mid-day. If this is accurate then we should expect to see more laying hens present underneath shade when solar radiation is high. Shade by solar radiation influence shows that laying hens are present at higher numbers under shade than not, until the upper ends of solar radiation exceed 90%. Solar radiation is measured in watts/meter$^2$.

We would expect to see, based on research, that as solar radiation goes up laying hen presence on range goes down. The data seen in Figures 2.18 and 2.19 support and confirm this trend. Laying hens see tetra- chromatically (four colors). When cross referencing data from temperature trial with the shade trial, as done in Figures 2.20 and 2.21, it appears that reduced laying hen use of range is in the middle of day is more of a factor of solar radiation than temperature.

Charts of solar radiation by shade by laying hens confirms that shade influences activity at virtually every solar level. The season one box plot (Figure 2.22) shows a crossover event over 90. Once again, a small sample size of the data set at the extremes compromises strong statements of significance of this crossover. Season two results can be seen in Figure 2.23.

The trial using solar radiation as an influencer confirms that shade has a strong influence on laying hen behavior when cross referenced with solar radiation.

### *2.4.6 Shade/direction*

During the research, a question was raised about the possibility of camera orientation (facing North or South) having an impact on the results of the other studies. To address this question, a two sample T-test was run. The data used was from time of day – no shade. The results of this T-test can be seen in Table 2.1. A P-value of 0.788 showed that the directional exposures were not different.

All data were reviewed with the variables of shade present or absent, precipitation, temperature and solar radiation and then looking at camera orientation of South and North. There was no statistical significance identified on any of the parameters based on camera orientation. The conclusion is laying hen orientation South or North does not influence other parameters relative to shade.

## 2.5 Summary and conclusions

The results of the research confirmed, in a commercial setting, behavioral patterns related to shade that have previously been identified in research settings. This is valuable information that can be carried forward to the commercial free-range egg industry. The research also demonstrated that under a wide variety of environments portable shade can serve as a new and novel tool in range management. The ability to move laying hens around the range to avoid overgrazing will long-term improve the sustainability of ranges and free-range egg production.

2.6 Tables

$\mu_1$: mean of Time No Shade South

$\mu_2$: mean of Time No Shade North

Difference: $\mu_1 - \mu_2$

*Equal variances are not assumed for this analysis.*

Descriptive Statistics

| Sample | N | Mean | StDev | SE Mean |
|---|---|---|---|---|
| Time No Shade South | 11 | 6.64 | 4.37 | 1.3 |
| Time No Shade North | 11 | 6.09 | 5.01 | 1.5 |

## Estimation for Difference

| Difference | 95% CI for Difference |
|---|---|
| 0.55 | (-3.65, 4.74) |

## Test

| | |
|---|---|
| Null hypothesis | $H_0$: $\mu_1 - \mu_2 = 0$ |
| Alternative hypothesis | $H_1$: $\mu_1 - \mu_2 \neq 0$ |

| T-Value | DF | P-Value |
|---|---|---|
| 0.27 | 19 | 0.788 |

P-value of 0.788 shows that the directional exposures were not different.

*Table 2.1 2-Sample T-Test*

## 2.7 Figures

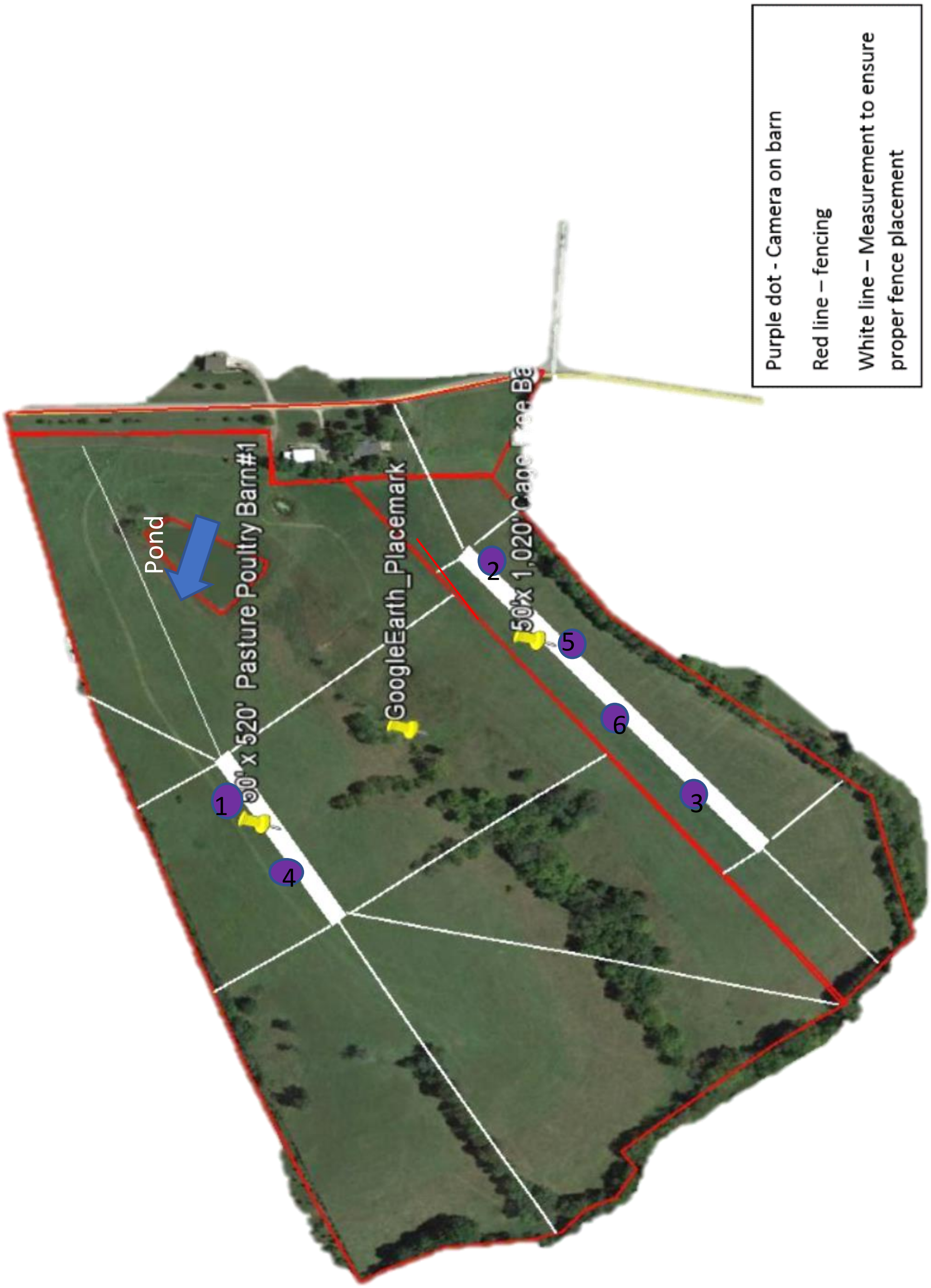



*Figure 2.1 Aerial view of property with fence lines*

**Hens Present Fall/Winter**

| Time | | | Temperature | | | Precipitation | | | Solar Radiation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Military | % Photos w/Shade | % Photos w/No Shade | °F | % Photos w/Shade | % Photos w/No Shade | Inches | % Photos w/Shade | % Photos w/No Shade | Watts/Meter$^2$ | % Photos w/Shade | % Photos w/No Shade |
| 9 | 0.00% | 100.00% | 10-19 | 0.00% | 0.00% | 0-0.09 | 70.76% | 29.24% | 0-99 | 64.23% | 35.77% |
| 10 | 20.00% | 80.00% | 20-29 | 0.00% | 0.00% | 0.1-0.19 | 80.00% | 20.00% | 100-199 | 60.12% | 39.88% |
| 11 | 63.16% | 36.84% | 30-39 | 68.18% | 31.82% | 0.2-0.29 | 40.00% | 60.00% | 200-299 | 68.75% | 31.25% |
| 12 | 72.09% | 27.91% | 40-49 | 68.59% | 31.41% | 0.3-0.39 | 0.00% | 0.00% | 300-399 | 61.67% | 38.33% |
| 13 | 75.93% | 24.07% | 50-59 | 65.61% | 34.39% | 0.4-0.49 | 0.00% | 0.00% | 400-499 | 74.36% | 25.64% |
| 14 | 80.00% | 20.00% | 60-69 | 75.45% | 24.55% | 0.5-0.69 | 33.33% | 66.67% | 500-599 | 92.54% | 7.46% |
| 15 | 72.50% | 27.50% | 70+ | 56.10% | 43.90% | 0.7-0.79 | 40.00% | 60.00% | 600+ | 80.00% | 20.00% |
| 16 | 67.03% | 32.97% | | | | 0.8-0.89 | 0.00% | 0.00% | | | |
| 17 | 69.00% | 31.00% | | | | 0.9-0.99 | 55.56% | 44.44% | | | |
| 18 | 58.06% | 41.94% | | | | 1+ | 44.44% | 55.56% | | | |
| 19 | 0.00% | 0.00% | | | | | | | | | |

*Figure 2.2 Results from photos including laying hens for season one of experiment (Winter 2017)*

**Hens Present Summer/Fall**

| Time | | | Temperature | | | Precipitation | | | Solar Radiation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Military | % Photos w/Shade | % Photos w/No Shade | °F | % Photos w/Shade | % Photos w/No Shade | Inches | % Photos w/Shade | % Photos w/No Shade | Watts/Meter$^2$ | % Photos w/Shade | % Photos w/No Shade |
| 9 | 87.50% | 12.50% | 50-59 | 100.00% | 0.00% | 0-0.09 | 82.14% | 17.86% | 0-99 | 62.50% | 37.50% |
| 10 | 83.33% | 16.67% | 60-69 | 79.66% | 20.34% | 0.1-0.19 | 82.14% | 17.86% | 100-199 | 78.52% | 21.48% |
| 11 | 89.58% | 10.42% | 70-79 | 74.77% | 25.23% | 0.2-0.29 | 66.67% | 33.33% | 200-299 | 73.01% | 26.99% |
| 12 | 89.29% | 10.71% | 80-89 | 83.18% | 16.82% | 0.3-0.29 | 88.89% | 11.11% | 300-399 | 87.76% | 12.24% |
| 13 | 98.15% | 1.85% | 90+ | 83.21% | 16.79% | 0.4-0.49 | 85.71% | 14.29% | 400-499 | 81.52% | 18.48% |
| 14 | 84.62% | 15.38% | | | | 0.5-0.59 | 0.00% | 0.00% | 500-599 | 82.46% | 17.54% |
| 15 | 92.42% | 7.58% | | | | 0.6-0.69 | 100.00% | 0.00% | 600-699 | 88.89% | 11.11% |
| 16 | 90.91% | 9.09% | | | | 0.7-0.79 | 0.00% | 0.00% | 700-799 | 96.55% | 3.45% |
| 17 | 80.34% | 19.66% | | | | 0.8-0.89 | 66.67% | 33.33% | 800-899 | 100.00% | 0.00% |
| 18 | 70.07% | 29.93% | | | | 0.9-0.99 | 73.33% | 26.67% | 900-999 | 100.00% | 0.00% |
| 19 | 70.91% | 29.09% | | | | 1-1.19 | 100.00% | 0.00% | 1000-1099 | 100.00% | 0.00% |
| 20 | 83.33% | 16.67% | | | | 1.2-1.29 | 0.00% | 0.00% | 1100+ | 100.00% | 0.00% |
| | | | | | | 1.3-1.49 | 0.00% | 0.00% | | | |
| | | | | | | 1.5-1.59 | 50.00% | 50.00% | | | |
| | | | | | | 1.6-1.79 | 0.00% | 0.00% | | | |
| | | | | | | 1.8-1.99 | 0.00% | 0.00% | | | |
| | | | | | | 2-2.09 | 0.00% | 0.00% | | | |
| | | | | | | 2.1+ | 100.00% | 0.00% | | | |

*Figure 2.3 Results from photos including laying hens for season two of experiment (Summer 2018)*


*Figure 2.4 Photo taken in the early morning*


*Figure 2.5 Photo taken late in the evening*

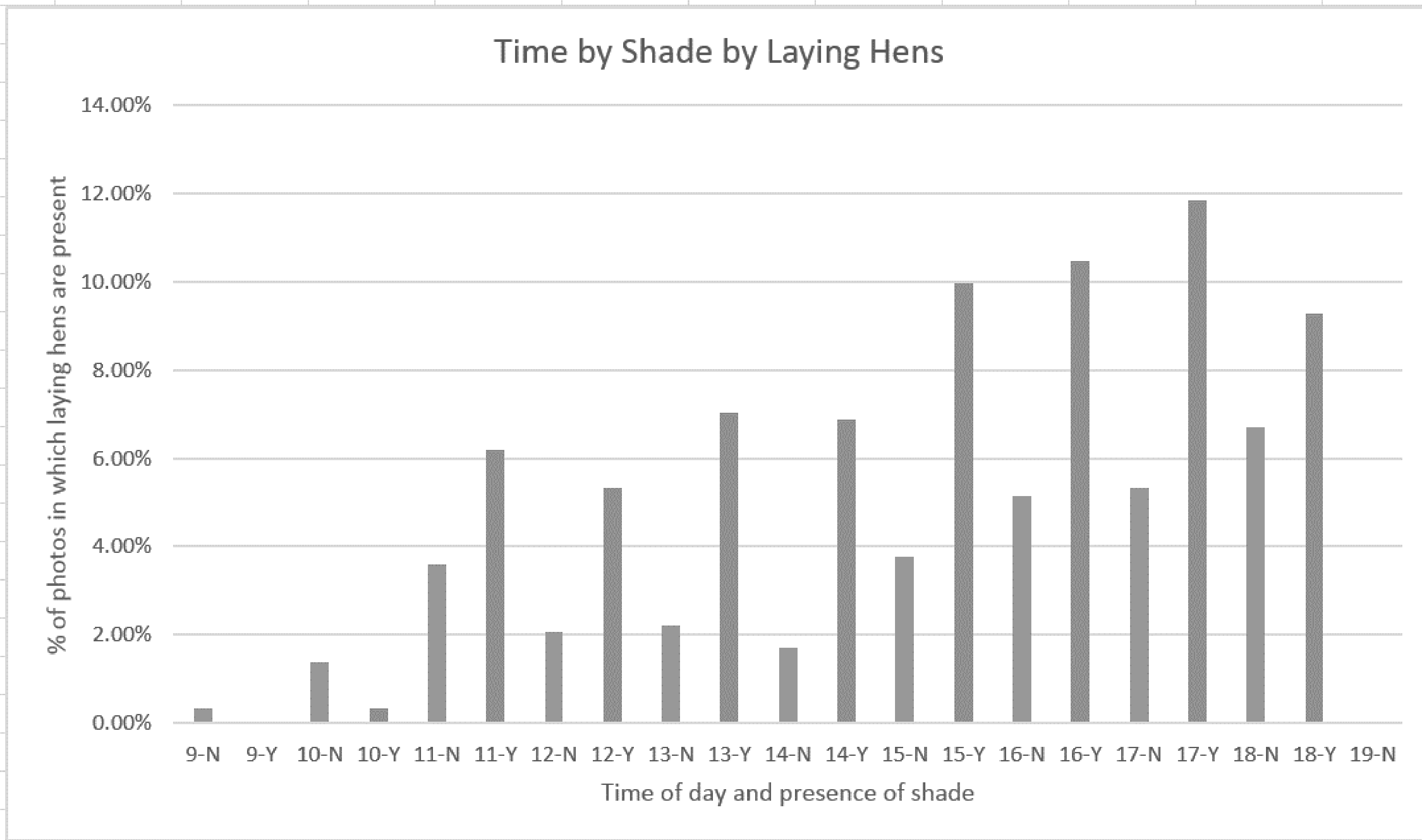



*Figure 2.6 Laying hens present by time of day (with and without shade present) for season one of experiment (Winter 2017)*

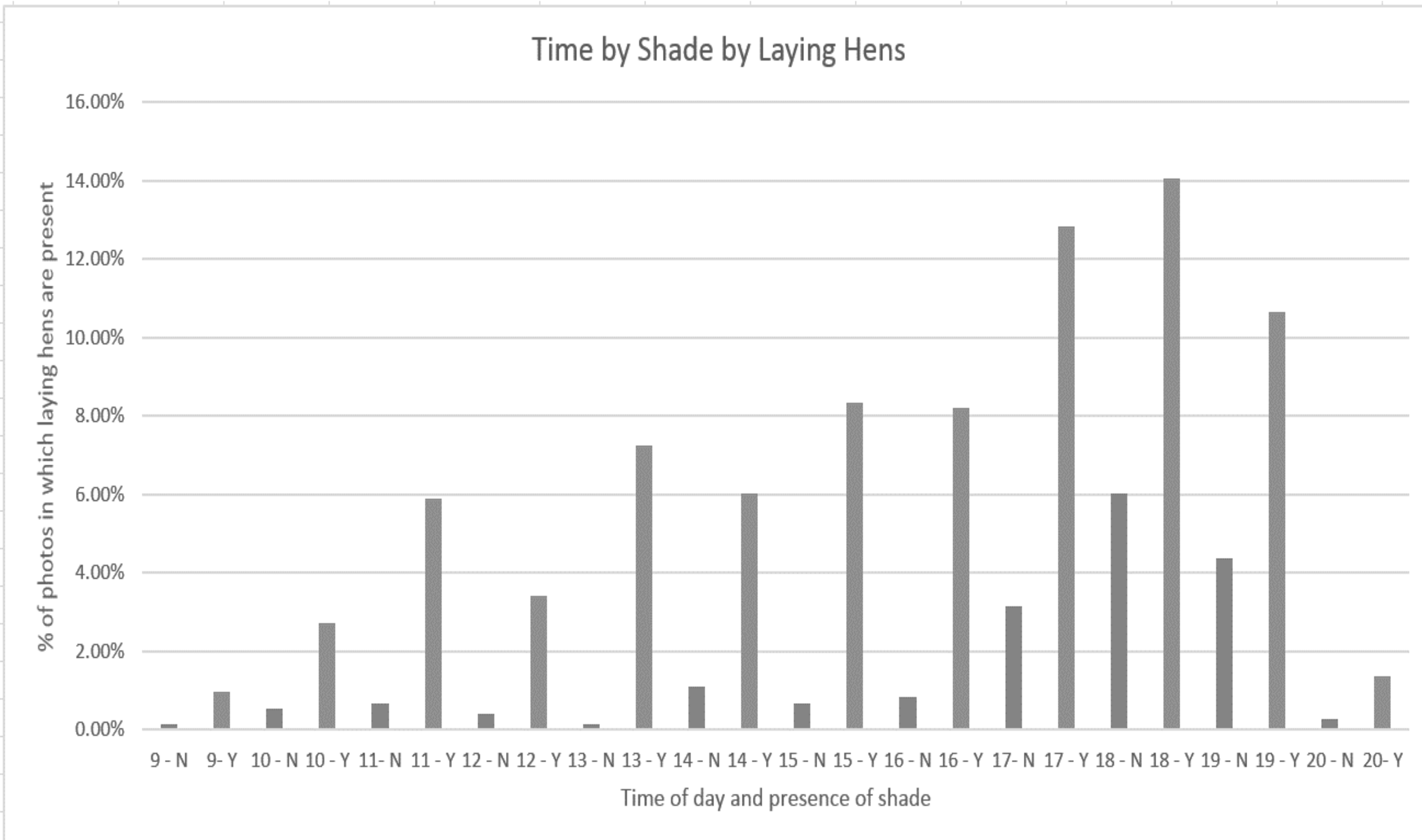



*Figure 2.7 Laying hens present by time of day (with and without shade present) for season two of experiment (Summer 2018)*

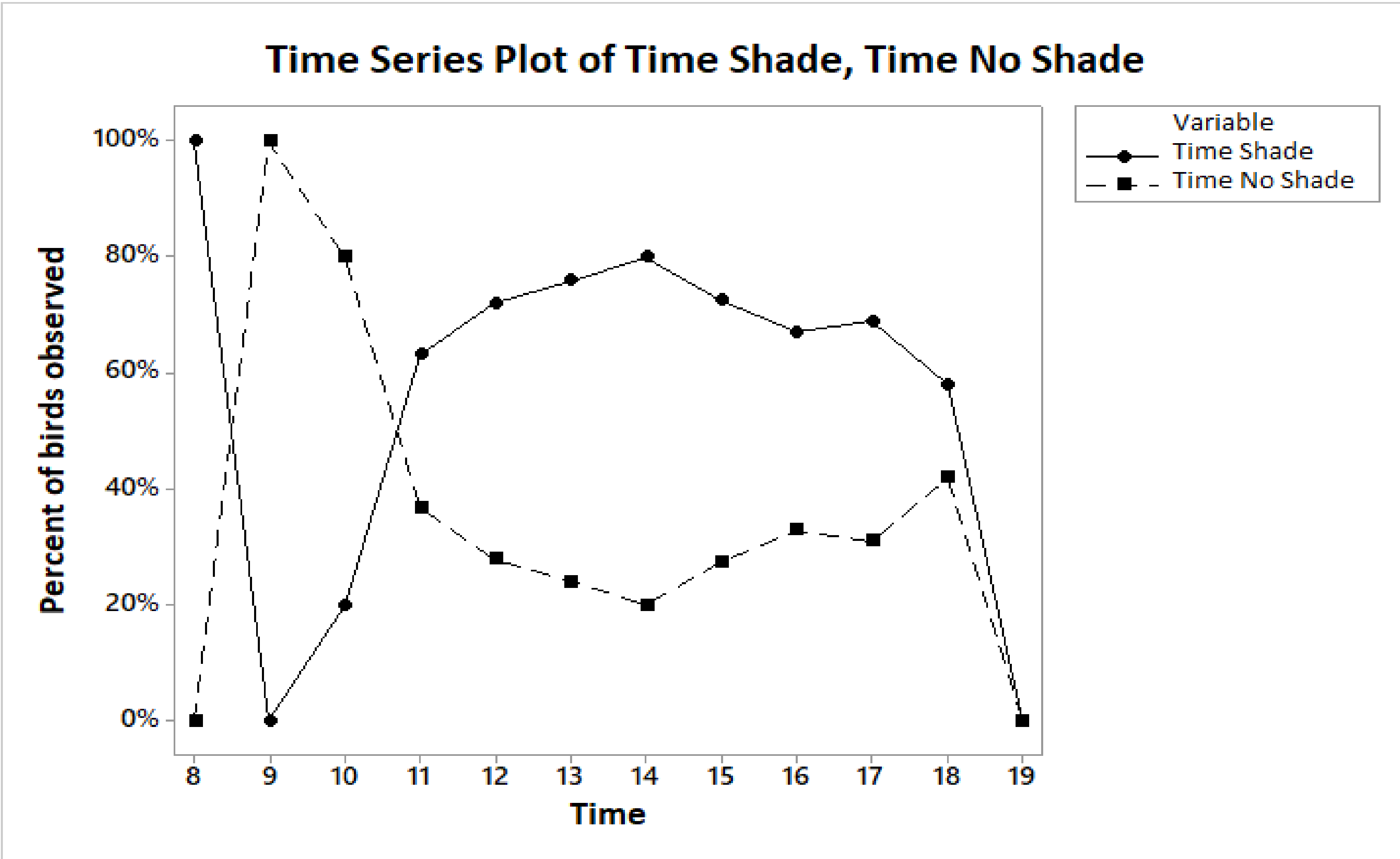



*Figure 2.8 Time series plot of time shade/time no shade for season one of experiment (Winter 2017)*

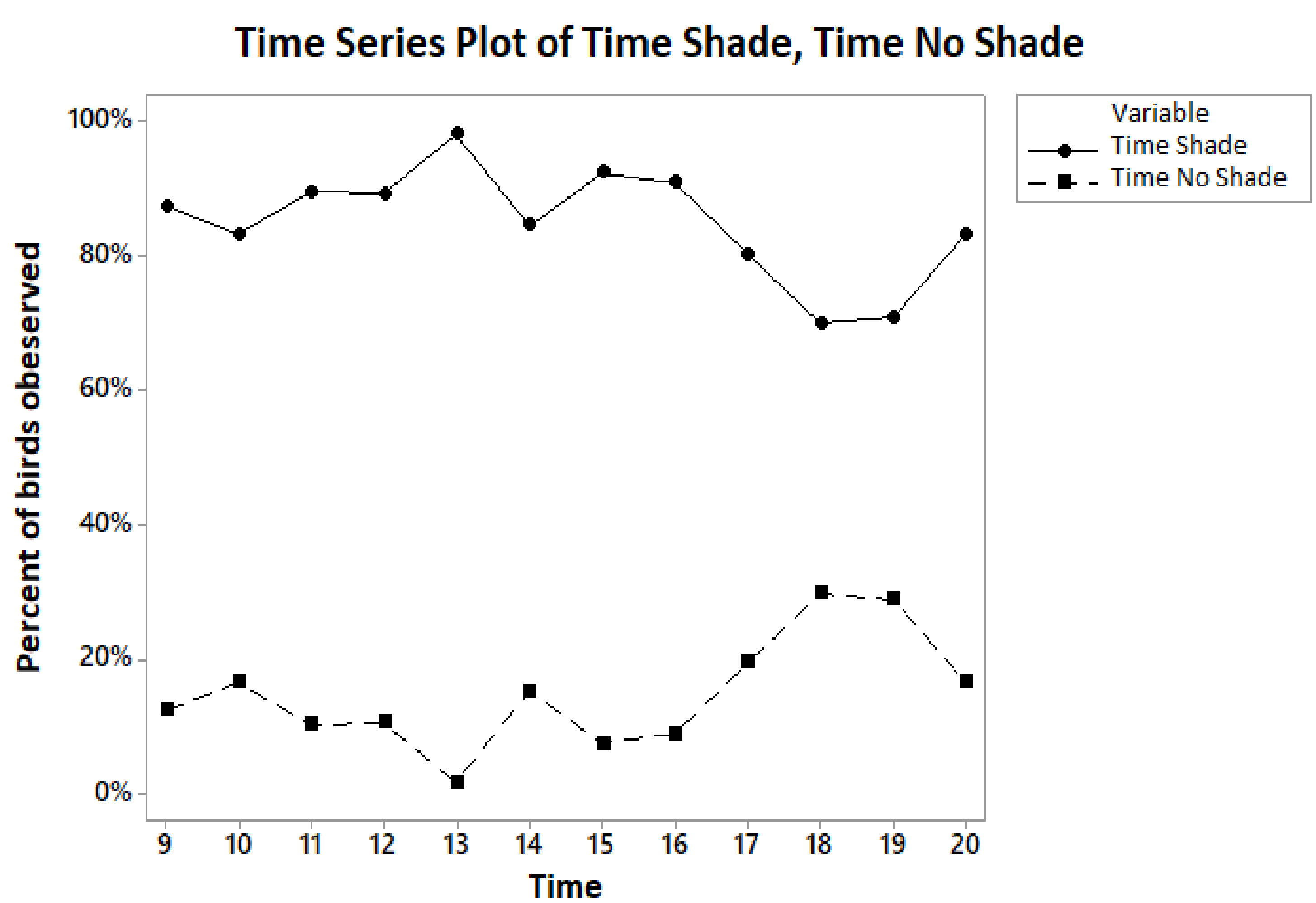



*Figure 2.9 Time series plot of time shade/time no shade for season two of experiment (Summer 2018)*

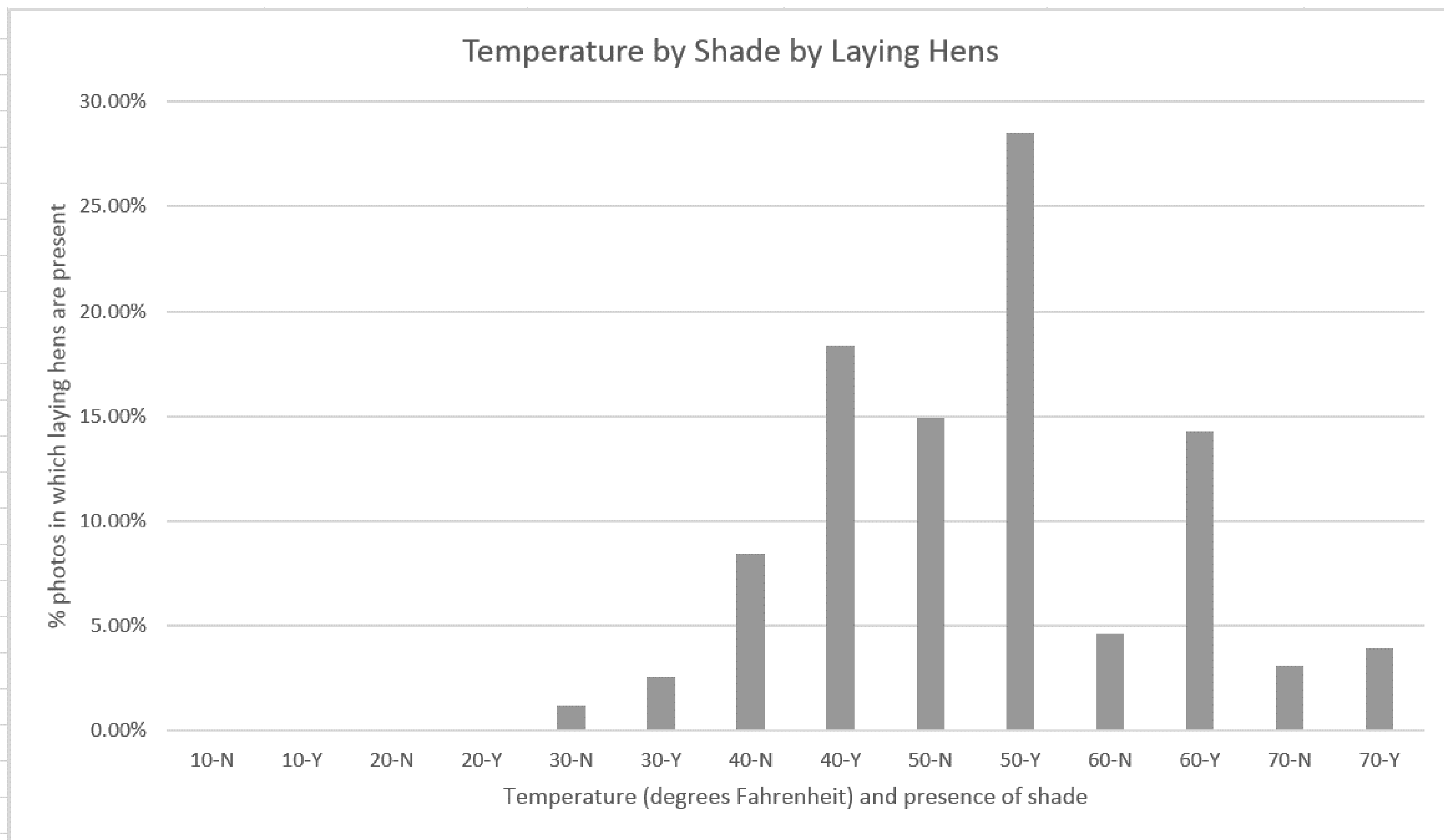



*Figure 2.10 Laying hens present by temperature (with and without shade present) for season one of experiment (Winter 2017)*

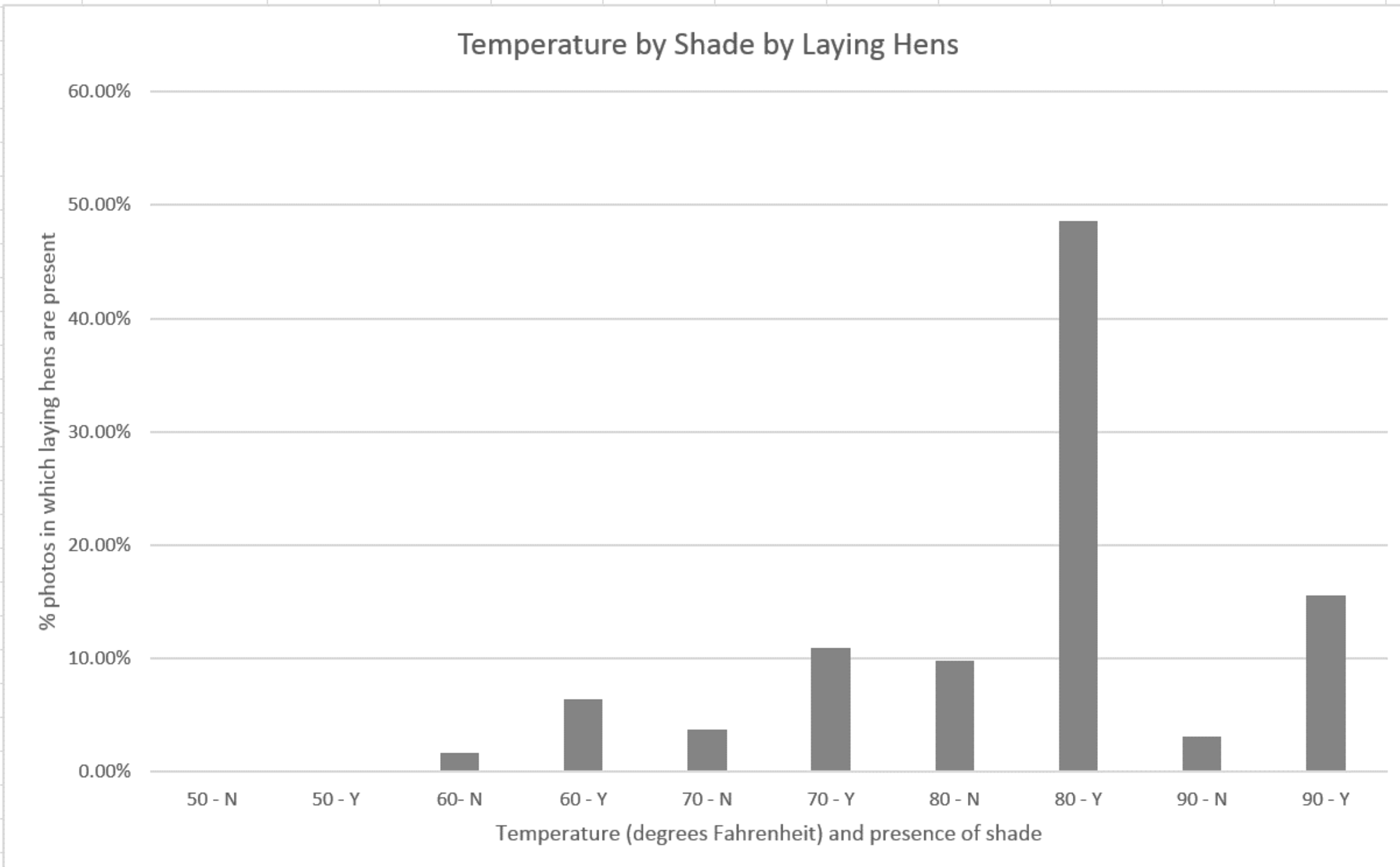



*Figure 2.11 Laying hens present by temperature (with and without shade present) for season two of experiment (Summer 2018)*

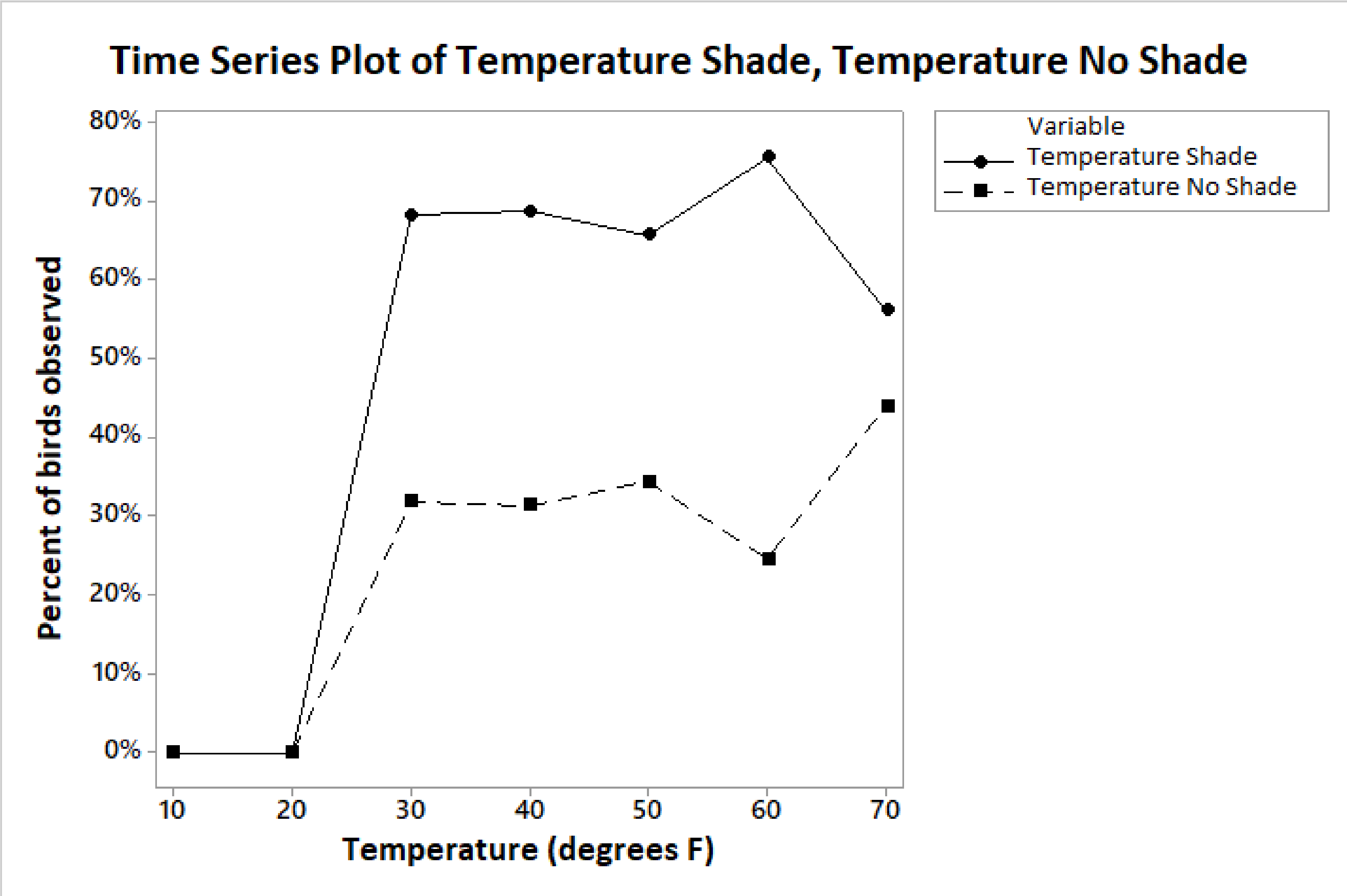



*Figure 2.12 Time series plot of time shade and  no shade in relation to temperature for season one of experiment (Winter 2017)*

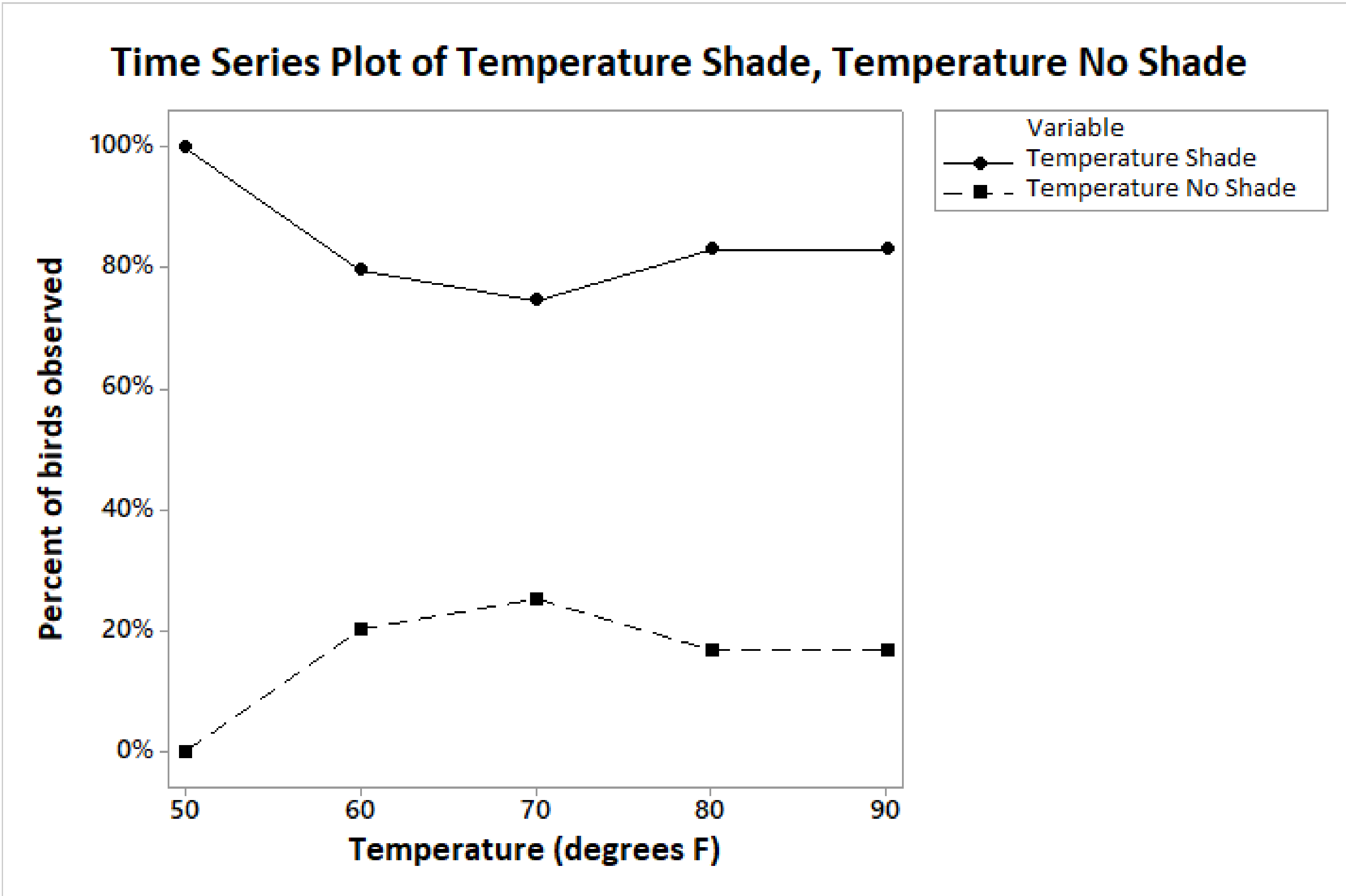



*Figure 2.13 Time series plot of shade and  no shade in relation to temperature for treatment two of experiment (Fall 2018)*

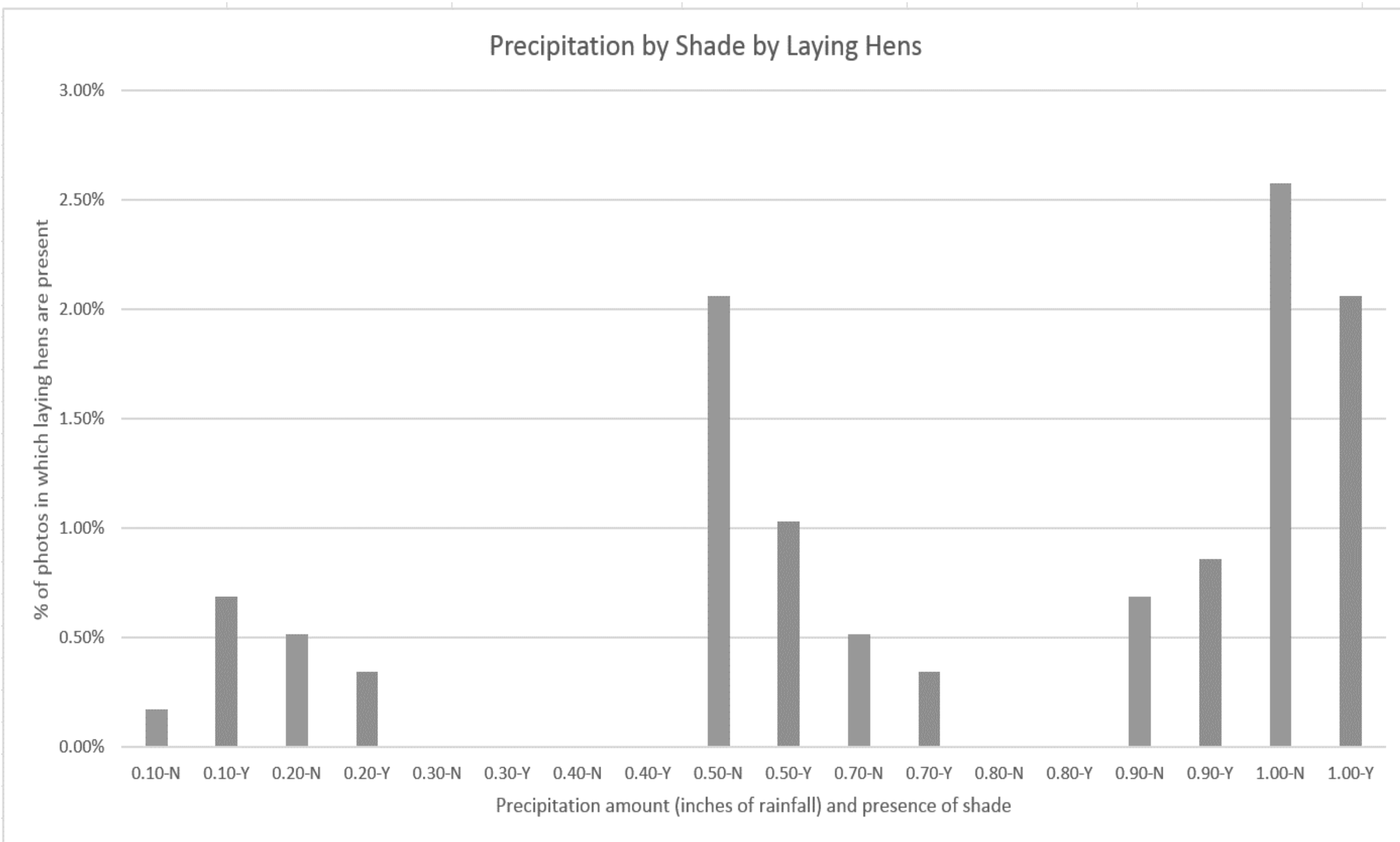



*Figure 2.14 Laying hens present by precipitation level (with and without shade present) for season one of experiment (Winter 2017)*

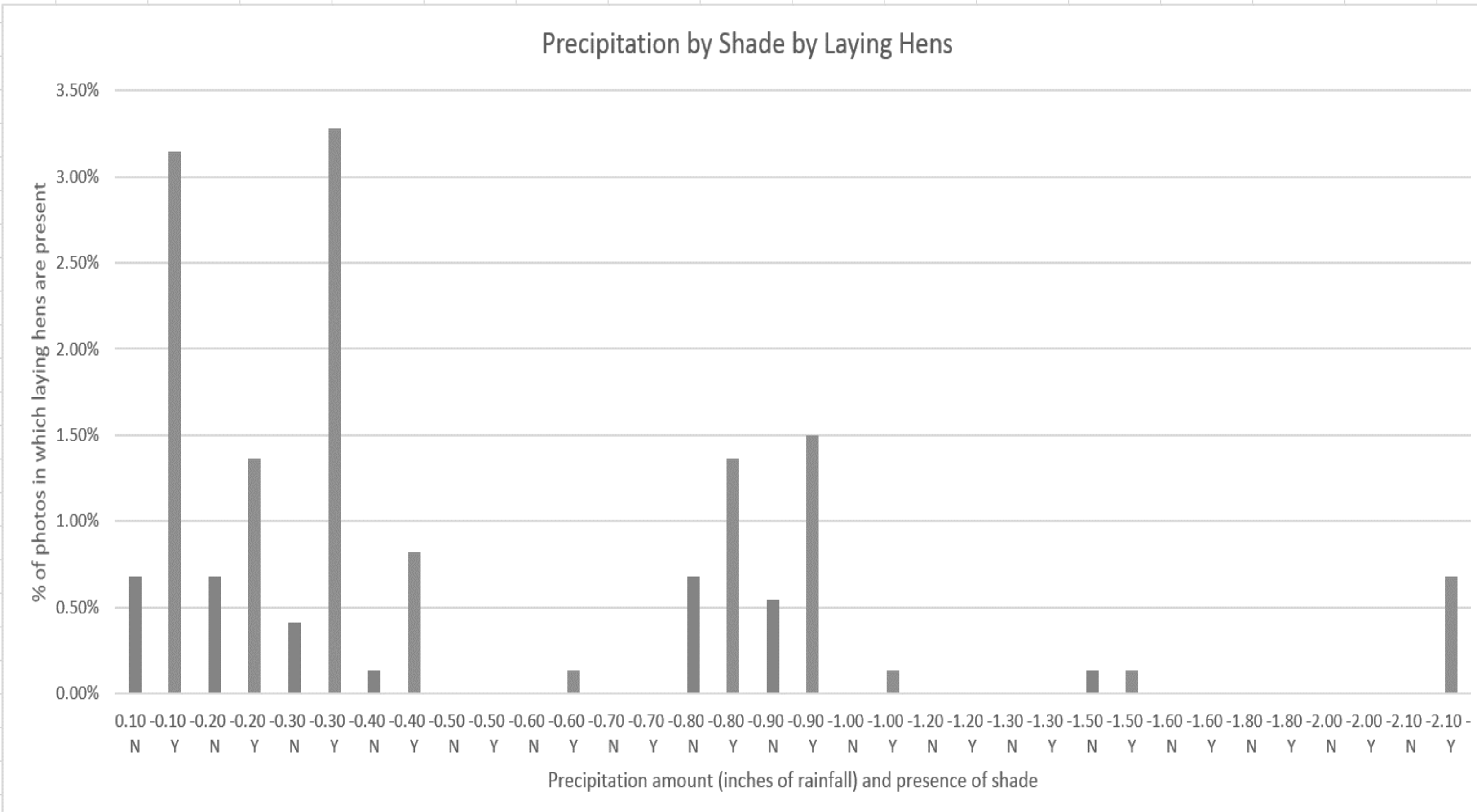



*Figure 2.15 Laying hens present by precipitation level (with and without shade present) for season two of experiment (Summer 2018)*

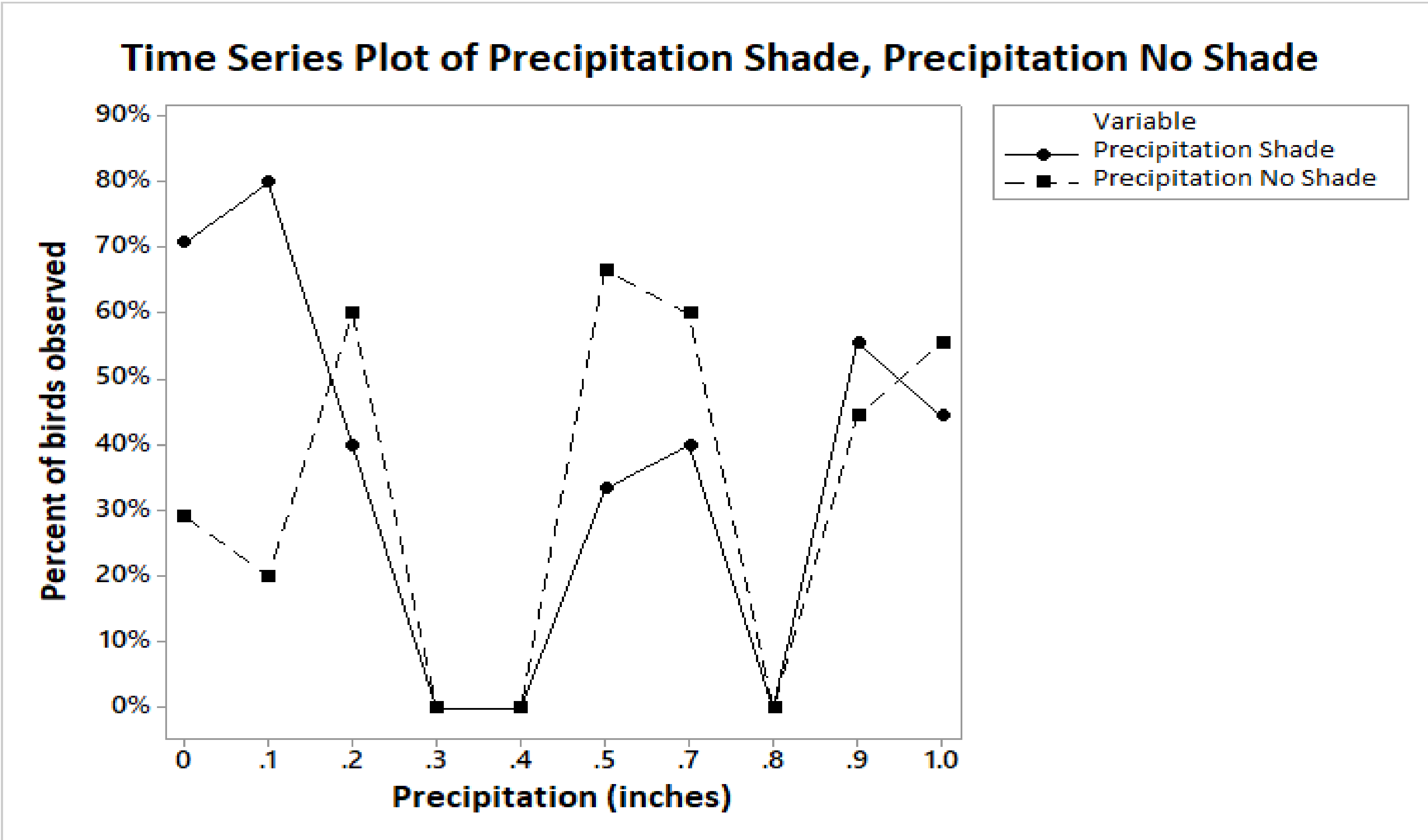



*Figure 2.16 Time series plot of time shade/no shade in relation to precipitation for season one of experiment (Winter 2017)*

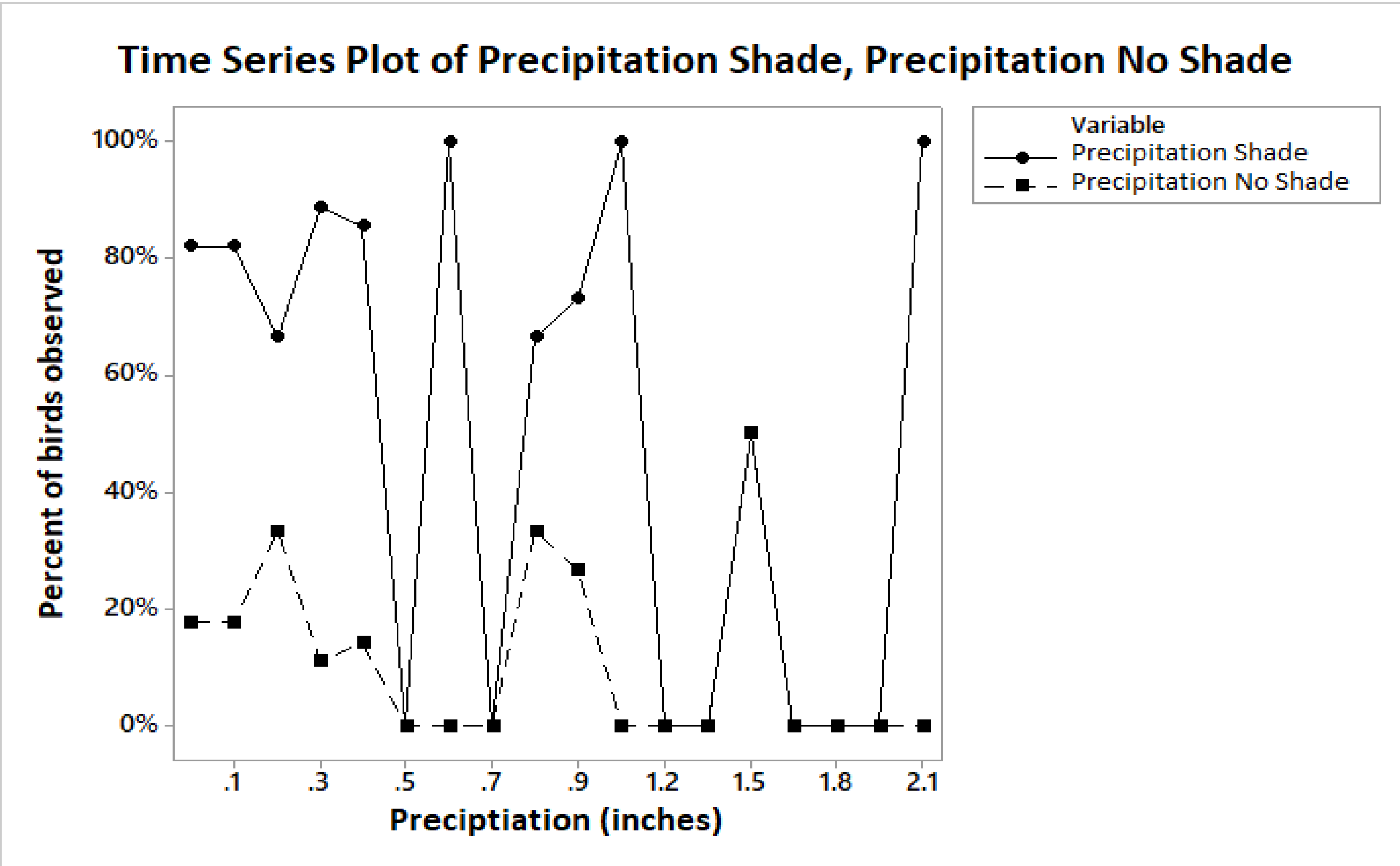



*Figure 2.17 Time series plot of time shade/no shade in relation to precipitation for season two of experiment (Summer 2018)*

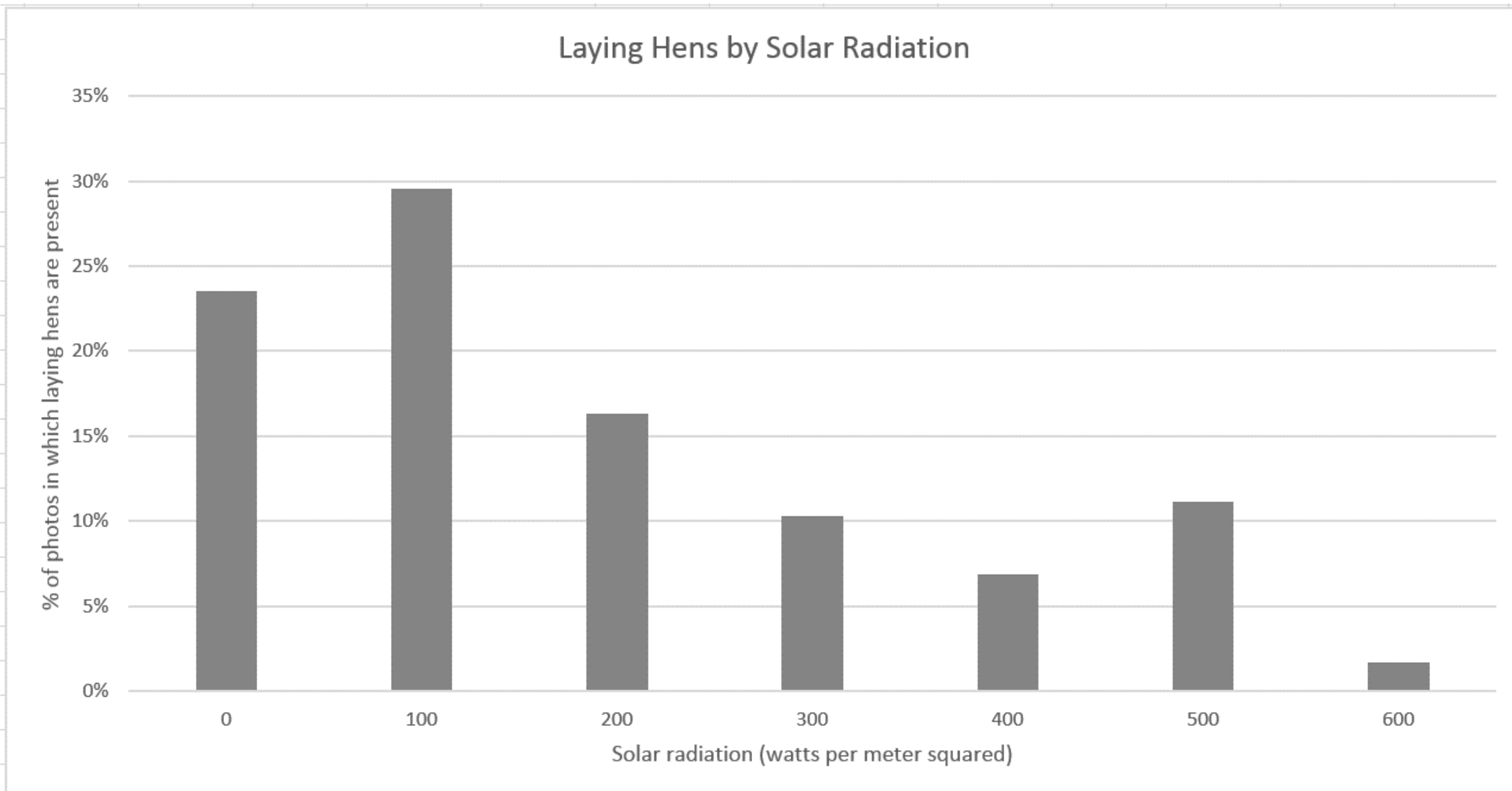



*Figure 2.18 Laying hens present by solar radiation for season one of experiment (Winter 2017)*

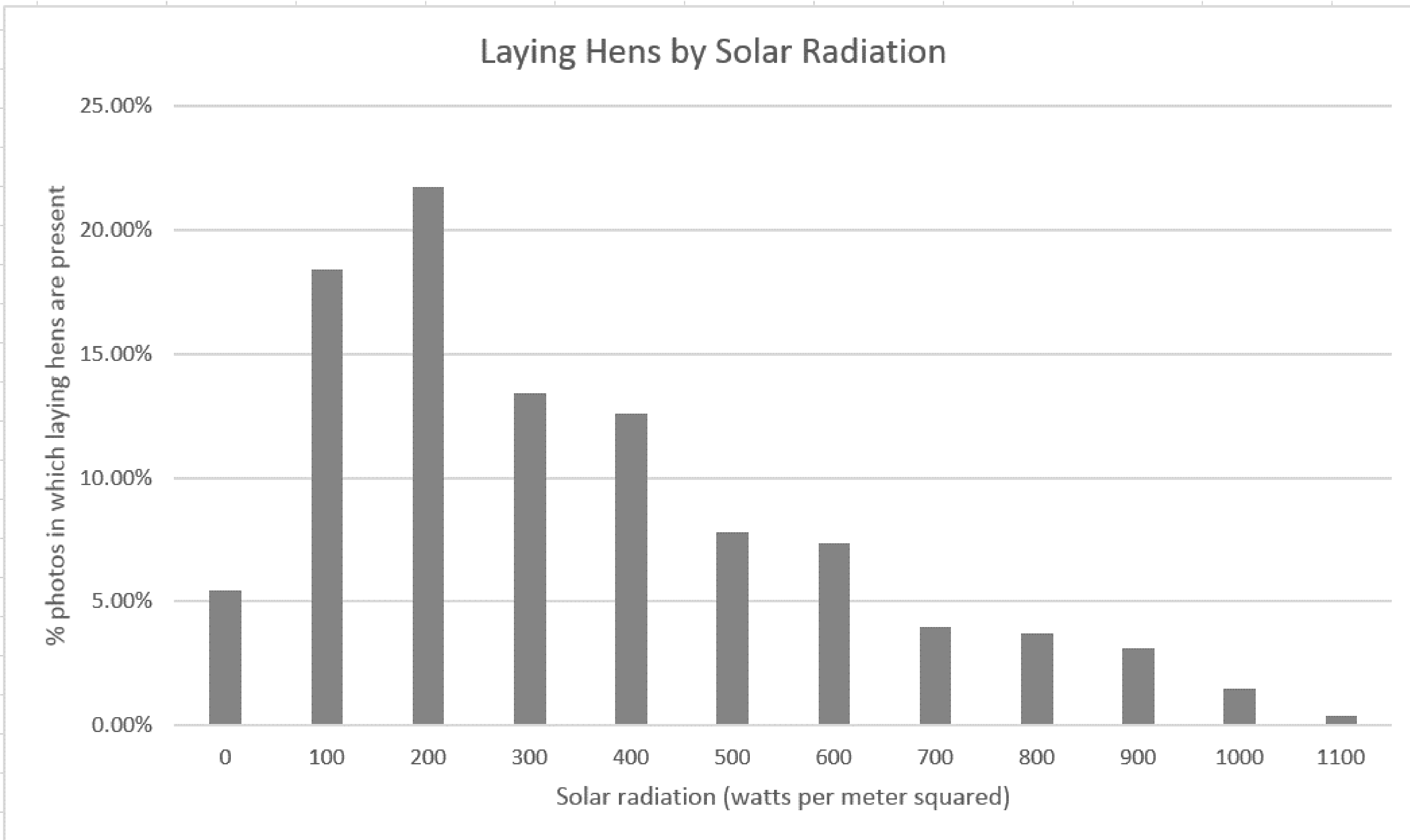



*Figure 2.19 Laying hens present by solar radiation for season two of experiment (Summer 2018)*

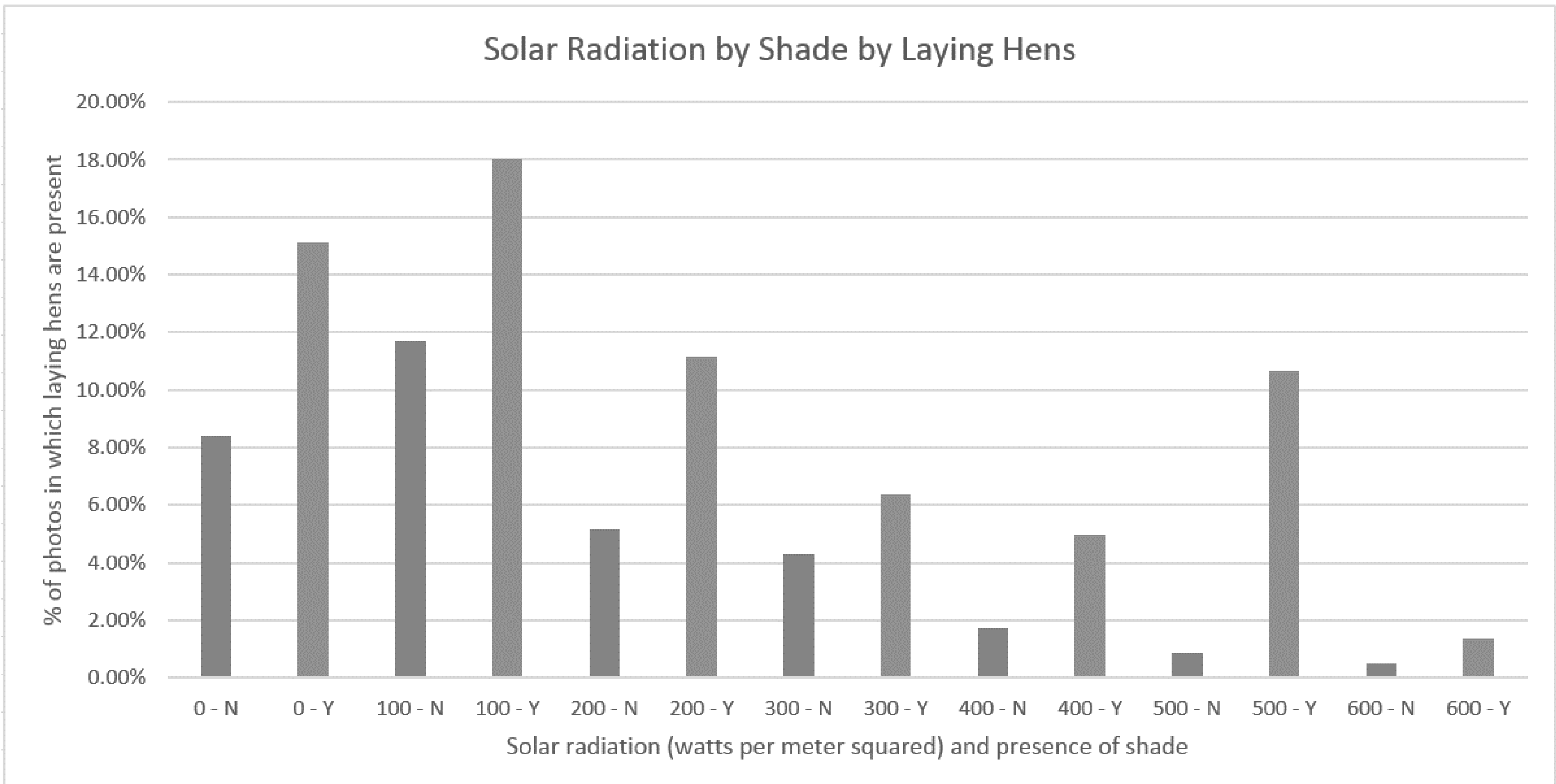



*Figure 2.20 Laying hens present by solar radiation (with and without shade present) for season one of experiment (Winter 2017)*

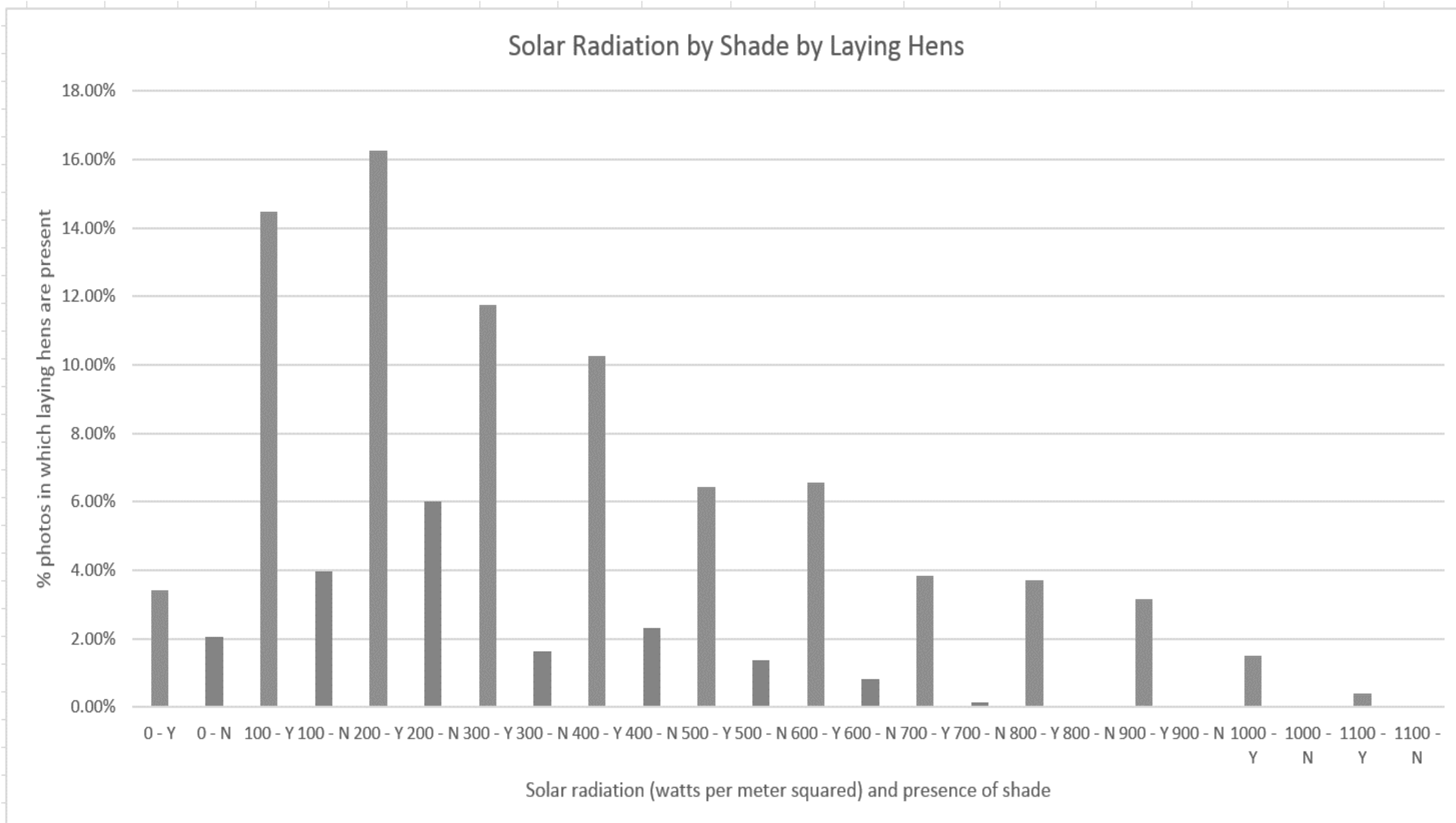



*Figure 2.21 Laying hens present by solar radiation (with and without shade present) for season two of experiment (Summer 2018)*

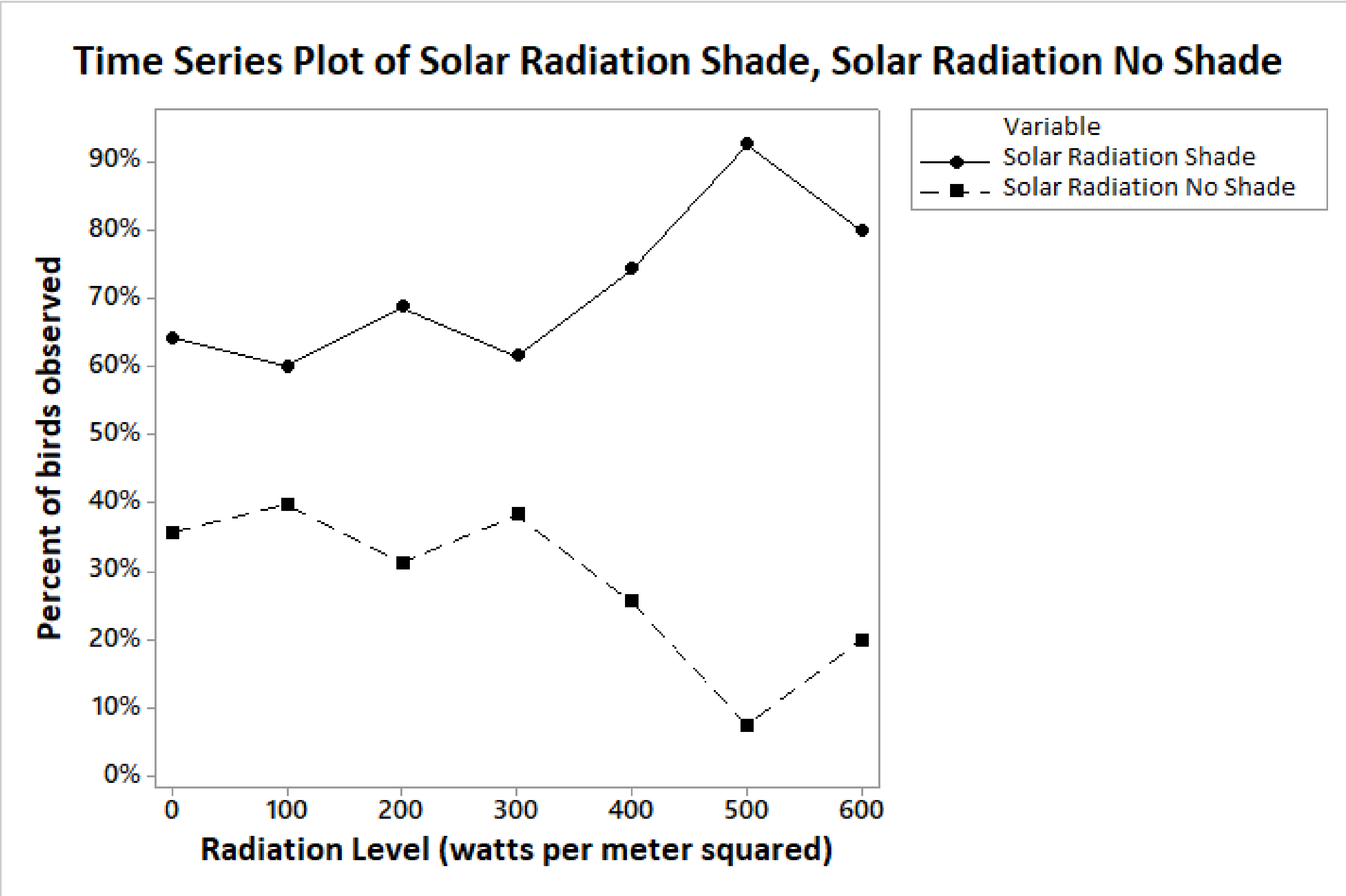



*Figure 2.22 Time series plot of time shade/no shade in relation to solar radiation level for season one of experiment (Winter 2017)*

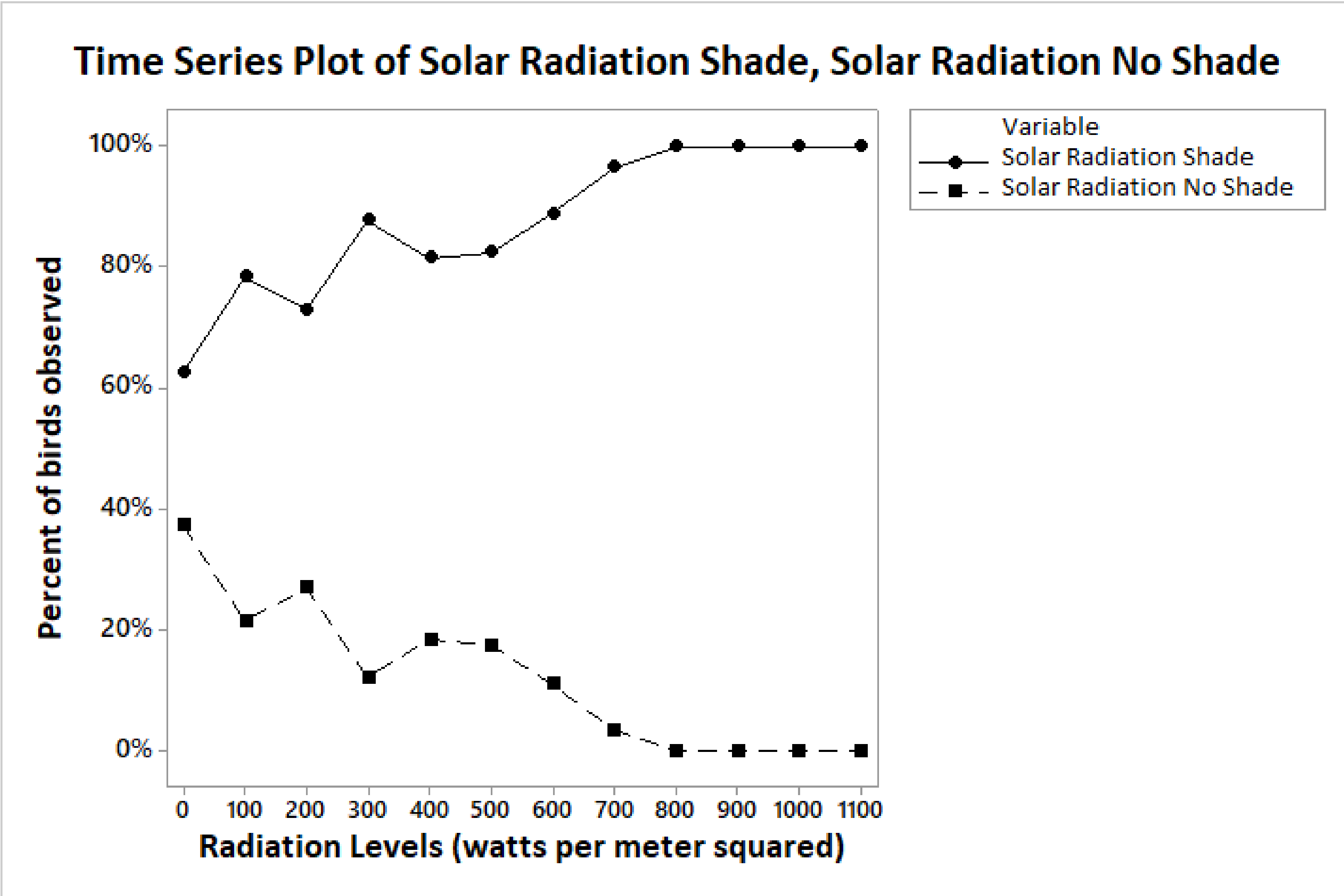



*Figure 2.23 Time series plot of time shade/no shade in relation to solar radiation level for season two of experiment (Summer 2018)*

# Chapter 3 - Correlation between stockperson personality and flock productivity

## 3.1 Abstract

Prior to the industrialization of agriculture in the mid-1900s, stockpeople managed small flocks of laying hens and the quality of management had a smaller aggregate economic impact on productivity or health of the laying flock (Zimmerman, 2006; D'Silva, 2006). As flock size grew management had to intensify due to the increased financial impact of stockperson decisions. Poultry science can be taught, but human-animal emotional interactions and connectivity, which greatly affect egg production and animal welfare, cannot (Hemsworth & Coleman, 2011). Because human interactions affect laying hens, it is likely that personality attributes of a stockperson may also influence stockperson success as measured through egg production. Knowing gaps in personality profiles related to flock management, can provide the stockman awareness of future potential challenges. The objective was to identify personality trait(s) of stockpeople that affect their ability to elicit optimal performance from a flock of laying hens, as measured by the delta of actual performance to projected performance of commercial laying hens at 70 weeks of age. The performance standard used for this research was laying hen-day egg production at 70 weeks of age compared to the target as set by the breeder company management guide. Laying hen-day egg production is an industry standard and corrects for mortality. To identify influential variables to hen- day egg production data on traditional metrics (e.g., mortality, feed conversion, production) was collected. A personality profile test was administered to 40 poultry stockpeople. Metrics including measurements of emotional control, versatility (ability to adapt), and assertiveness was applied in a novel manner to commercial egg production results. The analysis indicates that personality traits are an integral part of understanding and quantifying flock success and can be an innovative way to assess and improve laying hen husbandry and egg production.

Key words: Profile, Emotional Control, Detail, Assertiveness, Versatility Level Delta

## 3.2 Introduction

Prior to the industrialization of animal agriculture, the ratio of stockpeople to laying hens was much lower than it is today. Because flocks were very small, whether a stockperson was substandard or excellent (however that is defined) had little impact on the global economic impact of the flock (Zimmerman et al., 2006). However, as flock size has grown, so has the amount of responsibility that comes along with it. For example, if 20% of a backyard flock of five laying hens perishes due the carelessness of stockperson, only one hen is lost. However, in a commercial flock of 20,000 laying hens, that would be 4,000 laying hens lost, and have a severe impact on egg production totals and economic viability of the flock. Hemsworth and Coleman (2011) reported that the effects of human behavior on animals – both physiologically and behaviorally, is profound and that human-animal interactions markedly affect animal welfare. Thus, it is important to understand the personality traits of a stockperson that contribute to successful management. The science of poultry husbandry can be taught. Unfortunately, identifying and enlisting the personality traits to achieve success is less tangible, but is equally as critical.

There is a direct correlation between stockperson attitude and behavior, and the productivity of the animals under their management (Barnett et al., 1994; Gonyou et al., 1986; Hemsworth, 2007). The relationship between the stockperson and the animals under their care is referred to as the human/animal relationship (HAR). Poor HAR affects animal productivity negatively (Gonyou et al., 1986). High HAR can reduce the perceived effects of traumatic events (e.g., isolation, restraint) on animals. The nature of 'communication' (e.g., aggressive versus kind) between an animal and a human can profoundly influence the way the HAR develops (Grandin, 1984).

The general public in the U.S. views the use of animals by humans as acceptable if it is humane (Ohl & Van der Staay, 2012), although the focus on animal welfare has been recent. Historically, philosophers and society have not concerned themselves with the topic of duties toward animals, presumably because most believed it did not raise serious moral issues (Hemsworth, 2007). Perspectives of animal welfare, however, change with time, societal, and cultural views (Ohl & Van de Staay, 2012). Recently, there has been a national discussion in the United States on animal welfare with opinions ranging from extreme animal rights groups demanding elimination of factory farms (D'Silva, 2006) to zoo keepers advocating for more natural enclosures, better food, and an integration of normal social behavior for captive animals (Rushen, 2003). With this background, an ethical dialogue grounded in science should be used to establish stockperson competencies and underpin targeted animal welfare outcomes (Hemsworth, 2007).

### *3.2.1 Ethical Stockmanship*

Assessments of the role of stockpeople in modern agriculture indicate that they are, by necessity, professionals who determine animal performance and welfare within their company. Stockpeople are encouraged to form bonds with their animals and participate in discussions within industry on farming practices and animal welfare standards (Hemsworth, 2007). This is a critical component of both animal welfare and achieving high productivity of the flock. "Stockmanship is a key factor because, no matter how otherwise acceptable a system may be in principle, without competent, diligent stockmanship, the welfare of animals cannot be adequately catered for" (Hemsworth and Coleman 2011). The British Codes of Recommendations for Welfare of Farm Livestock (1983) are the foundation for Hemsworth and Coleman's (2011) research. The British Codes (1983) outline the duties of a modern stockperson including a comprehensive knowledge of the requirements (from nutritional to social) of farm animals; practical experience in maintaining animals; an ability to recognize issues out of the normal (e.g. health, social interactions); and an ability to meet the daily responsibility of caring for large numbers of animals.

Although the British Codes and animal welfare practices provide an ethical guidance for a more global view of animal welfare, in the United States, we look to the standards of American Humane Association (AHA) and Humane Farm Animal Care (HFAC) for specific animal welfare best management practices (American Humane, 2017; Humane Farm Animal Care, 2018). These codes provide guidance to minimize stress in laying hens.

Despite countless generations of selective breeding, the most stressful event a farm animal is likely to experience is exposure to humans, followed by sudden changes in their social or physical environments (Boissy et al., 2002; Jones, 1996). Persistent changes in adult layer hen behavior, physiology, and egg production can be made by manipulating human contact (Barnett et al., 1994). For example, the personality of the stockperson can affect an animal's fear of humans, its general welfare and overall productivity (Hemsworth, 2007).

#### *3.2.2 General stress to the laying hen*

One of the key roles of stockperson flock management is to elicit high performance from laying hens, in part, by reducing the stress experienced by the laying hens. Stress (increased agitation and excitation) induced by handling results in elevated body temperature, increased heart rate, high glucocorticoid values, and reduced immune function in laying hens. Characteristics and temperaments vary by breed and individual animals (Grandin, 1984).

The environment and how it is managed affects the animals, but the response is not always clear. In general, the less familiar the situation, the more likely animals will be stressed. However, animals also exhibit a degree of curiosity that can temper the stress of new situations (Grandin, 1984). For example, Grandin (1984) reported that animals raised in a non-routine environment were less likely to be stressed when they are confronted with a new situation.

Contrary to this, Zulkifli and Azah (2004) reported that a novel environment is a potent fear- and stress-elicitor in all animals.

The stockperson is part of the laying hen's environment and how the stockperson chooses to present himself/herself to the animal(s) is an issue tying stockman personality to animal stress. Farm animals are sensitive to brief, non-tactile, human interactions (Hemsworth, 2007) such that varying the individual person, as well as other aspects of the environment, has been suggested to condition them to irregularities in management (Grandin, 1984).

### *3.2.3 Impact of stress on laying hens*

Fear is a leading cause of stress in laying hens and can be caused by encountering alarming stimuli and disruption to the social environment (Jones, 1996). High or persistent fear of humans can seriously harm the welfare and performance of laying hens (Jones, 1994). Elevated fear of humans is also associated with reduced egg production, growth, feed conversion and product quality, with increased aggression and handling difficulties, and with immunosuppression (Barnett et al., 1994; Jones, 1996). Reducing fear is likely to have positive effects on egg production (Jones, 1993), suggesting that good animal husbandry will aim to reduce fear levels in the flock (Jones, 1996). While consistent good animal husbandry is of course important, the personality traits associated with that outcome are not clearly defined.

Most research on the response of laying hens to management practices supports the notion that the behavior of the stockperson significantly impacts the stress and productivity of the hen. The cautious handling of animals to reduce stress is more important than the specific way the animal is held (Langkabel et al., 2015). Furthermore, flock performance can be increased significantly through physical contact. Laying hens that were handled gently had improved body weight and feed conversion ratio (FCR) and showed less overall avoidance to human interaction (Jones, 1993; Zimmerman et al., 2006; Zulkifli & Azah, 2004). Similarly, there is significant cost to stress (i.e., fear). In laying hens, unproductive fear reactions like panic or violent escape attempts impose a metabolic cost by wasting energy and can result in injury or death when laying hens run into obstacles, pile on top of one another, and claw at one another (Waiblinger et al., 2006). Injuries can lead to infection, chronic pain, debilitation and social withdrawal (Jones, 1996), all of which contribute to a reduction in the general welfare of the flock and a subsequent reduction in productivity.

A stockperson's impact on its flock is easy to see. Regular, pleasant physical and visual interaction can reduce fearfulness and psychological stress response in laying hens (Zulkifli & Azah 2004). Research provides evidence to support the notion that laying hens are particularly sensitive to regular visual contact with humans (Zulkifli & Azah 2004). Laying hens habituated to one person through regular handling will also show reduced fear of other people regardless of whether they are wearing similar or different types of clothing (Jones, 1994). Reduced fear can also come through regular general interaction with humans, as well as routine exposure to rapid approach by humans and/or machinery (Jones, 1996). A stockperson has a strong influence on the amount of stress experienced by a flock. Understanding the contribution of personality traits to this influence is valuable information. Management can capitalize on this knowledge to minimize stress in laying hens and increase production by selecting stockpeople who possess positive personality traits relative to laying hen oversite.

#### *3.2.4 Selection of personality types*

Early research of stockperson personality trait research has been conducted on other animal species. This research used the five traits of extroversion, emotional stability, agreeableness, conscientiousness, and openness to new experience to assess personalities and how stockpeople with these traits would perform against a specific task (Hemsworth 2007). Results indicate there is high value in using personality profiling in selection of people to specific tasks (Barrick & Mount, 1991). Specific research on personalities and influence on laying hen flock management in commercial settings is scarce. It is known that personalities influence productivity of other animals so a reasonable assumption can be made that personalities of stockpeople will influence performance of laying hens.

The hypothesis of this research project is the personality profile of the stockperson will measurably influence flock productivity.

## 3.3 Materials and methods

### *3.3.1 Flock productivity*

Flock productivity was measured using the laying hen-day egg production at 70 weeks, feed conversion at 70 weeks and total feed eaten by laying hen from 20 weeks through 70 weeks. Data were analyzed from 40 different barns in five states (Wisconsin, Illinois, Indiana, Ohio and Kentucky) using data from two successive flocks of laying hens from each barn. All laying hens were owned by and barns contracted to the same integrator, Egg Innovations (Warsaw, Indiana). Each barn was managed by its own stockperson, an individual designated as the principal caretaker of the flock. Stockpeople were men, women, children and people hired to the position. Flock data were collected weekly and transmitted to the main office of the integrator. The performance metric was actual flock hen-day egg production compared to projected flock laying hen-day egg production at 70 weeks of age. The projected flock hen-day egg production was sourced from the breeder guides specific to each strain of laying hen used in each barn in the research. Associated data collected included mortality and feed conversion at 70 weeks of age and total feed eaten through 70 weeks of age. Performance metrics were specific to the strain of laying hen in each barn. Data were collected over a three-year period (2017 – 2019).

### *3.3.2 Selection of stockpeople and personality traits*

Fifty-five stockpeople were considered as candidates for the personality trait testing. The group was reduced to 40 stockpeople who met the criteria of:

1) Stockperson having two successive flocks with complete egg production data in the window of time defined.

2) Willingness to participate in and complete the survey process

The survey for personality assessment developed by Organizational Analysis and Design (OAD) was completed by each of the 40 selected stockpeople. This tool measures:

*Assertiveness/Autonomy:* (A) independence, need for control, self-confidence, resourcefulness;
*Extroversion*: (E) degree of social and people orientation guiding a person's behavior;
*Patience*: (P) degree to which individual needs system and predictability;
*Detail-orientation*: (D) concern for correctness, orderliness and structure, including sense of duty;
*Emotional Control:* (EC) extent to which individual exercises control over emotions and actions;
*Creativity:* (CR) degree of inventiveness and originality of thinking;
*Versatility Level:* (VL) indicator of behavioral flexibility, with higher scores indicating more flexible individuals who are willing to step outside of their 'comfort zone' and who are better equipped to 'bounce back' following periods of insecurity or stress
(The OAD Survey - Taxonomy of General Traits, n.d.).

The OAD Personality Assessment Instrument is the only adjective-based instrument that was built to the standards of the U.S. Equal Employment Opportunity Commission (EEOC), American Psychological Association, British Psychological Society, Canadian Psychological Association,

The survey consisted of a list of 110 adjectives. The stockperson checked the box next to each adjective that they felt was reflective of their personality. Seven traits were measured for each participant. The traits measured were assertiveness (A); extroversion (E); patience (P); detail orientation (D); creativity (CR); emotional control (EC); and versatility level (VL).

The sums of certain traits, as determined by OAD, were also measured. The first sum measured was detail orientation - assertiveness (D-A). This sum provides an analysis of the survey taker's compliance to structure. If D-A is high a survey taker provides evidence that they will "stay on track" as trained to a task. The second sum measured was detail orientation - emotional Control (D-EC). This sum provides an analysis of technical orientation and analytical skill of the survey taker. If D-E is high, a survey taker provides evidence that they can learn technical and analytical skills and deploy the skills against a specific task. The third sum measured was patience - assertiveness (P-A). This sum provides an analysis of process orientation and willingness to follow a systematic process by the survey taker. If P-A is high a survey taker provides evidence that they will stay on a systematic process rather than freelance (The OAD Survey - Taxonomy of General Traits, n.d.).

Ten variables were available to determine the effect of personality traits in influencing flock productivity; the seven traits and the three sums. The data were analyzed with linear regression using an optimizer algorithm to make the final selection of personality traits that provided the highest predictability of the results. The final personality traits selected were (EC) and detail orientation minus assertiveness, or D-A.

### *3.3.3 Hens and housing*

Egg production data were measured at 40 barns that housed ~20,000 laying hens each. Each barn had one strain of laying hen per flock, but multiple strains were represented across barns (e.g. Hy-Line, Bovan, H and N). All barns used the same nesting equipment (Big Dutchman) and had the same ventilation system (Munters). Interior living areas were 24,000 $ft^2$ and ranges were between 2-50 outdoors acres (Appendix A). All pullets were grown by the integrator. Farms were certified by HFAC and AHA for free range standards.

Laying hens at all barns were fed using guidelines of three standardized diets based on age and flock productivity as determined by the integrator. The diets varied in their use of conventional, Non-GMO and organic grain based on management decisions of the integrator. All feed was produced either by the integrator or manufactured using the integrator's diet recipes (Appendix C).

#### *3.3.4 Survey questionnaire*

Personality assessment surveys must meet validity and reliability standards and guidelines set forth by credible testing organizations to be useful in research. The survey developed by OAD uses two questionnaires to categorize personalities and creates a predictive tool of the behaviors of the survey takers. The survey process is an adjective-based diagnostic instrument (Appendix E).

Using this tool, management from any industry can build an ideal personality for a position and then cross reference an applicant or employee with the ideal profile. Applicants and employees can take the survey then have their results compared to the profile to identify fits and gaps between the baseline model and the survey taker. The personality of a successful salesperson will be different then the personality of a successful accountant. The former must handle routine rejection and persuade. The latter must focus on accuracy and numbers. The tool provides guidance on which ideal personality traits the survey taker possesses in abundance and which traits are less dominant. The OAD tool can also be used to reverse-engineer a profile. If data exists that can be ranked and was performed by a wide variety of people, the OAD process can be used to identify common personality traits of the people at different performance levels. This strategy was used in this research. Specifically, the laying hen performance achieved by 40 stockpeople was ranked. Personality profile tests were then administered to see if there were common personality attributes in the high performers. The survey provided to stockpeople for this experiment, as well as a sample of a completed profile can be found in Appendix E.

### *3.3.5 Personality traits*

The flock performance achieved by 40 stockpeople were ranked using flock hen-day egg production compared to standard and placed into hierarchical order of performance from highest to lowest. Each grower completed the survey after both flocks that provided the data had completed their life cycle. The selection of personality traits was a reverse engineering process, meaning the flock performance results were known prior to knowing the personality traits. Having the data first allowed for the flocks and to a degree, the stockperson's management, to be ranked from highest to lowest. The goal was to identify up to five variables (combinations of production and personality) that were best at predicting delta of productivity. Linear regression analysis was used to identify the variables that provided the greatest statistical accuracy of predicting the Y delta results. The Y delta is defined as the difference between potential flock productivity at 70 weeks of age and actual flock productivity at 70 weeks of age.

### *3.3.6 Statistical analysis*

Data were assessed for normality using the Anderson-Darling normality test. After determining normality ($p > 0.05$), linear regression and a regression optimizer were used (Minitab 18) to determine which personality traits had greatest influence on the ability to predict flock hen-day egg production. Variables were correlated to higher egg production outputs as measured by delta to a standard. Delta to standard is defined as the difference between projected flock hen-day production at 70 weeks of age and actual hen-day production as 70 weeks of age. Because the regression analysis that was used is limited to five variables (Minitab 18), Design of Experiment (DOE) was used to rank the effect on predictability of all variables and then eliminate the least influential. DOE and regression analysis were also used to evaluate and rank from highest to lowest, the variables relating to stockperson character traits, measured by delta to standard egg production outputs. The personality traits that increased predictability of hen-productivity the most were combined with the egg production traits that increased predictability the most from the two independent regression analyses. The first analysis looked at personality traits only. The second analysis looked at production traits only. A third regression analysis was performed with an optimizer function. The final result provided a model that predicted with 81.85% accuracy the variation in the Y delta (variance from standard of flock hen-day egg production at 70 weeks.)

## 3.4 Results and discussion

Specific personality traits in stockpeople that increased the predictability of flock hen-day egg production levels and predictability of the Y delta was identified. Y delta being the variance of actual flock hen-day production at 70 weeks compared to potential hen-day flock production at 70 weeks based on specific breeder guides.

There are seven trait variables and three sums of variables scored using the OAD personality profile test. Variables A, E, D, and P are raw data. It is the relationships between these sets of data, or sums, that are the critical variables to be analyzed (The OAD Survey - Taxonomy of General Traits, n.d.). This leaves six variables (three traits - CR, EC, VL, and three sums - D-A, D-E, P-A) to consider using linear regression. The first step was to test the personality and production data for normality using an Anderson -Darling normality test. If any of the production parameters or the Y response had outlier data, the entire data set from that individual stockperson was eliminated. This reduced the pool of data from 40 to 28 stockpeople. All remaining data were normal and subject to statistical analysis. The summary reports of this can be seen in Figures 3.1-3.4.

Conducting the Anderson - Darling normality test showed 12 of the 40 stockpeople had a non-normal distribution of the data. P-values > 0.05 are defined as normal data. The before and after distribution of personality types can be seen in Figure 3.5. OAD assigns a label to each of the different personality groups. The labels of the original group and final group of participants are listed in the chart.

The final data group had 28 stockpeople. The stockpeople removed from the analysis were: one independent generalist, one negotiator, two perfectionists, three specialists, one technical specialist, one variation of independent generalists, two variation of processor, and one variation of social diplomat. The stockpeople eliminated had non-normal distribution of at least one parameter of their data set.

Skewed data when completing the profile questionnaire can happen for several reasons. One reason is the stockperson not taking the survey seriously, yielding a nonsensical pattern. A second reason is lack of understanding, and therefore selection of an abnormally low number of adjectives. A third reason is fear of results implications. A fourth reason is a misunderstanding of directions. An example of production data that triggers outlier data would be a health challenge in one of the two flocks from the stockperson, therefore distorting flock hen-day performance.

Design of Experiment was used to analyze the six variables of personality from OAD to rank their contribution to the predictability of results. DOE analyzes based on medians. Results from using DOE in this manner are guidance and do not confirm proof of any hypothesis. In this step D-E was determined to be the least influential on predictability of results. The five variables used for the first linear regression were VL, EC, CR, D-A, P-A. The results of this can be seen in Table 3.1 and Figure 3.6.

In the first regression 41.01% of the variance to standard could be explained using the five variables inputted. The regression also identified that CR and P-A had no influence on the equation. A second regression was run were CR was dropped and D-E was tested. CR could be dropped because it was determined to be non-influential to the equation and D-E was the variable not used in the initial regression. The second regression produced the same results of 41.01% predictability of variance D-E and P-A were determined to be non-influential. The three personality traits that were influential to the equation were VL, EC, and D-A. All other variables were dropped from further analysis. The results of this can be seen in Figure 3.7.

Using personality tools alone can explain 41.01% of the percent of response variation. The first round of regression analysis looked exclusively at the influence of personality traits on the predictability of variation from standard. Six personality variables were analyzed it was determined that three attributes of personality (VL, EC and D-A) were useful in understanding the predictability of flock performance.

Data for mortality, feed conversion and total feed consumption from 20 weeks-70 weeks of age were gathered from the producer pool. The next step was to assess the impact these parameters had on the predictability of percent of response variation.

Regression analysis with normal data were used to understand the relationship between the production variables of feed conversion ratio, cumulative mortality and feed consumption and the y-response delta. Using egg production parameters alone without personality profile influencers in the regression model can explain 67.76% of the variation in the response. All three variables for meaningful to the final regression equation using production data only. The results of this can be seen in Figure 3.8.

Regression analysis that explains 65% or more of the variation in a response are robust enough to run an Optimizer analysis that predicts the response based on choosing optimal setting for the variables in the analysis. The results of this can be seen in Figure 3.9.

Analyzing the sensitivity (slope of graph in the optimizer report) of each of the five variables provides great insight. The steeper the slope of a parameter in the optimizer the greater that parameter can influence the potential result. Production parameters are traditionally evaluated and managed on an ongoing basis so one would not expect to see great opportunity to influence these parameters up or down based on elevated focus. However, it becomes very clear in the graphs that placing a higher emphasis on positive personality traits can yield more significant positive results to the regression analysis and ultimately to the performance of the flock. This leads to the third round of regression analysis. In this round production and personality data are combined.

The third regression model combined the first and second models. Traits EC and D-A from the original model for the farmers traits were added to feed consumption, mortality and feed conversion in a regression model. This regression yielded 81.85% of the variation being explained. The results of this can be seen in Figure 3.10. The results of the regression model showed all five variables of feed consumption, mortality, feed conversion, EC and D-A were relevant to the final formula. A final equation was developed.

X1: Feed consumption 20-70 weeks of age, X2: Feed Conversion, X3: Mortality X4: EC X5: D-A

Final Model Equation

$$Delta = 26.7 + 0.659\,X1 - 24.10\,X2 + 4.21\,X3 + 0.843\,X4 - 5.56\,X5 - 0.585\,X3*X4 + 0.666\,X4*X5$$

The final equation explains 81.85% of the delta of variation on the Y axis. All five variables have significance in the regression formula.

## 3.5 Summary and conclusions

Personality traits of stockpeople have direct impact on flock productivity. The predicted Y (variation from standard of flock egg production at 70 weeks of age) represents the difference between expected and actual performance of the laying flock. Using the model developed, a person can predict with an 81.85% accuracy the performance a flock will achieve in hen-day egg production at 70 weeks of age when the five defined variables are known. The five variables that make egg production at 70 weeks of age predictable at an 81.85% level are mortality, feed consumption from weeks 20-70, feed conversion, EC and D-A. Two of the five variables are related to the stockperson's personality. Assessing personality traits that are influential to hen-day egg production (i.e. emotional control and detail orientation score minus assertiveness score) prior to hiring increases the chances of success in the barn and for the integrator. Personality profile testing provides a new and powerful tool to the integrator's arsenal in achieving quality hens and high productivity.

3.6 Tables

| | | | | Formula Designation | | |
|---|---|---|---|---|---|---|
| Statisical Designation | Project Name | Original P-Value | P-Value w/o Outliers | Regression 1 | Regression 2 | Final Regression |
| Response | Delta to Standard | <0.005 | 0.736 | Y | Y | Y |
| Variable | Versatility Level | | | X1 | | |
| Variable | Emmotional Control | | | X2 | | X4 |
| Variable | Creativity | | | X3 | | |
| Variable | Detail - Assertiveness | | | X4 | | X5 |
| Variable | Patience - Assertiveness | | | X5 | | |
| Variable | Feed Consumption 20-70 Wks | 0.055 | 0.161 | | X1 | X1 |
| Variable | Feed Conversion | 0.632 | 0.731 | | X2 | X2 |
| Variable | Mortality | <0.005 | 0.676 | | X3 | X3 |
| | | | | | | |
| | | **Variation Explained by Regression Model** | | **41.01%** | **67.76%** | **81.85%** |

*Table 3.1 Summary table of regression variables*

## 3.7 Figures

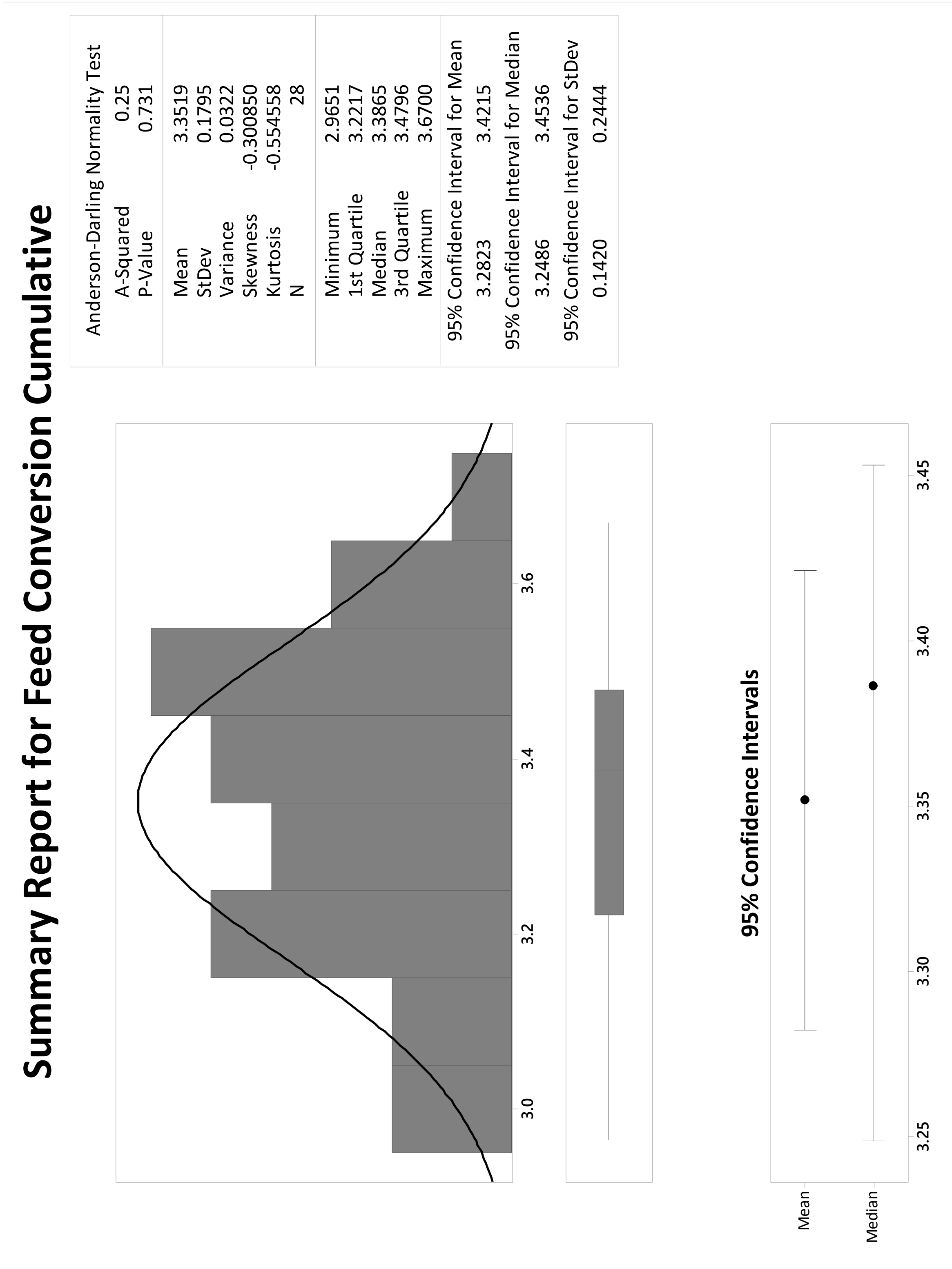



*Figure 3.1 Summary report for feed conversion to cumulative*

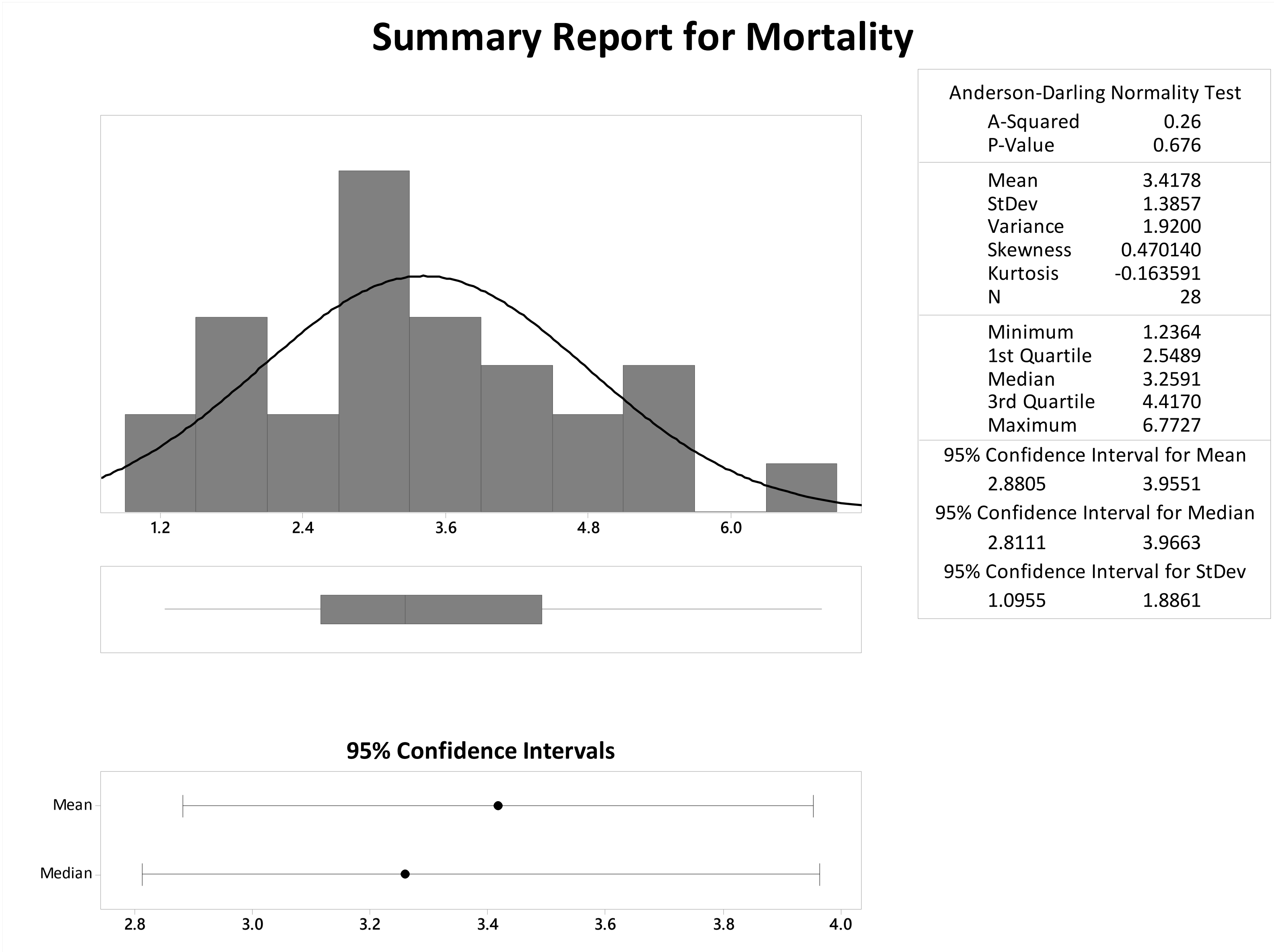



*Figure 3.2 Summary report for mortality*

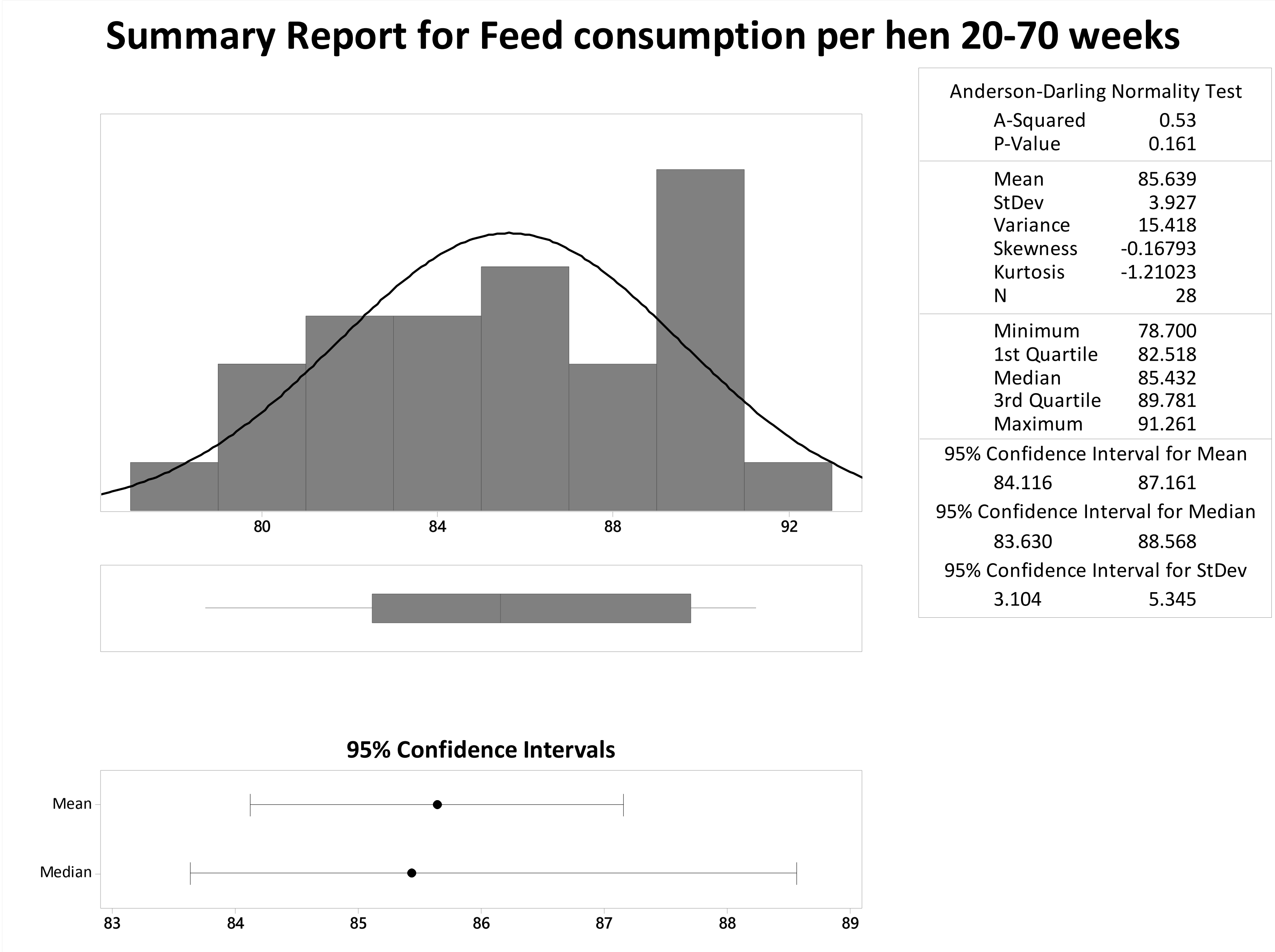



*Figure 3.3 Summary report for feed consumption per hen 20-70 weeks*

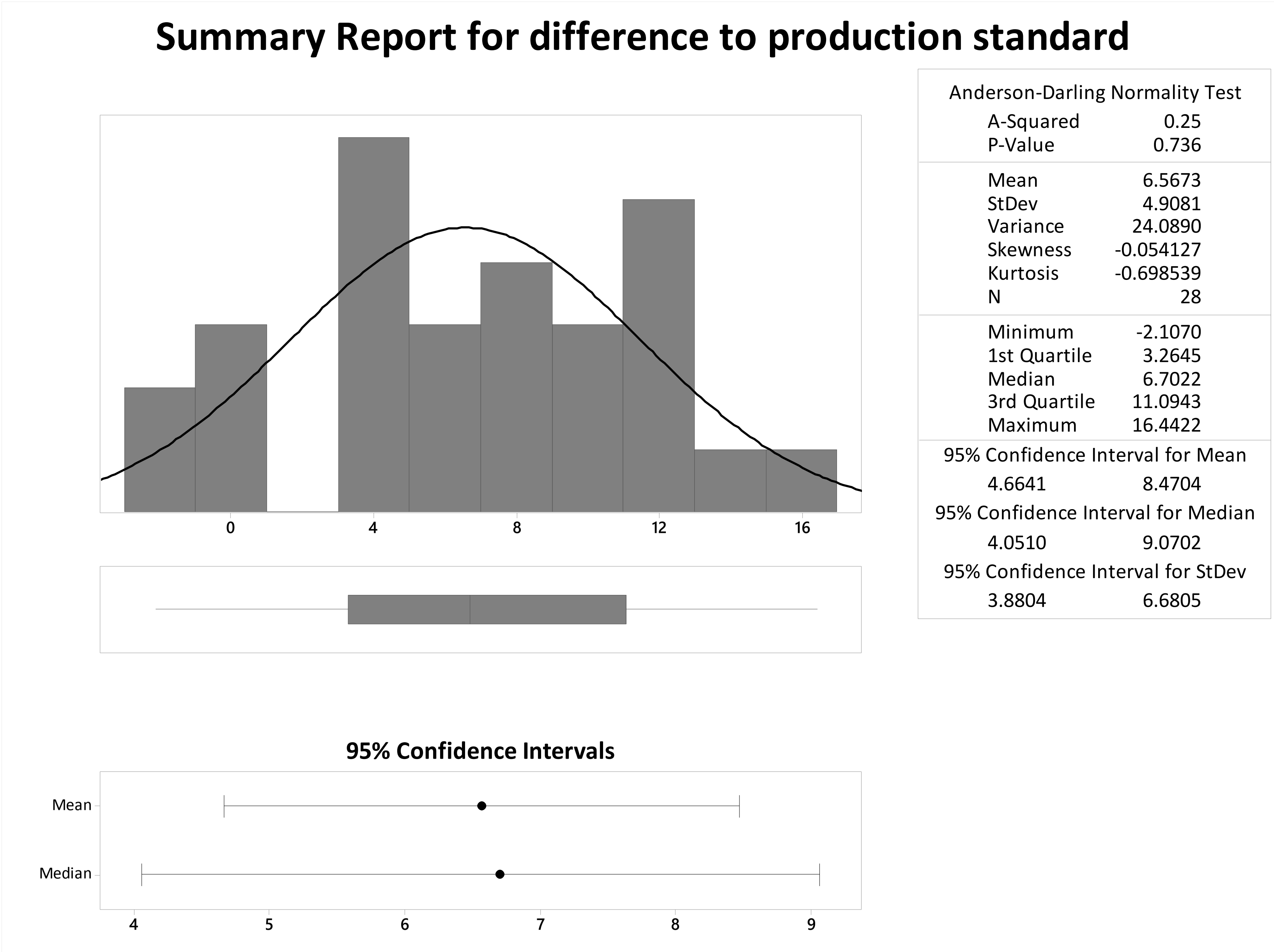



*Figure 3.4 Summary report for delta to standard all data*

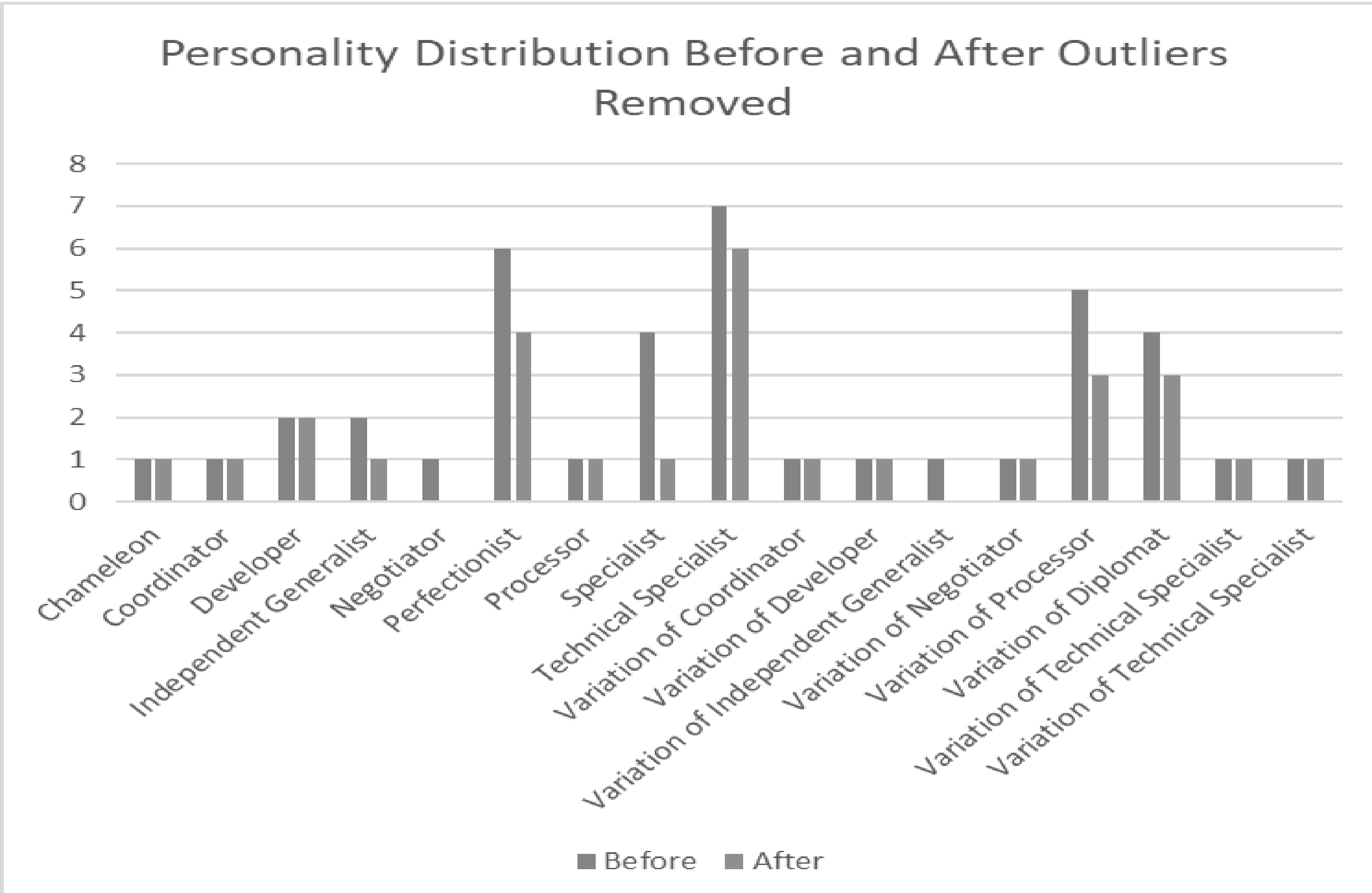



*Figure 3.5 Personality distribution before and after outliers removed*

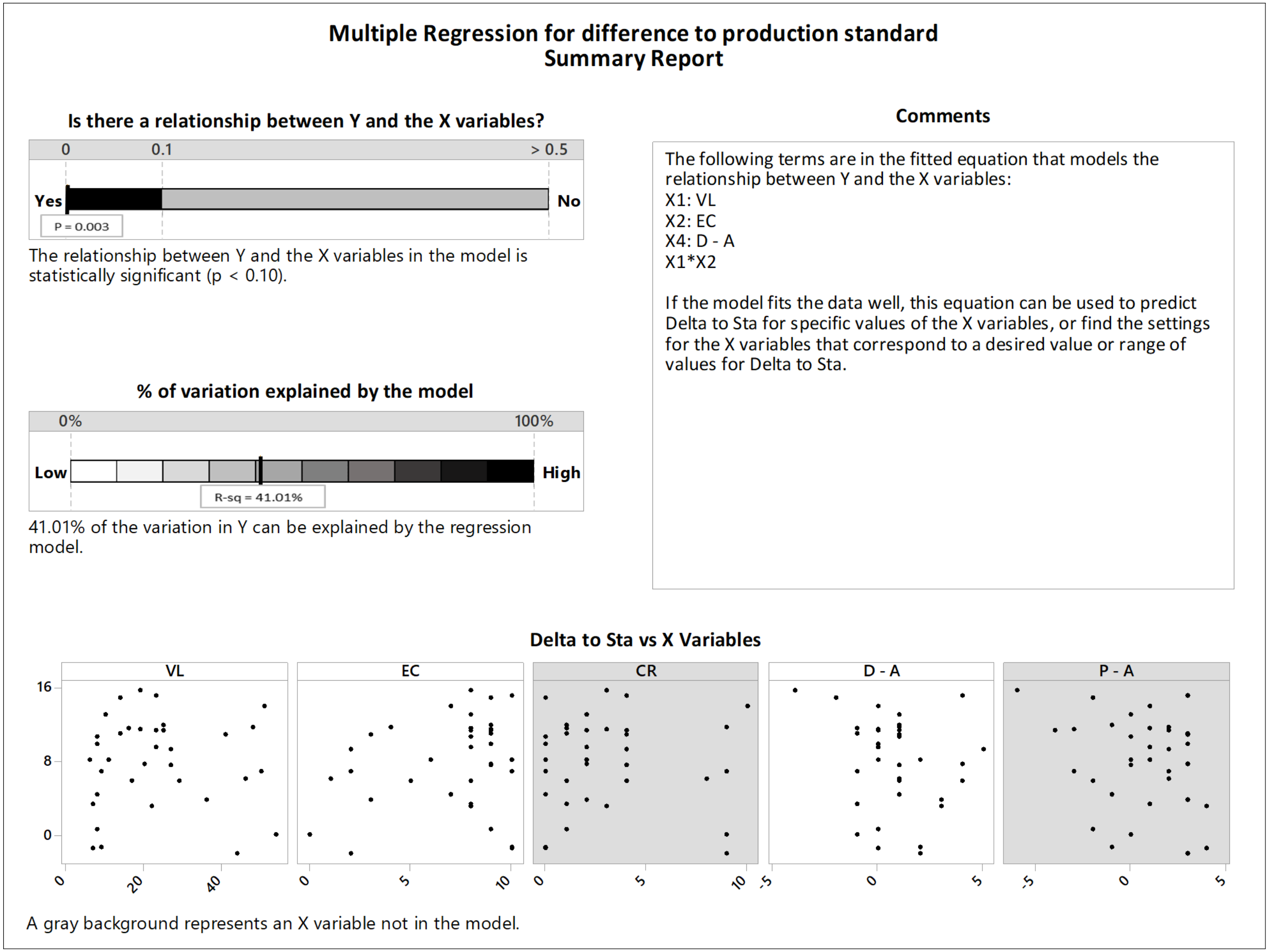



*Figure 3.6 Multiple regression summary table, personality variables only*

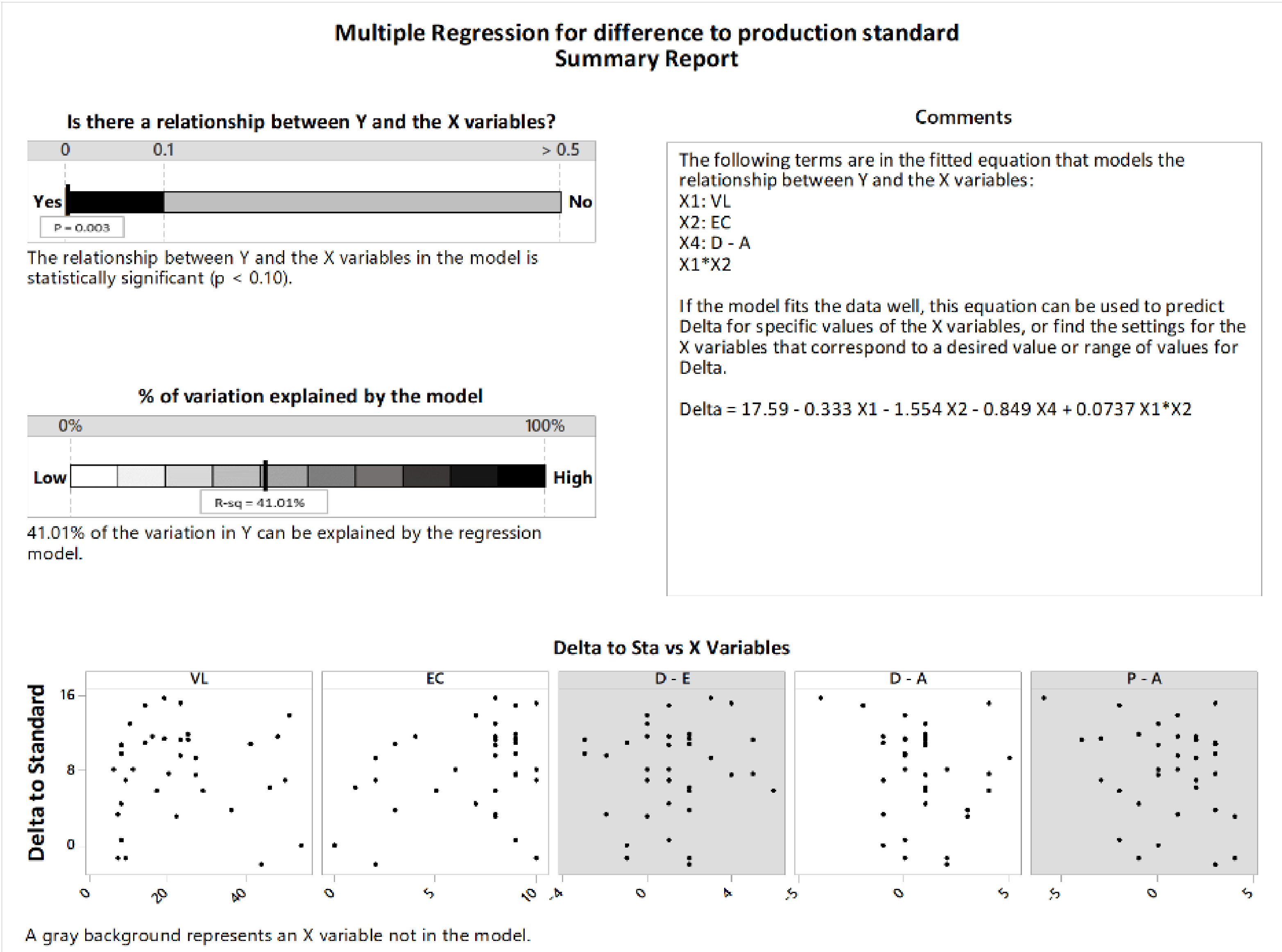



*Figure 3.7 Multiple regression summary table, personality variables only (rejection of the null hypothesis)*

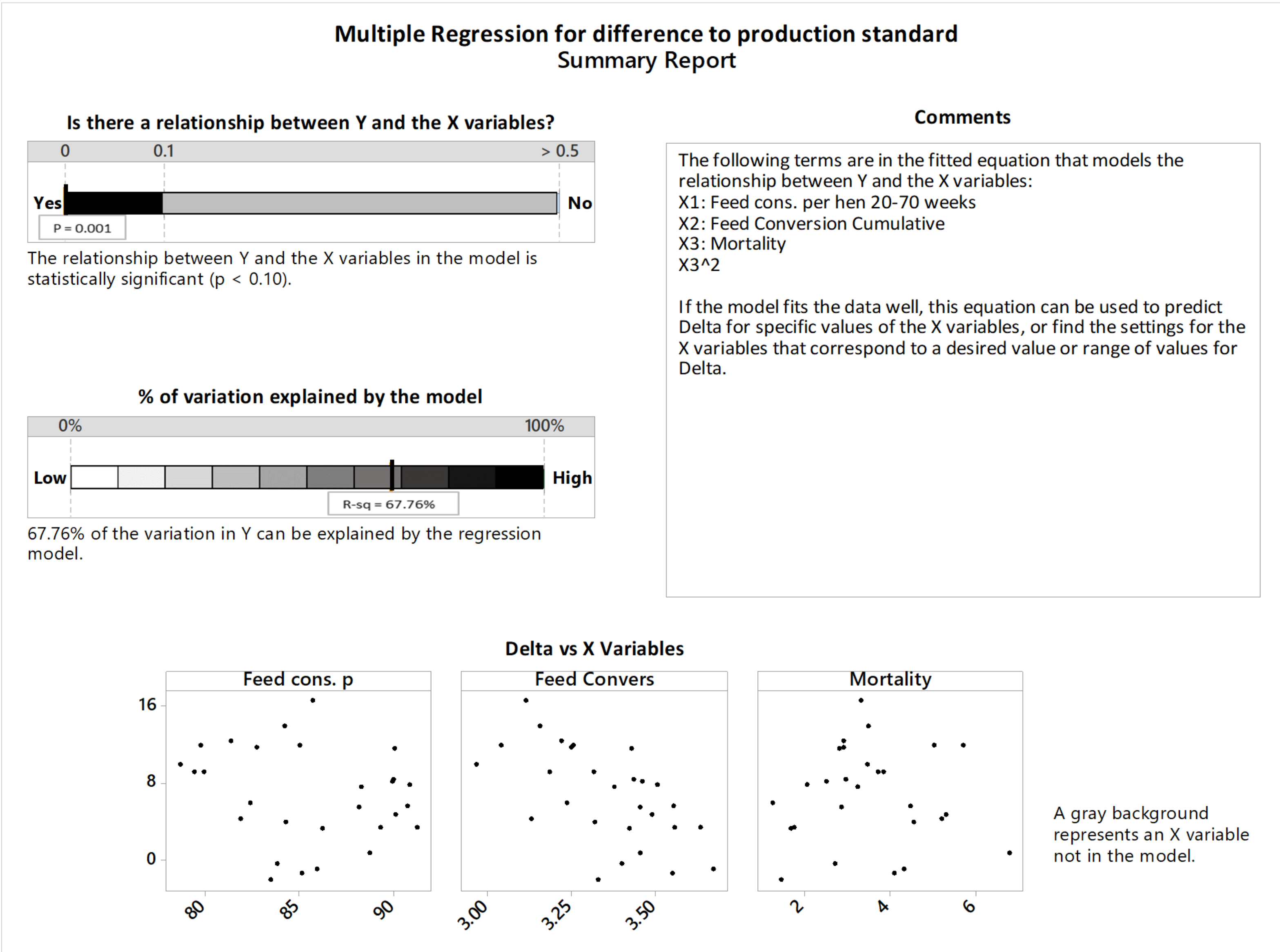
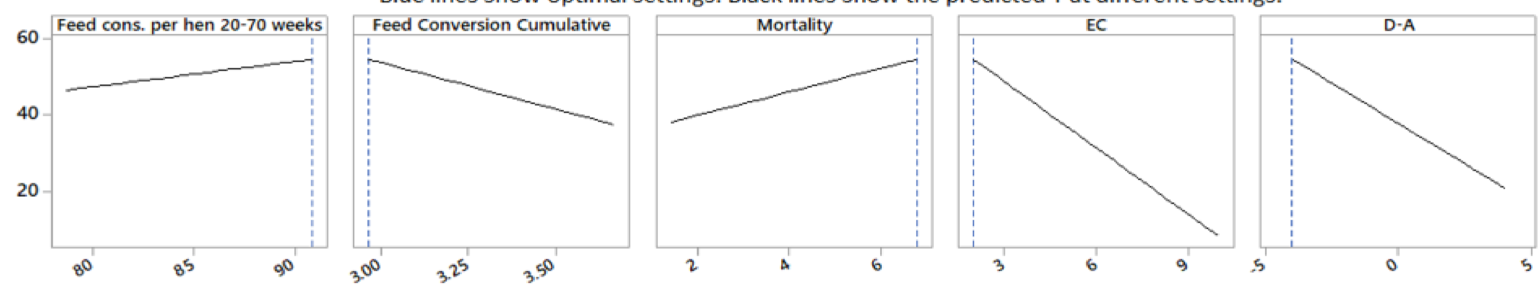



*Figure 3.8 Multiple regression summary table, egg production variables only*

**Multiple Regression for Delta**
**Prediction and Optimization Report**

| **Goal: Maximize Delta** | | **Solution: Optimal Settings** | | | |
|---|---|---|---|---|---|
| Predicted Y | 54.2750 | X1: Feed cons. p | 90.8453 | X4: EC | 2 |
| 95% PI | (31.778, 76.772) | X2: Feed Convers | 2.96512 | X5: D-A | -4 |
| | | X3: Mortality | 6.77271 | | |

Settings and Sensitivity for Optimal Solution
Blue lines show optimal settings. Black lines show the predicted Y at different settings.




**Top Alternative Solutions**
Sample points with predicted Y values closest to the optimal solution. Evaluate these and the optimal solution to determine if any are adequate.

| **X1** | **X2** | **X3** | **X4** | **X5** | **Predicted Y** |
|---|---|---|---|---|---|
| 85.7073 | 3.11257 | 3.28716 | 6 | 0 | 15.4972 |

*Figure 3.9 Multiple regression for delta to standard prediction and optimization report*

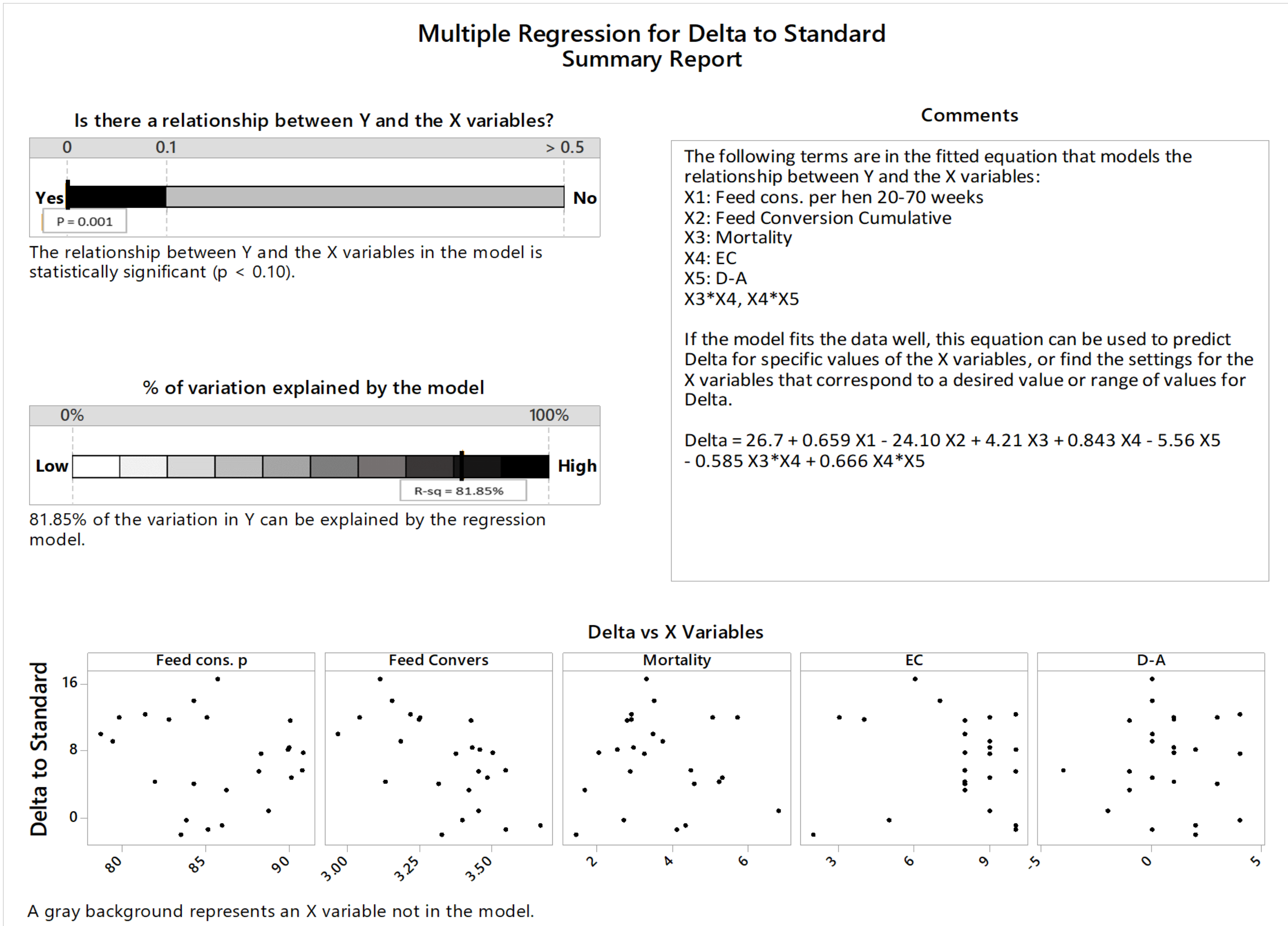



*Figure 3.10 Multiple regression for delta to standard summary report*

# Chapter 4 - Effect of using different spectra of light during nighttime transfer of pullet flocks

## 4.1 Abstract

Transferring pullets from pullet barns to laying barns can cause considerable stress and injury (Nicol et. al, 1999). Bone breakage during pullet collection, loading and transport is estimated at 13-41% (Nicol et. al, 1999). As the United States egg laying flock continues a transition to more cage free egg production replacing caged production, injuries, to pullets, will likely occur with more frequency. Risk of increased injury rates will require new strategies for pullet transfer to reduce or eliminate the risk of injury. Transfer distances and handling times vary by what type of system is used to rear pullets however as pullet barns get larger these distances and times will increase. Injury, including twisting and fractured bones will also increase as distance and handling time of pullets increase (Langkabel et al., 2015). Moving pullets to laying barns from cage free barns requires more human involvement than moving pullets from caged pullet barns. The human element includes the potential for human-handler fatigue and the associated increase in dropped pullets (Kettlewell & Mitchell, 1994). Reducing stress to pullets during moves is likely to reduce the number and severity injuries that occur, and the related stress accompanying the injuries (Kettlewell & Mitchell, 1994). The research objective was to test the use of different light spectra: blue light (470 nm) and white (700 nm) on stress levels of pullets during moves made under darkout conditions. Tonic immobility (TI) is a natural state of paralysis that can occur in pullets and other animals when stress is incurred. TI as a measure of stress was evaluated in pullets using two different light spectra. A total of 2000 pullets from 20 flocks were tested for TI during this trial. Analysis of variance (ANOVA) was used to determine if there was a difference in TI of the pullets moved in different light spectra. Analysis using only parametric data showed no significant difference in TI observed under blue

and white spectra. Looking at the data using non-parametric tools disclosed strain variation response to different light spectra.

Key words: Pullet, Tonic Immobility (TI), Darkout, blue light, white light, ANOVA

## 4.2 Introduction

There is a transformation of commercial egg production practices occurring in the United States. In 2019 alone, production capacity in excess of 11 million cage free egg laying hens was added to the nation's commercial laying flock, while many cage production systems are concurrently shutting down (Gregory, 2019). Consequently, the pullet industry is seeing a rapid transformation to cage free pullet production adding numerous and larger pullet barns. Transfer of pullets from pullet barns to laying barns can cause considerable stress and injury. Between collection, loading and transport, bone breakage is estimated at 13-41% (Nicol et al., 1999). As the United States laying flock population continues its transition to more cage free and less caged production, it is reasonable to expect the quantity of injuries to increase. To address this, new strategies are needed to reduce injuries and stress associated with transfer. Efforts to mitigate loss will improve the health and economics of the flock. New designs of pullet facilities will introduce new types of stress to the pullet. Depending on the pullet rearing system pullets may be carried longer distances with more handlers before arriving at a crate or cart, which can lead to more twisting and bone fractures (Langkabel et al., 2015). With more physical human activity to move cage free pullets, there is also the potential for greater fatigue of handlers and a greater likelihood that pullets will be dropped (Kettlewell & Mitchell,1994). Easing stress during pullet transfer is likely to lead to reduced pullet injury and lead to a higher level of productivity and flock health.

The commercial lifespan of a laying hen used in egg production can reach 95-100 weeks from hatch until removal from the laying barn when eggs are no longer being produced. The first 16 weeks are devoted to pullet development and the balance to egg production. Laying hens are described as pullets before they have laid their first egg and are reared separately from laying hens in a pullet barn. The first egg from a pullet is expected at ~ 17 weeks of age (Hy-Line

International, 2016). At about 16 weeks of age, pullets are transferred to a laying barn where environmental conditions are different. A simple example of the difference is the presence of nest equipment in layer barns for the eggs. This equipment is not necessary in pullet barns.

The most stressful days of a laying hen's life occur when there is significant unexpected disruption. Predictable high stress events in a hens' life are the day of hatch (and subsequent hatchery activity related to placement in a commercial facility. i.e. vaccinations, beak treatment), the transfer from a pullet facility to a layer facility, and depopulation and euthanization at the end of life. The pullet to layer move is arguably the day that has the greatest impact on the subsequent productivity of the laying hen through the remainder of its life. Typically, the stockperson has little involvement in the hatchery activities and the final day of life is irrelevant in terms of forward economics of the flock. However, the impact of negative consequences associated with transfer day can be minimized to reduce economic loss. Because these times are predictable, they can be prepared for. Manual catching and transportation of pullets to a layer barn is a major source of stress in pullets (Kettlewell & Mitchell, 1994) which is compounded by the subsequent introduction to a novel environment that also causes fear (Jones, 1996).

### *4.2.1 Impact of light*

In the wild, birds tend to lay eggs in spring because of increasing photoperiod (Takeshima et. al, 2019). The challenge for the commercial egg producer is to stimulate pullets into production during all months of the year, regardless of natural day-length. Traditionally stimulus is accomplished by confining pullets to windowless barns and manipulating the duration and intensity of light experienced by the pullets by using artificial light on time clocks to re-create an increasing daylength spring like schedule at any time of the year. In recent years two additional light characteristics, source and wavelength, have been defined that contribute to an optimization of hen performance (Li et al., 2014). Pullets and laying hens are more sensitive to blue and red spectra than other wavelengths (Hy-Line International, 2017). Light spectra can significantly influence the onset of egg production in laying hens with red light having the greatest positive influence (Hassan et. al, 2013, Li et al., 2014). Light spectra can also affect egg weight (Hassan et al 2013) In contrast, the rate of egg production was best when pullets were reared on green light (Hassan et. al, 2013). Light has been demonstrated to have a broad impact on egg productivity and component ratios. The better we understand light regimes the more we can beneficially impact laying hen health and economic productivity.

### *4.2.2 How laying pullets and laying hens perceive light*

Pullets and laying hens detect light not only through the retinal cone receptors in the eyes, but also via extra retinal photoreceptors in the pineal gland and the hypothalamic gland (Hy-Line International, 2017). The laying hens' response to light controls the Circadian rhythm, a 24-hour cycle of the laying hens' hormones and behaviors. The effects of stimulatory light wavelengths do not require a functional retina in the eye. Retinal stimulation does not affect initiation of reproduction (Baxter et. al, n.d.).

Pullets rely on photoreceptors located in different organs and sensitivity to different light wavelength to regulate various physiological processes (Baxter & Bedecarrats, n.d.). There are multiple strains of laying hens used in the industry and there are differences among strains in response to specific wavelengths light (Abdo et. al, 2017). Strain variation response to light stimulation can be expected like strain variation of other production measurements. While humans are trichromatic in their light sensitivity and have retinal cones that can determine red, green and blue pullets and laying hens are tetrachromatic and perceive light differently than humans (Hy-Line International, 2017). This wavelength of light response is more important than intensity to laying hens and how they perform (Huber-Eicher et. al, 2013). The key point is the stockperson experiences light different than the laying hen under his/her management.

### *4.2.3 Source of light influence on pullets and laying hens*

Light to stimulate pullets can be originated from multiple sources – each with pros and cons (Hy-Line International, 2017). Sources include sunlight, incandescent light (INC), compact fluorescent light (CFL), linear fluorescent light (LFL) and light emitting diode (LED) (Hy-Line International, 2017). LED lights are emerging as one of the more powerful tools for optimizing hen performance and the full benefits can be found in Table 4.1. In Switzerland, all new poultry barns have been required to use LED light for the last 20 years (Widowski et al., 1992).

While many sources of light exist if the focus is on stress reduction of the pullet/laying hen then a light source must be chosen that can provide specific (nm) of wavelength that is optimal to the pullet/laying hen relative to its life cycle.

### *4.2.4 Impact of specific wavelengths of light on poultry*

#### *4.2.4.1 White light*

White light represents a broad range of light wavelength spectra. Research using white light has been done on pullets and laying hens that has looked at discreet situations such as age of laying hen, influence on egg characteristics and overall productivity. A variety of research has been conducted generally comparing white light to some alternative wavelength. Much of the research focused on influence of light on onset of egg production. In this research laying hens performed better when managed with full spectrum simulated sunlight than artificial white light (Li et al., 2014). Pullets reared under a white light regimen were initially significantly heavier than those reared under a green light regimen at six weeks, but there were no significant differences between the two groups at 12, 15, 17, or 19 weeks when they became laying hens (Lewis et al., 2007). Red and white light spectra stimulation resulted in higher estradiol concentrations after photo-stimulation, indicating stronger ovarian activation, which translated into a significantly lower age at first egg when compared with the green light (Lewis et al., 2017).

Laying hens managed under red and white lights had a longer and higher peak production and higher cumulative egg number than laying hens under green light (Baxter et al., n.d.).

#### *4.2.4.2 Red light*

Red light influence is different on the laying hens than pullets. Until onset of egg production, red light appears to have little positive impact on traditional pullet measurements. Red spectrum light during the rearing of pullets did not impact growth or subsequent production performance, however, exposing adult laying hens to 60% red LED light was beneficial to maintain high egg production (Takeshima et al., 2019). Red light, if not instrumental to stimulate egg production, certainly influences the process. It has been shown that monochromatic red light does enhance egg production (Hassan et al., 2013). Red wavelength light also accelerates sexual maturity (Baxter et al., n.d.; Huber-Eicher et al., 2013).

Higher wavelengths, such as those in the red spectrum, can stimulate hypothalamic photoreceptors more efficiently than short wavelengths, which is necessary to effectively stimulate the reproductive axis in pullets. The onset of sexual maturity (calculated based on the age at first egg) was significantly delayed for laying hens maintained under blue and green light spectra. Wavelength of the red spectrum are the most potent stimulator of sexual maturation and egg-laying improved in both blind and sighted laying hens. Higher wavelengths also may increase activity and may stimulate aggression (Baxter & Bedecarrats, n.d.).

#### *4.2.4.3 Blue light*

The impact of the shorter wavelength of blue light appears to have a calming effect on pullets while having little or no positive influence on stimulation of egg production. Eggs laid under blue or green light were consistently larger than those under red light (Li et al., 2014). The performance of laying hens while under heat stress is improved when using blue light (Abdo et al., 2017). Blue light is also known to maintain ambient comfort. The blue light (440-490nm) has a calming effect on pullets and has been used in catching and carting pullets (Barbosa et al., 2013).

Lower wavelengths of light, such as those in the green and blue spectrum enhance pullets' immune response, increase growth, and may trigger more sitting and perching behaviour. These effects may in part be mediated via retinal photoreception (Baxter & Bedecarrats, n.d.). Perching improved under blue light (Hassan et al., 2013). Monochromatic blue light also improves performance of the pullet's weight gain and reduces fear and stress of laying hens during pre-slaughter handling and transportation (Mohamed et al., 2014). In broilers blue light has been shown to be a good tool for improving welfare and mitigating stress not only in pre-slaughter handling, but also during transportation of broilers. Studies recommends that the catching of broilers should be carried out under such light to calm the pullets (Mohamed et al., 2014).

Light spectrum management in pullets and laying hens requires the use of different wavelengths of light at different stages of the life cycle. Wavelengths of light have different influence on laying hens at different stages of life. Shorter wavelength blue/green light appears to have a positive effect on pullet development and stress reduction. Longer wavelength of light in the red spectrum appears to be more beneficial to stimulate pullets into production and keep them producing at a high level. In pullets there is little research on the impact of wavelength of light used when moving pullets to a laying house in dark out conditions in contrast to traditional white light usage. The lack of published literature in this area is the motivation of the research conducted.

## 4.3 Materials and methods

### *4.3.1 Tonic immobility*

Tonic immobility is a natural state of semi-paralysis that animals can enter when presented with a stressor. Specific to pullets in this experiment the semi-paralytic state was induced when the pullet was picked up and laid on its back. The time it took for the pullet to return to its feet and move was measured with a stopwatch. The longer the pullet remained in the semi-paralytic state the greater the influence the stressor had on the pullet.

### *4.3.2 Integrator participation*

A key element of this paper is that all research be conducted in commercial facilities. Egg Innovations is an integrator egg company in the United States uniquely set up with over 50 certified free-range laying hen barns that are highly similar and meets the standard of being a commercial egg operation. The laying hen barns all contain the same brand of equipment and floor plan, and all house ~ 20,000 laying hens. Further specifications can be found in Appendix A. The pullets are all raised using Egg Innovations approved protocols. All pullet and layer stockpeople are trained to use the same rearing and production protocols. Egg Innovations has opened their pullet facilities to conduct research for 10 trials of white light treatments and 10 trials blue light treatments (6 white egg type laying flocks/14 brown egg type laying flocks) when moving pullets from the pullet barn to the layer barn. The imbalance of white and brown flocks was driven by existing schedules of the integrator as they are dominantly a brown egg production company.

### *4.3.3 Housing*

All pullets were raised in single floor pullet facilities. Multi-tier aviary facilities were not used. The pullet flocks varied in size from 20,000 to 60,000 pullets. Pullets had wood shavings for litter, nipple drinkers and a combination of pan and chain feeders. The facilities were cross ventilated as opposed to tunnel ventilation with all exhaust fans along the sides of the pullet barns and no fans at the end of the barns. There were no light traps allowing natural light to bleed in through the louvers. Living area space for pullets was variable between 0.4 $ft^2$ to 1.1 $ft^2$ per pullet depending on which facility was used.

### *4.3.4 Strain genetics*

Four different strains of commercial egg laying genetics were utilized during the research trials. This was dictated by existing schedules of the integrator. Fourteen flocks were brown egg layer genetics and six flocks were white egg layer genetics. All strains are commercially available and common in the egg industry. The distribution of strains was:

| | |
|---|---|
| 3 | H and N (HnN) white egg layer flocks |
| 3 | LSL white egg layer flocks |
| 11 | Hy-Line brown egg layer flocks |
| 3 | Lohman brown egg layer flocks |

### *4.3.5 Age*

The research occurred at the age of life when transferring pullet flocks to a laying facility. All flocks were ~ 16 weeks old at time of treatments and collecting data. The transfer day from pullet barn to layer barn is one of the most stressful days on a pullet because of human handling when pullets are physically picked up one at a time and placed into a moving crate or cart, transported down the highway to a layer barn and finally picked up one at a time and released into new environment of a layer barn. This is a significant disruption to the daily routine of the pullet.

### *4.3.6 Seasonal Timing*

All trials and replications were conducted over a four-month period between 9/18/2018 and 1/25/2019. The schedule was driven by operational timelines at the integrator.

### *4.3.7 Light regimens*

All pullet facilities were equipped with monochromatic white light (700 nm) from ONCE (brand) 8-watt LED bulbs. Bulbs were spaced on 12-foot centers throughout the pullet barn. Light management (duration and intensity) followed relevant guidelines specific to each strain of genetics. The baseline lighting of the building was the same wave length as the white light treatment in the trial.

Pullet transfer moves were conducted during dark out conditions in the evening. Crews used either blue light of 470 nanometers white light of 700 nanometers. The source of light during darkout pullet moves were light bulbs attached to miners' hats.

### *4.3.8 Locations of pullet farms*

The pullet farms where trials were conducted, and data were collected were on four separate properties located in three separate states in the Midwest. The Wisconsin facility is referred to as the "Saager" pullet facilities located in Lodi, WI. This farm is composed of one barn with three separate pullet rearing rooms referred to as Saager – west, Saager - east top and Saager east - bottom.

The Indiana facilities are referred to as the "Atwood" and "Valley View" farms. Both facilities are in Warsaw, IN. The Atwood farm is composed of four separate barns referred to as Atwood 1, Atwood 2, Atwood 3 bottom and Atwood 3 top. The Valley View farm is composed of two separate barns referred to as Valley View 1 and Valley View 3. At the Valley View farm, the company practices a strategy called "brood and move". Using this strategy, the company raises the pullet from day 1 to ~ 8 weeks old in a smaller pullet barn and then transfers them to a larger "growout" pullet barn for weeks 9-16 of the pullet's life. This explains the chart below why Valley View three was depopulated in November and then again in January with all flocks being 16 weeks old.

The Ohio facility is referred to as the "Shurgreen" farm and has two separate pullet facilities. The facilities are in Ansonia, OH. The two pullet facilities are referred to as Shurgreen 1 and Shurgreen 2. The distribution of genetics, light color and facilities is summarized in Table 4.2.

### *4.3.9 Data Collection*

A portable light system was worn via miners' hats by the moving crew for pullet transfer during dark out conditions. In collaboration with Egg Innovations, one of the US' largest producers of free-range eggs, 20 flocks were tested for TI in 10 pullet barns (ten trials with blue light; ten trials with white light). TI times from 100 pullets per treatment were collected to assess stress. During transferring pullets 100 pullets were individually collected and laid on their back and timed for TI. As the pullet righted itself and moved away the stopwatch was stopped.

### *4.3.10 Statistical analysis*

The research was conducted to evaluate the impact on stress levels in pullets using different light regimens during pullet moves to layer barns under darkout conditions. Anderson-Darling analysis of histograms were used to test for normality and assign a P-Value. P values > 0.05 were determined to be a normal data set. The data were then analyzed using analysis of variance (ANOVA) to compare the influence of different light spectra on TI scores of pullets being handled in darkout conditions. The ANOVA test is robust when data is normally distributed (P < 0 .05). Of the 20 data sets five were determined to have normal distribution and analyzed using ANOVA. The remaining 15 data sets were treated as non-parametric data and analyzed using the Mann-Whitney test for medians of non-parametric data sets. Non-parametric analysis is used to compare data that are not normally distributed and is sometimes referred to as distribution free tests.

## 4.4 Results and discussion

The purpose of the research was to determine if there is a statistically significant difference in the TI scores of pullets under different light spectra when moving pullets to a layer barn. ANOVA was used to compare the light spectra influence on TI in data sets that had normal distribution.

Non-parametric distributions are not a rare occurrence in data sets. They can occur for a variety of reasons including;

1. Underlying data does not meet the assumptions of the population leading to skewed data
2. The population size is too small
3. The analyzed data is not continuous

Normal distributions assume that any data points occurrence being by chance is 0.30% or less. First analysis of the data that had normal distribution was reviewed. This was followed by a review of the data from a non-parametric perspective using the Mann-Whitney test.

Anderson-Darling normality tests were conducted combining all blue light trials in one analysis and combining all white light trials in a second analysis. In both cases the groups of 10 data sets of each light spectra were found to be non-parametric. This required further stratification of the of the data to determine if there were opposing light spectra data that could be compared. Two of the 10 white light farm settings had normally distributed data. The data were from Saager west and Saager east bottom. These two white light data sets remained normally distributed when combined. Three blue light farm settings had normally distributed data. The data sets were two pullet flocks out of Valley View three (January 2019) and one pullet flock from Atwood two, all used Hy-Line genetics. These data sets did not remain normally distributed when combined.

Blue light data could not be combined for comparison to the white light. When blue data were combined the data became non-parametric. Each of the 3 blue light data sets were compared individually to the combined white data set and to each other, as seen in Figures 4.1, 4.2, and 4.3.

Each of the 3 blue light data sets were compared individually to the combined white light data sets using Tukey. The results in Figure 4.4 show that TI scores for pullets under white light were not statistically different from any of the blue light data sets. Additionally, none of the blue light data sets were statistically different from each other. $P > 0.05$ proves that all means are statistically equal. The results of all this can be found in Table 4.3.

When comparing the normal data sets pulled from this research there were no comparisons that provided significant differences between the treatments. Given that white light is the presence of all visible light including blue light the distinction in the two light spectra chosen was not significant enough to cause differences in TI scores. Having one treatment be the same wavelength as the normal light the pullets have acclimated to may have introduced a confounding factor. An alternative theory would be the hypothesis is incorrect and spectra of light does not influence TI scores during pullet moves. To prove out the original and alternative thesis follow-up research trials should be conducted comparing wider spreads of the light spectra. Comparing the influence of red light to blue light in similar research may yield some significant results.

Testing the normally distributed data did not disclose significant difference in light spectra and severely reduced the data pool. The data were then analyzed using the nonparametric tool of Mann-Whitney analysis. Nonparametric analysis is used to compare data that are not normally distributed. Nonparametric analysis tools analyze based on medians of the data. Data from each of the trials (blue and white light) were assessed independently and presented in Figure 4.5 and Table 4.4. The null hypothesis for this test is that the medians of the data sets are equal. P-value of 0.05 or above confirms the hypothesis. This test shows that the medians are not different. P-value of 0.503.

In addition, no differences in response to light wavelength relative to strain of the pullet were found as seen in Figure 4.6 and Table 4.5. The null hypothesis for this test is that there is no difference between the data sets in TI scores. P-value of .05 or above confirms the hypothesis. The TI scores for the white light trial using Hy-Line Brown pullets were not different. P-value of 0.184. This result is potentially significant as it potentially points out strain variation and response to different wavelengths of light. To validate this, result the other strains need to be analyzed to see if significant differences occur. The distribution shape of the Hy-Line brown strain data was the least similar of the comparisons.

The next analysis was LSL White hen TI data compared under the two light spectra, as seen in Figure 4.7 and Table 4.6. Here for the first time we see a result that was significantly different at a P-value of 0.003. The TI score of the white light trial on LSL white pullets was significantly shorter than the TI score of LSL white pullets treated with blue light. This was contrary to the results that were predicted. The hypothesis was that blue light would provide less stress, and lower TI scores to pullets than white light. Strain variation can be expected in almost every parameter that is measured in a laying hen. The strains, while broadly similar, always have uniqueness embedded in their gene pools. Seeing a difference in TI scores at a significant level was not expected. The surprise is the white light had a more calming effect on the LSL white pullets then the blue light did. This effectively broadens the need of future research. Instead of looking at the influence of a wavelength of light on a strain of pullets and assuming the results will be homogenous for all strains, this data opens the door to a thought that a wavelength of light influence on one strain of pullets may have a different influence on a second strain of hens.

The final comparison was Lohman brown pullets X blue light and H&N white pullets X white light, as seen in Figure 4.8 and Table 4.7. This comparison was done as these were the two remaining strains of pullets.  The medians of these two data sets were significantly different at a P-value of 0.000. In this comparison, the pullets under the white light regimen had a longer TI score than those under blue light at a significant level. It is noted that using LSL white pullet TI data exclusively TI scores under white light were shorter than under blue light. When comparing Lohman browns and HnN white TI scores the TI scores using white light were longer.

The data the interaction of light spectra on TI scores of pullets is more complex than what the experimental design could pull apart. The conundrum was having a data set showing significant influence of white light extending TI scores relative to blue light using Lohman brown pullets and HnN pullets and in the next data set white light shortened TI scores relative to blue light with LSL white pullets exclusively. The positive value of working in a commercial environment is collection of data from active commercial operations which is something routinely missing in the literature. The downside is one cannot control the number of variables as tightly as in an academic research setting. In the final trial, there were multiple other variables that the analysis could not factor in because of the way the data were collected. In addition to the light spectra variable there were also differences in location, building design and strain to name a few of the co-variates. There appears to be an influence between white and blue light on pullet TI scores in select situations. There also appears to be strain variation influence on TI scores and light spectra. Future research should look, not only at wavelength of light but tightening up other parameters, such as strain and building design as the light influence on pullets appears to be a more complex process then initially understood.

## 4.5 Summary and conclusions

The initial summary of the research using only parametric data were no significant difference in TI observed when pullets are transferred under blue or white light in commercial pullet facilities. When the data was analyzed using non-parametric tools that conclusion appears inaccurate.  There are a multitude of light combinations that can be compared. This can include both wavelength as well as source of light. This project should be viewed as one broader data point of how to positively impact stress reduction at time of pullet move. However future research should consider other spectrums of light and other sources of light as the literature suggests that light has the potential to be a positive influence when the proper parameters are defined. Future research should also take a closer look at strain variation and each strains response to a specific wavelength of light. The aggregate interactions appear to be more complex than originally thought.

## 4.6 Tables

*The benefits of LED include:*

- *Provides a full spectrum of light*
- *Typically the most efficient light bulb measured in lumens per watt*
- *Can be constructed out of non-glass materials that are waterproof and shatterproof*
- *Typically manufactured from non-toxic materials*
- *Can be designed to focus the light onto desired areas*
- *Color spectrum of the light can be adjusted depending on phosphors used*
- *Easier to dim than CFL bulb*
- *Dimming can extend bulb's lifespan*
- *Very long lifespan – up to 10 years at 16 hours per day (50,000 – 60,000 hours)*
- *Rapidly reaches peak light intensity after being turned on*
- *Ideal for areas where lights are frequently turned on and off*
- *Efficient in cold weather with no change in performance*

(Hy-Line International, 2017)

Table 4.1 The benefits of LED to laying hens, according to Hy-Line International

| Location | Strain | Egg Color | Light regimen | # flocks | Date of move |
|---|---|---|---|---|---|
| | | | | | |
| Saager West | H and N | White | White | 1 | 9/18/2018 |
| Saager East Top | H and N | White | White | 1 | 9/19/2018 |
| Saager East Bottom | H and N | White | White | 1 | 9/20/2018 |
| Atwood 3 Bottom | Hyline | Brown | White | 1 | 9/24/2018 |
| Atwood 2 | Hyline | Brown | White | 2 | 9/26/2018 |
| Atwood 3 Top | Hyline | Brown | White | 2 | 9/28/2018 |
| Valley View 3 | LSL | White | White | 2 | 11/20/2018 |
| | | | | 10 | |
| | | | | | |
| Valley View 3 | LSL | White | Blue | 1 | 11/21/2018 |
| Shurgreen 1 | Lohman | Brown | Blue | 1 | 1/7/2019 |
| Shurgreen 2 | Lohman | Brown | Blue | 1 | 1/7/2019 |
| Atwood 1 | Lohman | Brown | Blue | 1 | 1/10/2019 |
| Valley View 3 | Hyline | Brown | Blue | 1 | 1/21/2019 |
| Valley View 3 | Hyline | Brown | Blue | 2 | 1/22/2019 |
| Atwood 2 | Hyline | Brown | Blue | 1 | 1/23/2019 |
| Atwood 3 Top | Hyline | Brown | Blue | 1 | 1/25/2019 |
| Atwood 3 Bottom | Hyline | Brown | Blue | 1 | 1/25/2019 |
| | | | | 10 | |

Table 4.2 Pullet move light trial

## One-way ANOVA: Tonic Immobility versus Light Spectrum

### Method

| | |
|---|---|
| Null hypothesis | All means are equal |
| Alternative hypothesis | Not all means are equal |
| Significance level | ? = 0.05 |

*Equal variances were assumed for the analysis.*

### Factor Information

| Factor | Levels | Values |
|---|---|---|
| Light Spectrum | 4 | Blue1, Blue2, Blue3, White |
| Density (Hens/Sq In.) | White | 0.80 |
| | Blue 1 | 0.50 |
| | Blue 2 | 0.50 |
| | Blue 3 | 1.10 |

### Analysis of Variance

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Light Spectrum | 3 | 11921 | 3974 | 1.66 | 0.175 |
| Error | 496 | 1186555 | 2392 | | |
| Total | 499 | 1198476 | | | |

### Model Summary

| S | R-sq | R-sq(adj) | R-sq(pred) |
|---|---|---|---|
| 48.9106 | 0.99% | 0.40% | 0.00% |

### Means

| Light Spectrum | N | Mean | StDev | 95% CI |
|---|---|---|---|---|
| Blue1 | 100 | 104.99 | 54.19 | (95.38, 114.60) |
| Blue2 | 100 | 100.39 | 51.91 | (90.78, 110.00) |
| Blue3 | 100 | 110.16 | 54.15 | (100.55, 119.77] |
| White | 200 | 112.90 | 41.26 | (106.10, 119.69] |

*Pooled StDev = 48.9106*

### Tukey Pairwise Comparisons

### Grouping Information Using the Tukey Method and 95% Confidence

| Light Spectrum | N | Mean | Grouping |
|---|---|---|---|
| White | 200 | 112.90 | A |
| Blue3 | 100 | 110.16 | A |
| Blue1 | 100 | 104.99 | A |
| Blue2 | 100 | 100.39 | A |

*Means that do not share a letter are significantly different.*

*Table 4.3 Tonic immobility versus light spectrum method*

# Mann-Whitney: Tonic Immobility_Blue, Tonic Immobility_White

## Method

$\eta_1$: median of Tonic Immobility_Blue

$\eta_2$: median of Tonic Immobility_White

Difference: $\eta_1 - \eta_2$

## Descriptive Statistics

| Sample | N | Median |
|---|---|---|
| Tonic Immobility_Blue | 1000 | 96.0 |
| Tonic Immobility_White | 1000 | 94.5 |

## Estimation for Difference

| Difference | CI for Difference | Achieved Confidence |
|---|---|---|
| -2 | (-7, 4) | 95.00% |

## Test

| | |
|---|---|
| Null hypothesis | $H_0: \eta_1 - \eta_2 = 0$ |
| Alternative hypothesis | $H_1: \eta_1 - \eta_2 \neq 0$ |

| Method | P-Value |
|---|---|
| Not adjusted for ties | 0.503 |
| Adjusted for ties | 0.503 |

*Table 4.4 Blue and white light Mann-Whitney Test for significance*

# Mann-Whitney: Tonic Immobil_Blue-Hyline Brown, Tonic ... line Brown

## Method

$\eta_1$: median of Tonic Immobil_Blue-Hyline Brown

$\eta_2$: median of Tonic Immobi_White-Hyline Brown

Difference: $\eta_1 - \eta_2$

## Descriptive Statistics

| Sample | N | Median |
|---|---|---|
| Tonic Immobil_Blue-Hyline Brown | 600 | 102 |
| Tonic Immobi_White-Hyline Brown | 500 | 83 |

## Estimation for Difference

| Difference | CI for Difference | Achieved Confidence |
|---|---|---|
| 5 | (-2, 13) | 95.00% |

## Test

| | |
|---|---|
| Null hypothesis | $H_0$: $\eta_1 - \eta_2 = 0$ |
| Alternative hypothesis | $H_1$: $\eta_1 - \eta_2 \neq 0$ |

| Method | P-Value |
|---|---|
| Not adjusted for ties | 0.184 |
| Adjusted for ties | 0.184 |

*Table 4.5 Hy-Line brown Mann-Whitney Test for significance*

# Mann-Whitney: Tonic Immobility_Blue-LSL White, Tonic ... e-LSL White

## Method

$\eta_1$: median of Tonic Immobility_Blue-LSL White

$\eta_2$: median of Tonic Immobilit_White-LSL White

Difference: $\eta_1 - \eta_2$

## Descriptive Statistics

| Sample | N | Median |
|---|---|---|
| Tonic Immobility_Blue-LSL White | 100 | 126.5 |
| Tonic Immobilit_White-LSL White | 200 | 110.0 |

## Estimation for Difference

| Difference | CI for Difference | Achieved Confidence |
|---|---|---|
| 27 | (10, 45) | 95.00% |

## Test

| | |
|---|---|
| Null hypothesis | $H_0$: $\eta_1 - \eta_2 = 0$ |
| Alternative hypothesis | $H_1$: $\eta_1 - \eta_2 \neq 0$ |

| Method | P-Value |
|---|---|
| Not adjusted for ties | 0.003 |
| Adjusted for ties | 0.003 |

*Table 4.6 LSL White Mann-Whitney Test for significance*

# Mann-Whitney: Tonic Immobil_Blue-Lohman Brown, ... ite-H&N White

## Method

$\eta_1$: median of Tonic Immobil_Blue-Lohman Brown

$\eta_2$: median of Tonic Immobili_White-H&N White

Difference: $\eta_1 - \eta_2$

## Descriptive Statistics

| Sample | N | Median |
|---|---|---|
| Tonic Immobil_Blue-Lohman Brown | 300 | 82.0 |
| Tonic Immobili_White-H&N White | 300 | 101.5 |

## Estimation for Difference

| Difference | CI for Difference | Achieved Confidence |
|---|---|---|
| -18 | (-26, -10) | 95.00% |

## Test

| | |
|---|---|
| Null hypothesis | $H_0$: $\eta_1 - \eta_2 = 0$ |
| Alternative hypothesis | $H_1$: $\eta_1 - \eta_2 \neq 0$ |

| Method | P-Value |
|---|---|
| Not adjusted for ties | 0.000 |
| Adjusted for ties | 0.000 |

*Table 4.7 Lohmann Brown vs H&N White Mann-Whitney Test for significance*

## 4.7 Figures

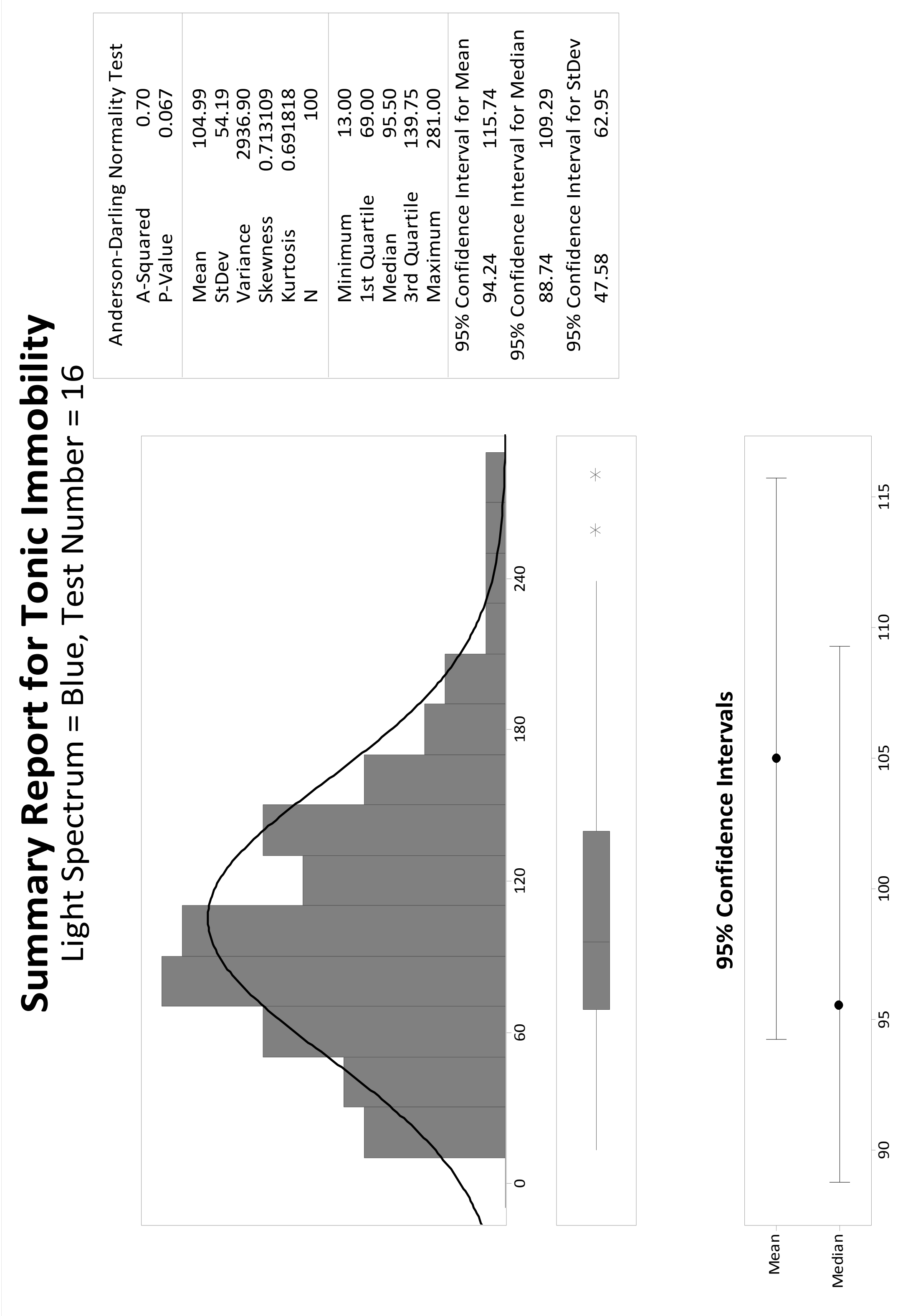



*Figure 4.1 Anderson-Darling blue light normality test, replication 16*

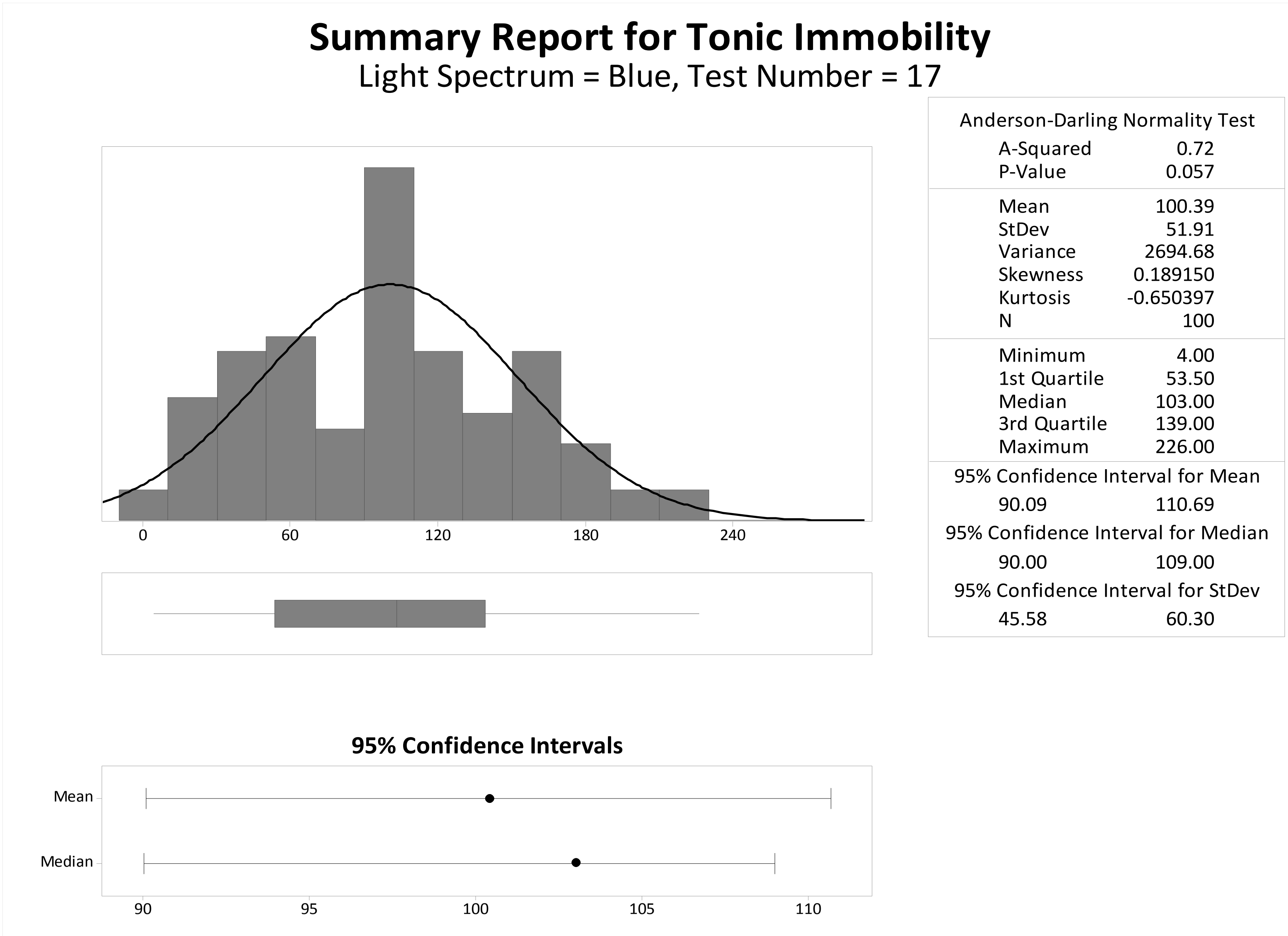



*Figure 4.2 Anderson-Darling blue light normality test, replication 17*

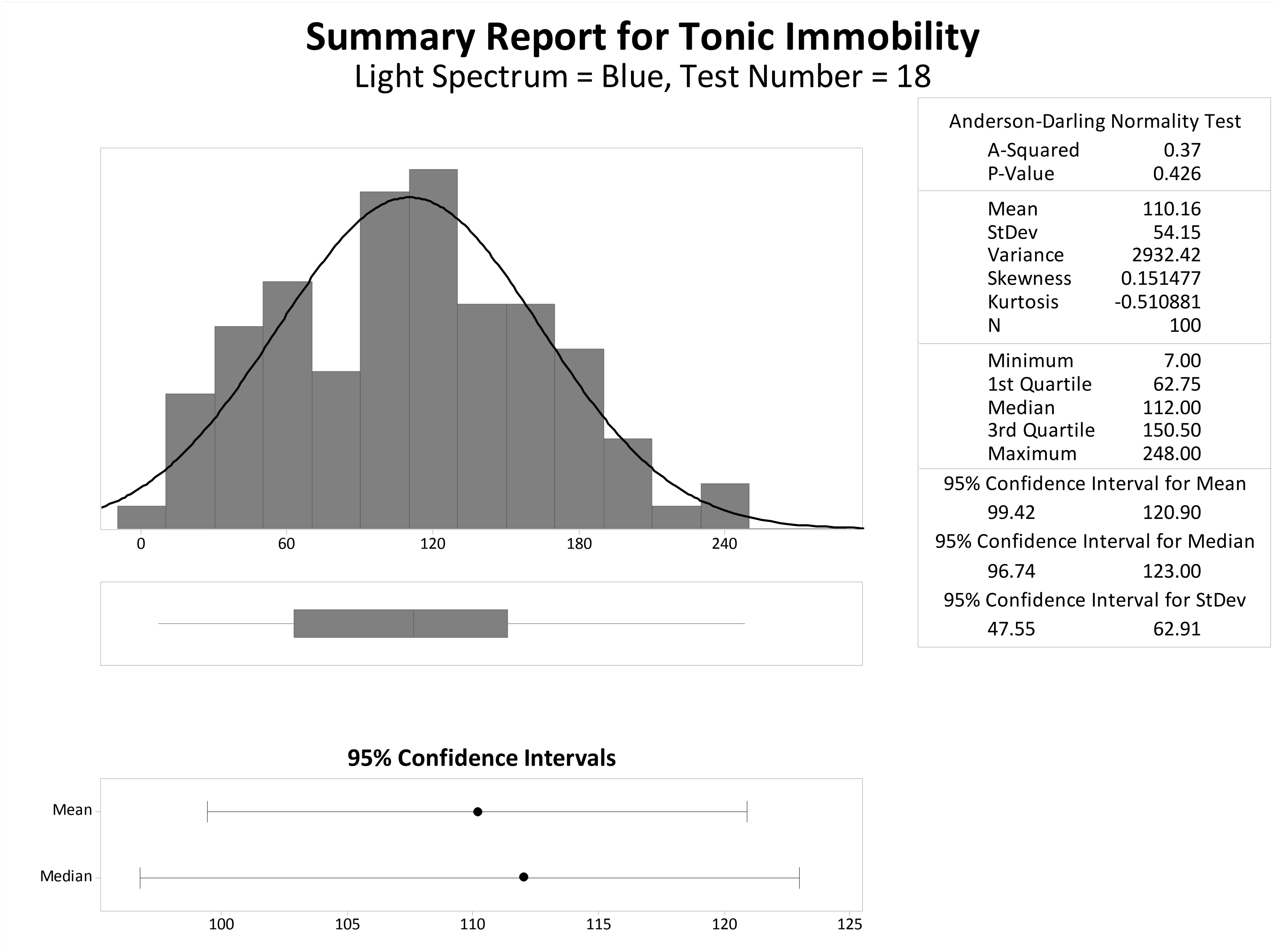



*Figure 4.3 Anderson-Darling blue light normality test, replication 18*

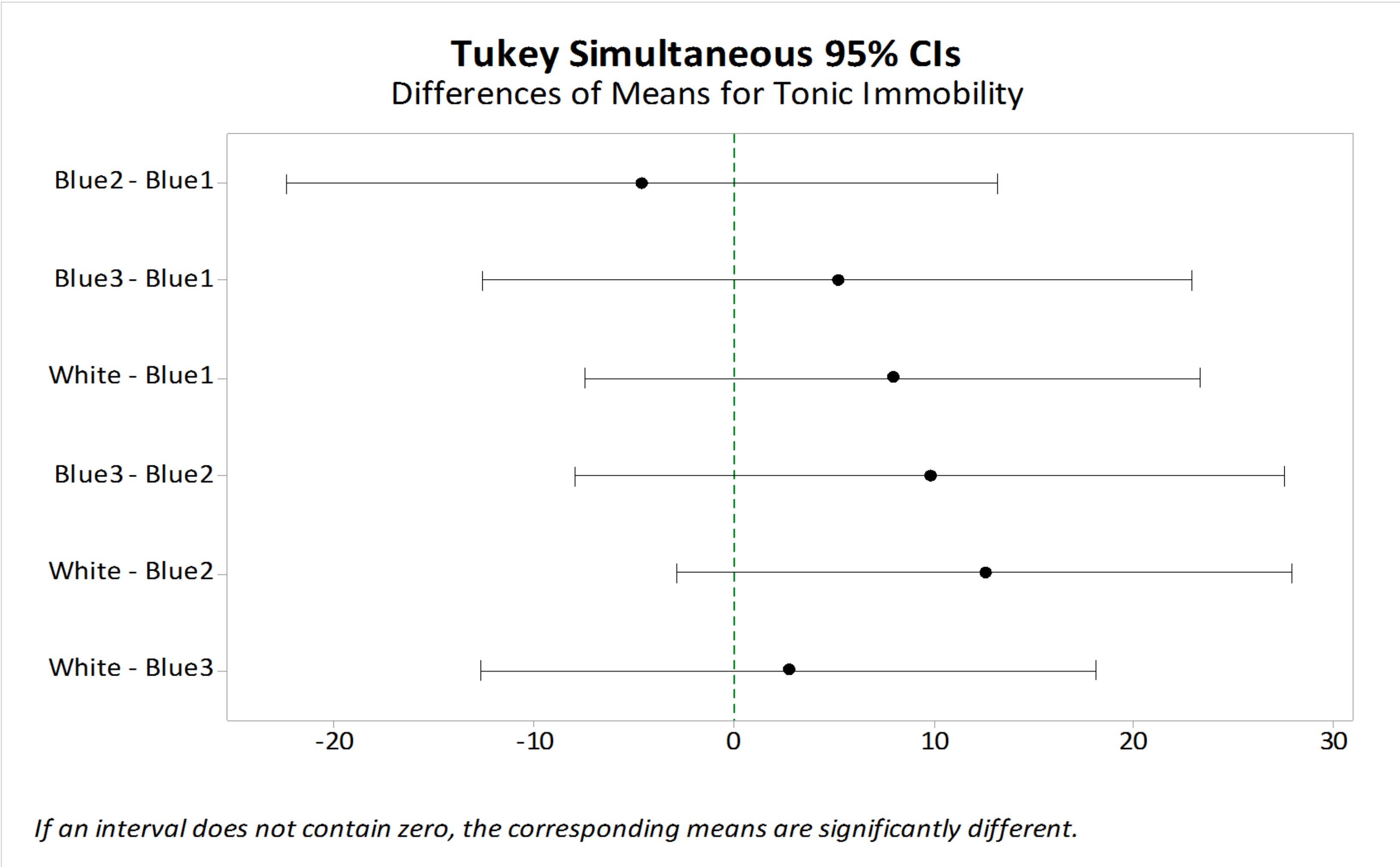



*Figure 4.4 Tukey analysis of blue versus white light*

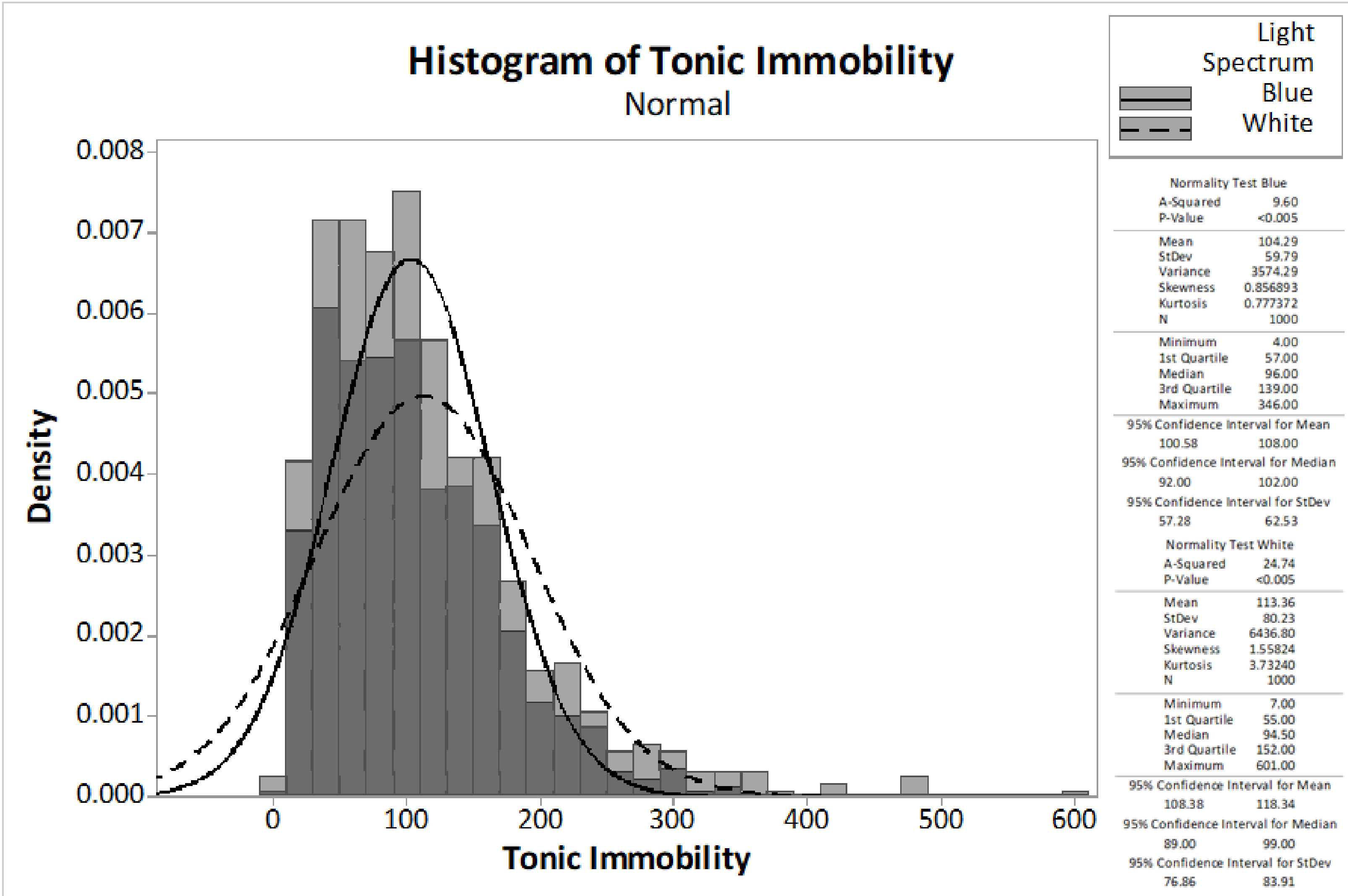



*Figure 4.5 Histogram of blue and white light distribution*

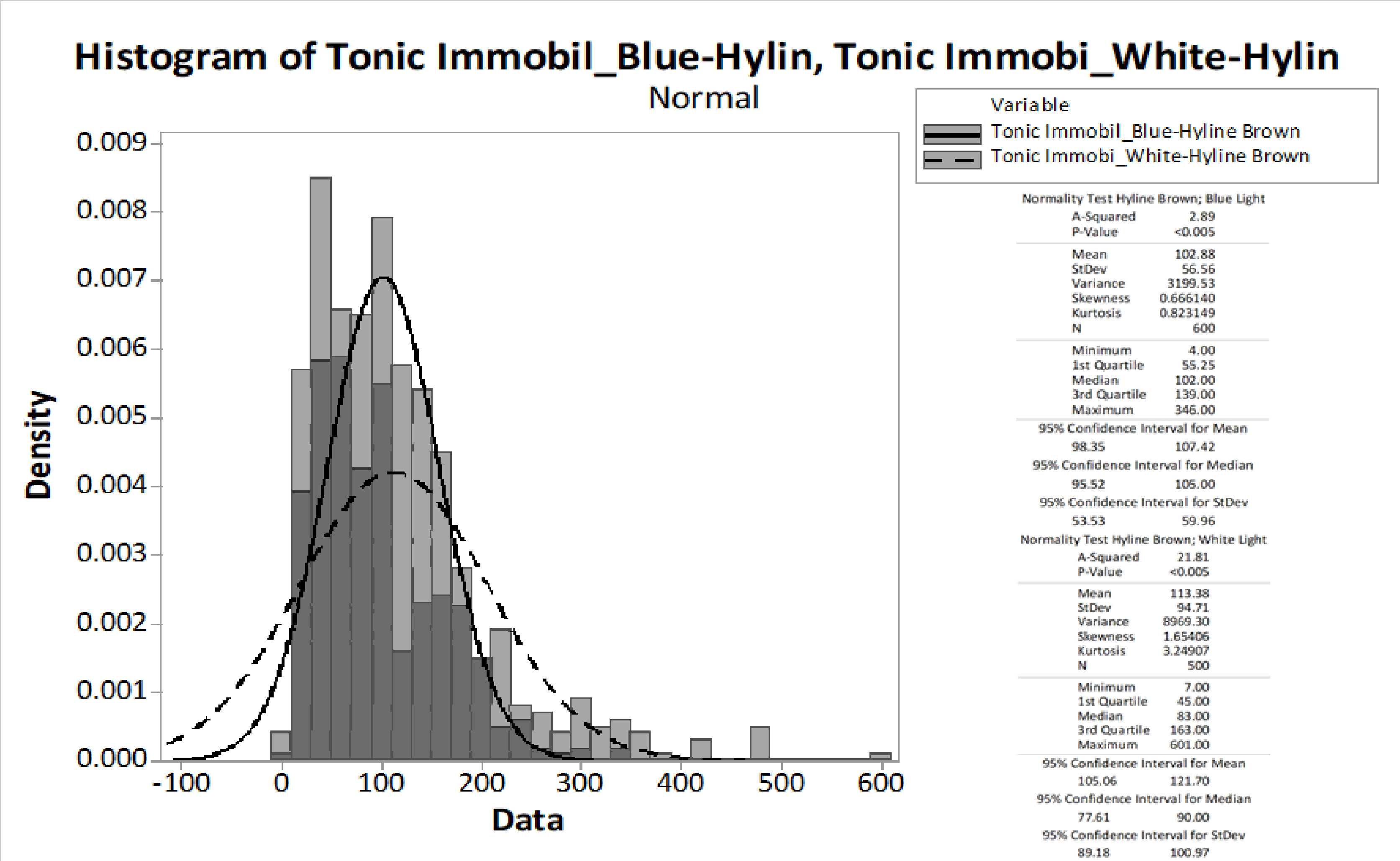



*Figure 4.6 Hy-Line Brown histogram for blue and white light distribution*

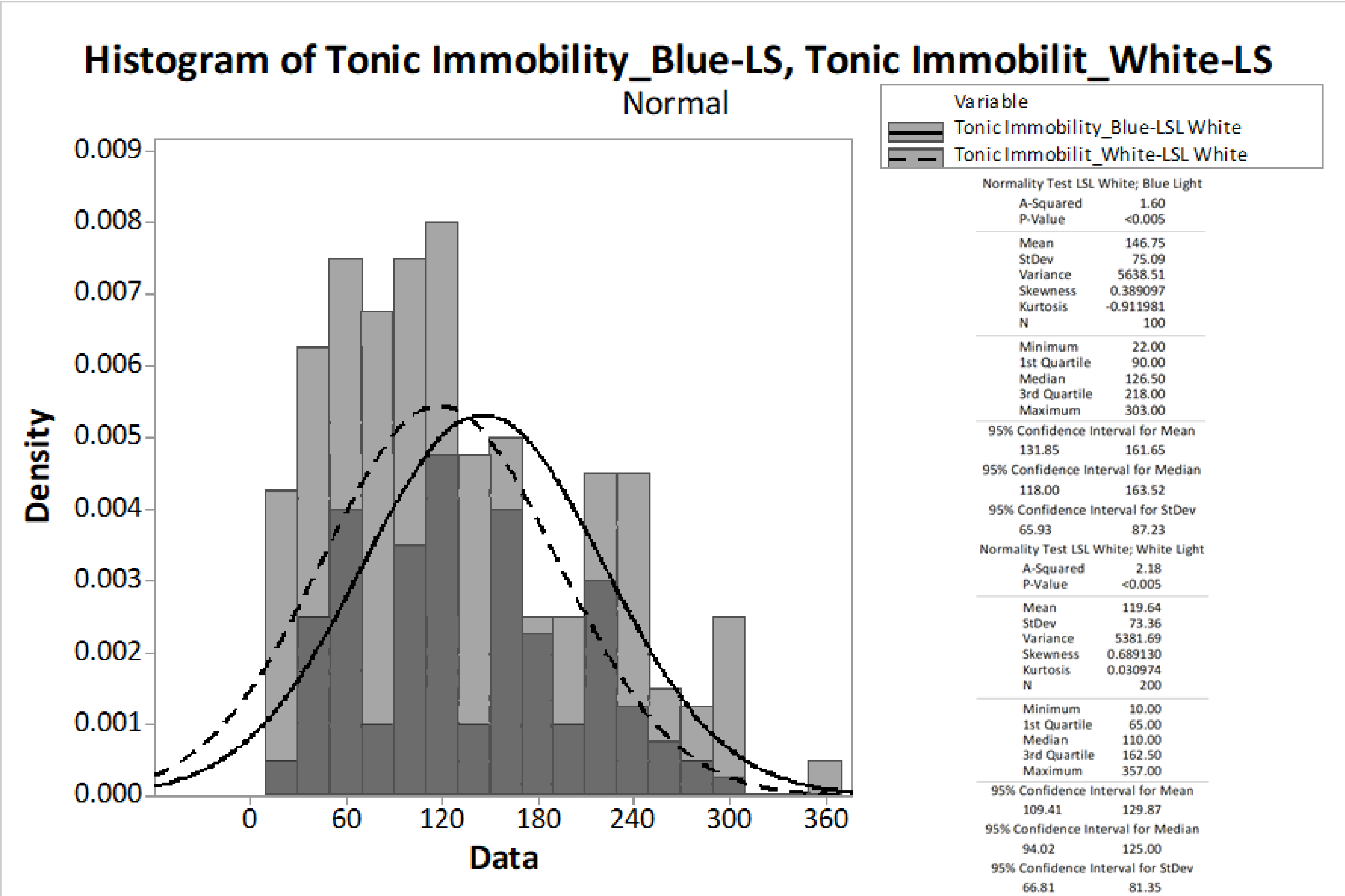



*Figure 4.7 LSL white hen histogram for blue and white light distribution*

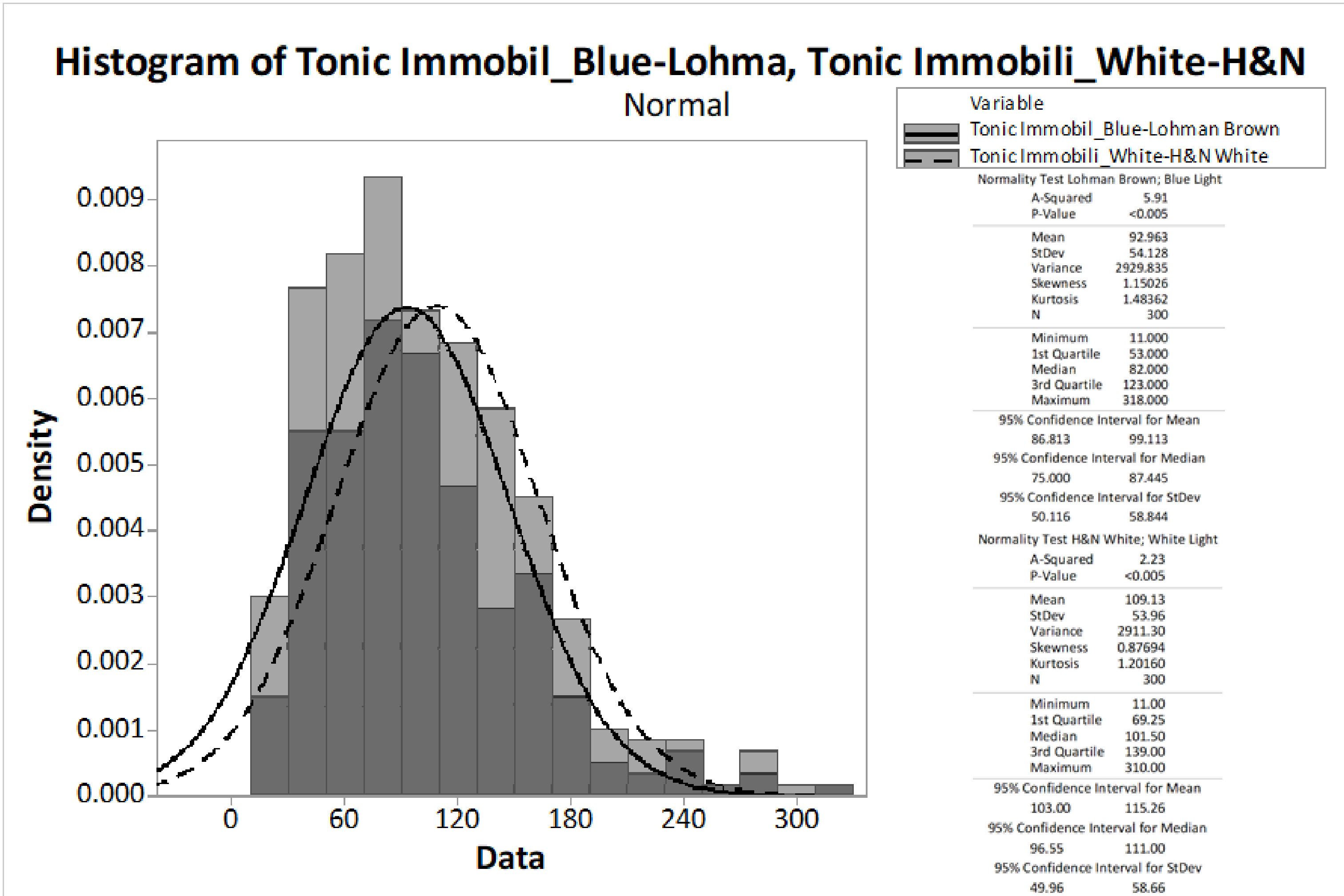



*Figure 4.8 Lohmann Brown vs H&N White histogram for blue and white light distribution*

# Chapter 5 Summary and conclusions

## 5.1 Review of purpose

A review of literature on the welfare of laying hens indicates a need for research conducted in commercial environment. Unique access to a large free-range egg company (Egg Innovations) presented an opportunity to contribute to the scientific community by performing all research in a commercial setting on multiple practical topics facing the free-range egg industry in the United States and possibly abroad. Egg Innovations is uniquely poised in the United States egg industry with over 55 farms that are virtually identical in construction and 100% of their facilities providing outside access for the hens. This commercial collaboration with academia provided a strong basis for the research in this dissertation, as well as the overall theme, which remains: Optimizing animal welfare in commercial laying hens through novel management practices and farm manager evaluation.

## 5.2 Review of Chapter 2

Chapter two research reviewed the impact of movable shade in a commercial free-range egg production setting. As more laying hens use range, an ensuing issue of range management evolves. Laying hens can be aggressive grazers. They may ingest some vegetation but more often destroy the vegetation on significant amounts of range if proper management is not exercised. One of the tools that has potential commercial value is being able to move the laying hens around on the range without significant human energy expended. The research documented that hens have strong propensity to utilize shade under a wide variety of environmental influences. Laying hens prefer shade regardless of time of day, temperature, seasonality, solar radiation and solar direction. The one parameter not following this trend was use of shade during precipitation. In both replications of the trial, when precipitation occurred there was not a strong preponderance to shade usage nor overall range use.

## 5.3 Review of Chapter 3

Chapter three researched the impact of human stockmanship on laying hen behavior. The research documented that a stockman's personality can have a significant influence on flock productivity. Equally important is once the personality profile of the stockperson is known accurate predictive tools can be utilized to project flock productivity. When select production traits were combined with select personality traits a regression model was produced that had an 81.85% accuracy of predicting flock performance. The research suggests that in addition to specific knowledge of poultry and the related sciences, the personality of the stockman should be factored into the equation of who is placed in charge of managing flocks of laying hens. While the research was conducted exclusively on free-range hens, there is no reason to assume a different result in other types of egg production housing.

## 5.4 Review of Chapter 4

Chapter 4 researched the influence of wavelength of light on TI of pullets. The three most stressful days of a laying hen's life under normal conditions are day one at hatch, the day the pullet is transferred to a layer barn, and removal/euthanization of the laying hen at end of life. On day one the female chick will typically receive a beak treatment, be vaccinated and ultimately transported to a pullet facility. The pullet move occurs when all pullets are individually handled, placed into crates or carts and transferred to a layer facility at ~ 16 weeks of age. The last event is when a flock is depopulated at the end of their productive life. It can be argued of these three days the pullet move day has the greatest influence on profitability of the flock for the remainder of its life. Most pullet moves occur using white light which is the combination of the full spectrum of visible light ranging from 400 nm -700 nm. Research has shown that blue light can have a calming effect on pullets. This trial failed to show consistently significant difference between moving pullets under white light or blue light when using ANOVA. Much of the data were non-parametric. When analyzed as non-parametric data there appears to be strain variation with how the various flocks were influenced by two spectra of light. Overall it appears since blue light is a component of white light there was no significant perception difference to the pullet between the two light spectra. Follow up research should be conducted with experimental design looking at strain influence and additional wavelengths of light.

## 5.5 Final summary and conclusions

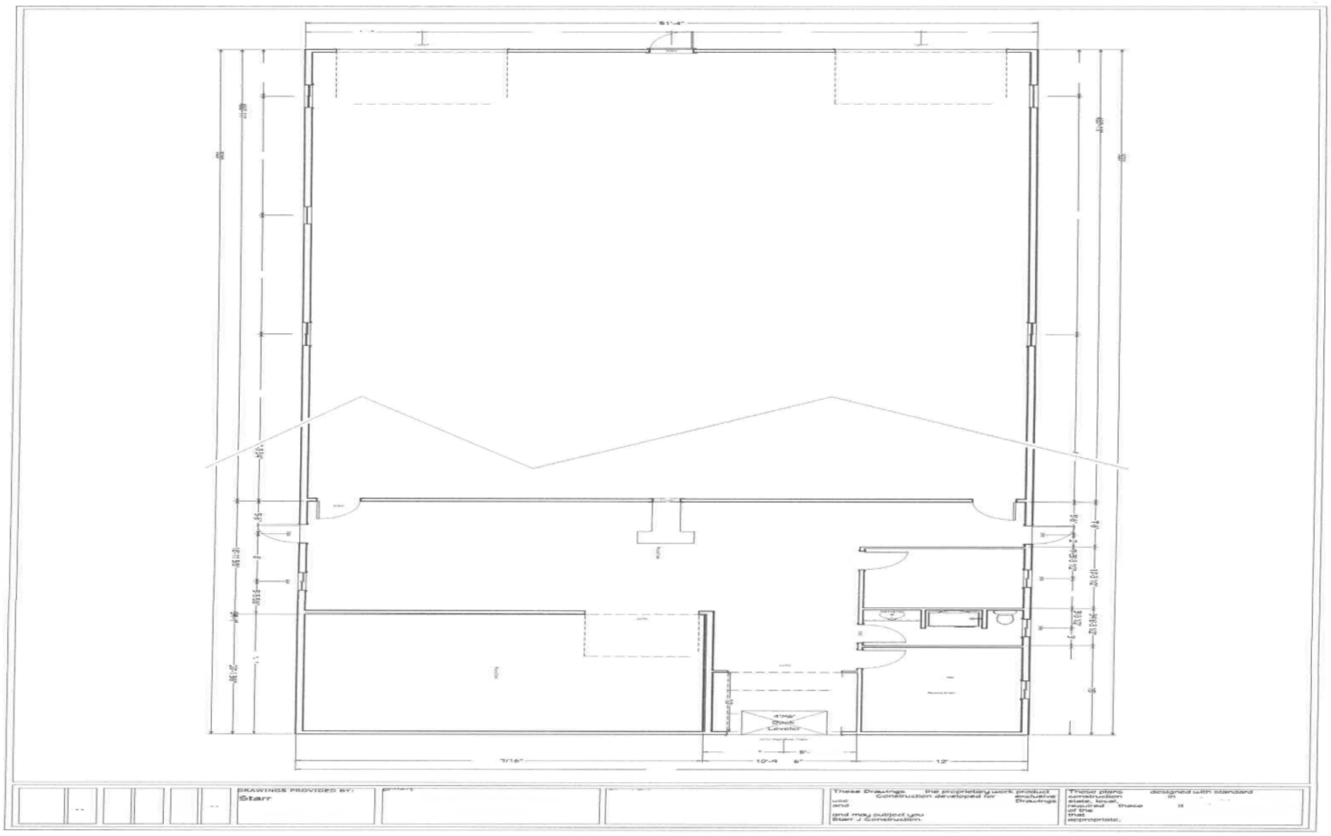
The overarching theme of the research was to look at animal welfare specifically in laying hens and specifically on commercial free-range egg farms. As free-range egg production expands in the United States, it is imperative that the human knowledge of managing these systems, as well as the temperament to manage such systems, continues to increase and be understood as important.

APPENDIXES

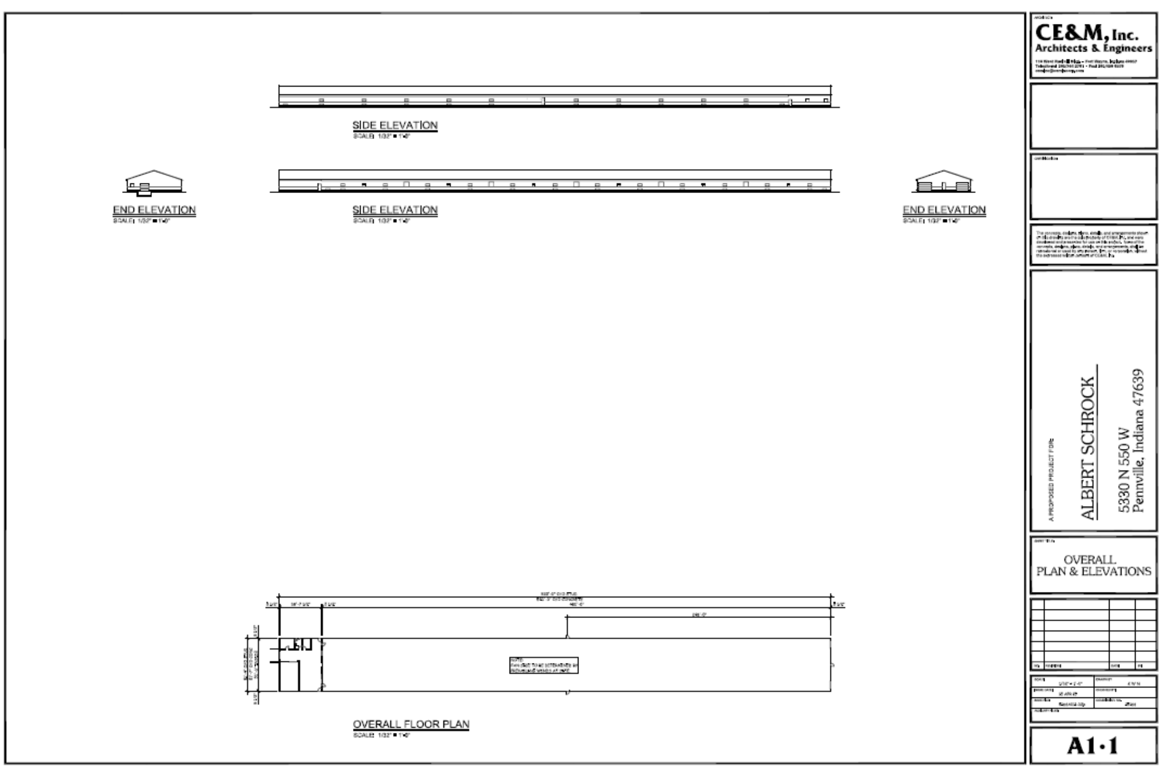
Appendix A – Egg Innovation Barn Schematics


Exterior of an Egg Innovations barn

*Interior of an Egg Innovations barn*



*Interior blue print of egg room*




*Exterior blueprint of barn*

Appendix B – Sample photos from Experiment 1


A shade sled

Non-treatment area that was alternated every two weeks

Treatment area that was alternated every two weeks


Photo taken in the early morning

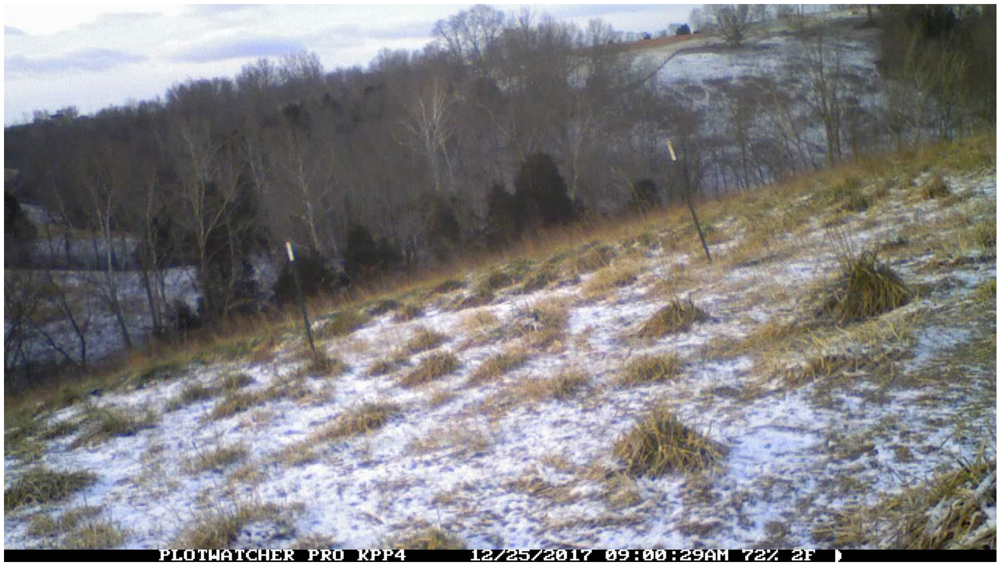


Photo taken at 2°F low temperature

Photo taken at 83°F high temperature

Photo taken with no precipitation

Photo taken with high rainfall

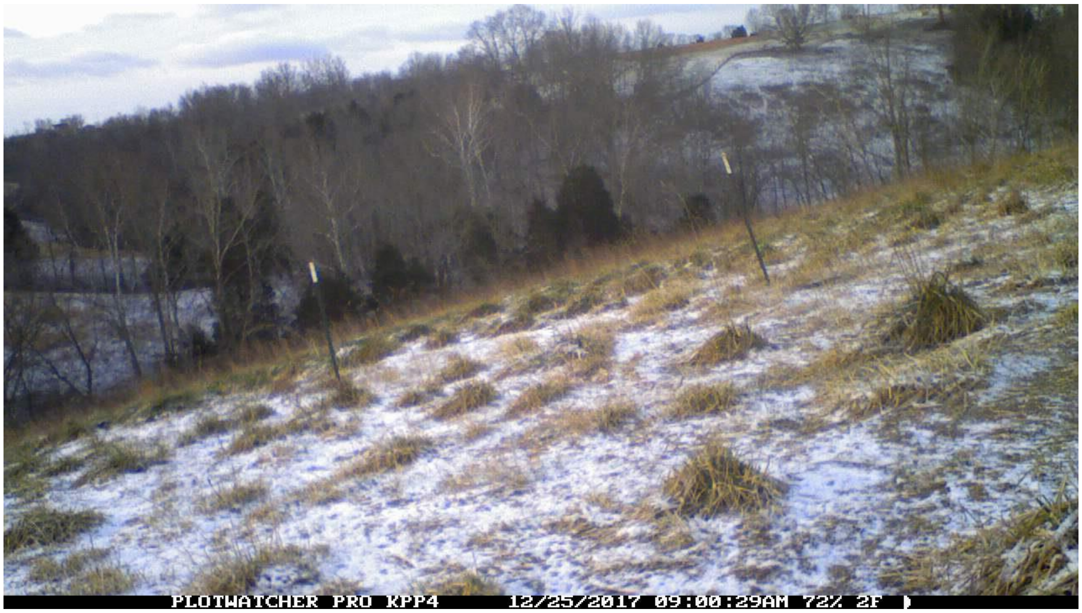


Photo taken with snow

Photo taken during low solar radiation

Photo taken during high solar radiation

Appendix C – Diets of Egg Innovations Laying Hens

| Seq # | Item | Type | LO Adj | Target Quantity | Units | Total % |
|---|---|---|---|---|---|---|
| 1 | Organic Corn | Ingredient | X | 1491.4200 | Pounds | 37.29% |
| 2 | Organic Wheat | Ingredient | | 1200.0000 | Pounds | 30.00% |
| 3 | Organic Soybean Roasted | Ingredient | | 440.0000 | Pounds | 11.00% |
| 4 | Organic Soybean Meal | Ingredient | X | 412.0000 | Pounds | 10.30% |
| 5 | Limestone - Course #8 | Ingredient | | 200.0000 | Pounds | 5.00% |
| 6 | Limestone - Fine #16 | Ingredient | | 168.0000 | Pounds | 4.20% |
| 7 | Monocalcium Phosphate | Ingredient | | 51.0000 | Pounds | 1.27% |
| 8 | Redmond Salt | Ingredient | | 16.3000 | Pounds | 0.41% |
| 9 | VMT Premix | Ingredient | | 4.0000 | Pounds | 0.10% |
| 10 | Methionine | Ingredient | | 3.8300 | Pounds | 0.10% |
| 11 | Rovabio AP 10% | Ingredient | | 2.0000 | Pounds | 0.05% |
| 12 | Choline | Ingredient | | 1.4500 | Pounds | 0.04% |
| 13 | Organic Oro Glo | Ingredient | | 6.0000 | Pounds | 0.15% |
| 14 | XPC Green | Ingredient | | 4.0000 | Pounds | 0.10% |

Organic "24" diet

| Seq # | Item | Type | LO Adj | Target Quantity | Units | Total % |
|---|---|---|---|---|---|---|
| 1 | VMT Premix | Ingredient | | 4.0000 | Pounds | 0.10% |
| 2 | NGMO Corn | Ingredient | X | 2450.6100 | Pounds | 61.27% |
| 3 | NGMO Roasted Soybeans | Ingredient | | 1082.2600 | Pounds | 27.06% |
| 4 | Limestone - Course #8 | Ingredient | | 200.0000 | Pounds | 5.00% |
| 5 | Limestone - Fine #16 | Ingredient | | 182.4800 | Pounds | 4.56% |
| 6 | Monocalcium Phosphate | Ingredient | | 55.8800 | Pounds | 1.40% |
| 7 | Mixing Salt | Ingredient | | 17.1600 | Pounds | 0.43% |
| 8 | Rovabio AP 10% | Ingredient | | 2.0000 | Pounds | 0.05% |
| 9 | Methionine | Ingredient | | 4.1600 | Pounds | 0.10% |
| 10 | Choline | Ingredient | | 1.4500 | Pounds | 0.04% |

NGMO "24" diet

.

| Code | Item | Weight | Pct |
|---|---|---|---|
| 26 | FINE ROLLED CORN BLK | 1227.10 | 61.36% |
| 1 | HI-PRO SOYBEAN MEAL BLK | 356.00 | 17.80% |
| 22 | DRY DISTILLERS GRAIN BLK | 140.00 | 7.00% |
| 13 | CALCIUM CARBONATE BLK | 90.00 | 4.50% |
| 890 | POULTRY CAL BITS BULK | 89.00 | 4.45% |
| 5 | WHEAT MIDDS BLK | 52.00 | 2.60% |
| 16 | MONOCALCIUM PHOSPHATE 21% BLK | 20.00 | 1.00% |
| 340 | SOY OIL MIXER | 10.00 | 0.50% |
| 11 | SALT BLK | 6.00 | 0.30% |
| 413 | LYSINE | 2.30 | 0.12% |
| 319 | METHIONINE 99% | 2.20 | 0.11% |
| 304 | S-CARB BLK | 2.00 | 0.10% |
| 165 | POULTRY TM PREMIX | 1.00 | 0.05% |
| 227 | POULTRY VIT PMX 2 50 LB | 1.00 | 0.05% |
| 418 | CHOLINE 70% DRY | 0.80 | 0.04% |
| 126 | HIPHOS GT (RONOZYME) 10000 | 0.40 | 0.02% |
| 906 | ECONASE XT | 0.20 | 0.01% |

Layer “22” diet

| Code | Item | Weight | Pct |
|---|---|---|---|
| 26 | FINE ROLLED CORN BLK | 1238.00 | 61.90% |
| 1 | HI-PRO SOYBEAN MEAL BLK | 329.00 | 16.45% |
| 22 | DRY DISTILLERS GRAIN BLK | 140.00 | 7.00% |
| 890 | POULTRY CAL BITS BULK | 93.00 | 4.65% |
| 13 | CALCIUM CARBONATE BLK | 90.00 | 4.50% |
| 5 | WHEAT MIDDS BLK | 68.00 | 3.40% |
| 16 | MONOCALCIUM PHOSPHATE 21% BLK | 17.00 | 0.85% |
| 340 | SOY OIL MIXER | 10.00 | 0.50% |
| 11 | SALT BLK | 6.00 | 0.30% |
| 305 | BICARB OF SODA (BULK) | 2.00 | 0.10% |
| 319 | METHIONINE 99% | 1.80 | 0.09% |
| 413 | LYSINE | 1.70 | 0.09% |
| 165 | POULTRY TM PREMIX | 1.00 | 0.05% |
| 227 | POULTRY VIT PMX 2 50 LB | 1.00 | 0.05% |
| 418 | CHOLINE 70% DRY | 0.90 | 0.05% |
| 126 | HIPHOS GT (RONOZYME) 10000 | 0.40 | 0.02% |
| 906 | ECONASE XT | 0.20 | 0.01% |

Layer “24” diet

| Code | Item | Weight | Pct |
|---|---|---|---|
| 26 | FINE ROLLED CORN BLK | 1263.00 | 63.91% |
| 1 | HI-PRO SOYBEAN MEAL BLK | 308.00 | 15.40% |
| 22 | DRY DISTILLERS GRAIN BLK | 140.00 | 7.00% |
| 890 | POULTRY CAL BITS BULK | 106.00 | 5.30% |
| 13 | CALCIUM CARBONATE BLK | 90.00 | 4.50% |
| 5 | WHEAT MIDDS BLK | 51.00 | 2.55% |
| 16 | MONOCALCIUM PHOSPHATE 21% BLK | 16.00 | 0.80% |
| 340 | SOY OIL MIXER | 10.00 | 0.50% |
| 11 | SALT BLK | 6.00 | 0.30% |
| 413 | LYSINE | 2.45 | 0.12% |
| 305 | S-CARB BLK | 2.00 | 0.10% |
| 319 | METHIONINE 99% | 1.15 | 0.06% |
| 418 | CHOLINE 70% DRY | 1.00 | 0.05% |
| 165 | POULTRY TM PREMIX | 1.00 | 0.05% |
| 227 | POULTRY VIT PMX 2 50 LB | 1.00 | 0.05% |
| 126 | HIPHOS GT (RONOZYME) 10000 | 0.40 | 0.02% |
| 906 | ECONASE XT | 0.20 | 0.01% |

Layer “26” diet

Appendix D – Chi Squares from Experiment 1

Fall 2017 Data

**Results for Camera = 1**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 151 | 3 | 154 |
| Y | 333 | 3 | 336 |
| All | 485 | 6 | 491 |

Cell Contents: Count

**Results for Camera = 2**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 278 | 63 | 341 |
| Y | 63 | 71 | 134 |
| All | 341 | 134 | 475 |

Cell Contents: Count

**Results for Camera = 3**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 301 | 58 | 359 |
| Y | 59 | 80 | 139 |
| All | 360 | 138 | 498 |

Cell Contents: Count

**Results for Camera = 4**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 338 | 44 | 382 |
| Y | 193 | 106 | 299 |
| All | 531 | 150 | 681 |

Cell Contents: Count

**Results for Camera = 5**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 25 | 10 | 35 |
| Y | 66 | 64 | 130 |
| All | 91 | 74 | 165 |

Cell Contents: Count

**Results for Camera = 6**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 24 | 10 | 34 |
| Y | 118 | 70 | 188 |
| All | 142 | 80 | 222 |

Cell Contents: Count

## Tabulated Statistics: Shade Present?, Birds Present?, Time

**Results for Time = 8**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 13 | 0 | 13 |
| Y | 37 | 2 | 39 |
| All | 50 | 2 | 52 |

Cell Contents: Count

**Results for Time = 9**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 136 | 2 | 138 |
| Y | 101 | 0 | 101 |
| All | 237 | 2 | 239 |

Cell Contents: Count

**Results for Time = 10**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 86 | 8 | 94 |
| Y | 67 | 2 | 69 |
| All | 154 | 10 | 164 |

Cell Contents: Count

**Results for Time = 11**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 76 | 21 | 97 |
| Y | 34 | 36 | 70 |
| All | 110 | 57 | 167 |

**Results for Time = 12**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 98 | 12 | 110 |
| Y | 51 | 31 | 82 |
| All | 149 | 43 | 192 |

Cell Contents: Count

**Results for Time = 13**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 115 | 13 | 128 |
| Y | 51 | 41 | 92 |
| All | 166 | 54 | 220 |

Cell Contents: Count

**Results for Time = 14**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 127 | 10 | 137 |
| Y | 69 | 40 | 109 |
| All | 196 | 50 | 246 |

Cell Contents: Count

**Results for Time = 15**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 130 | 22 | 152 |
| Y | 120 | 58 | 178 |
| All | 250 | 80 | 330 |

Cell Contents: Count

**Results for Time = 16**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 122 | 30 | 152 |
| Y | 121 | 61 | 182 |
| All | 243 | 91 | 334 |

Cell Contents: Count

**Results for Time = 17**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 134 | 31 | 165 |
| Y | 120 | 69 | 189 |
| All | 254 | 100 | 354 |

Cell Contents: Count

**Results for Time = 18**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 78 | 39 | 117 |
| Y | 61 | 54 | 115 |
| All | 139 | 93 | 232 |

Cell Contents: Count

**Results for Time = 19**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 2 | 0 | 2 |
| Y | 0 | 0 | 0 |
| All | 2 | 0 | 2 |

Cell Contents: Count

## Tabulated Statistics: Shade Present?, Birds Present?, Temp Blocks

**Results for Temp Blocks = 10**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 4 | 0 | 4 |
| Y | 2 | 0 | 2 |
| All | 6 | 0 | 6 |

Cell Contents: Count

**Results for Temp Blocks = 20**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 40 | 0 | 40 |
| Y | 20 | 0 | 20 |
| All | 60 | 0 | 60 |

Cell Contents: Count

### Results for Temp Blocks = 30

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 263 | 7 | 270 |
| Y | 209 | 15 | 224 |
| All | 472 | 22 | 494 |

Cell Contents: Count

### Results for Temp Blocks = 40

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 273 | 49 | 322 |
| Y | 225 | 107 | 332 |
| All | 499 | 156 | 655 |

Cell Contents: Count

### Results for Temp Blocks = 50

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 391 | 87 | 478 |
| Y | 256 | 166 | 422 |
| All | 647 | 253 | 900 |

Cell Contents: Count

### Results for Temp Blocks = 60

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 95 | 27 | 122 |
| Y | 108 | 83 | 191 |
| All | 203 | 110 | 313 |

Cell Contents: Count

### Results for Temp Blocks = 70

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 51 | 18 | 69 |
| Y | 12 | 23 | 35 |
| All | 63 | 41 | 104 |

Cell Contents: Count

## Tabulated Statistics: Shade Present?, Birds Present?, Precipitation Blocks

### Results for Precipitation Blocks = 0.00

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 981 | 150 | 1131 |
| Y | 745 | 363 | 1108 |
| All | 1727 | 513 | 2240 |

Cell Contents: Count

### Results for Precipitation Blocks = 0.10

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 12 | 1 | 13 |
| Y | 3 | 4 | 7 |
| All | 15 | 5 | 20 |

Cell Contents: Count

### Results for Precipitation Blocks = 0.20

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 10 | 3 | 13 |
| Y | 7 | 2 | 9 |
| All | 17 | 5 | 22 |

Cell Contents: Count

### Results for Precipitation Blocks = 0.30

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 1 | 0 | 1 |
| Y | 3 | 0 | 3 |
| All | 4 | 0 | 4 |

Cell Contents: Count

**Results for Precipitation Blocks = 0.40**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 4 | 0 | 4 |
| Y | 10 | 0 | 10 |
| All | 14 | 0 | 14 |

Cell Contents: Count

**Results for Precipitation Blocks = 0.50**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 28 | 12 | 40 |
| Y | 9 | 6 | 15 |
| All | 37 | 18 | 55 |

Cell Contents: Count

(No data for .60 precipitation)

**Results for Precipitation Blocks = 0.70**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 13 | 3 | 16 |
| Y | 18 | 2 | 20 |
| All | 31 | 5 | 36 |

Cell Contents: Count

**Results for Precipitation Blocks = 0.80**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 2 | 0 | 2 |
| Y | 4 | 0 | 4 |
| All | 6 | 0 | 6 |

Cell Contents: Count

**Results for Precipitation Blocks = 0.90**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 29 | 4 | 33 |
| Y | 5 | 5 | 10 |
| All | 34 | 9 | 43 |

Cell Contents: Count

**Results for Precipitation Blocks = 1.00**

Rows: Shade Present? Columns: Birds Present?

| | N | Y | All |
|---|---|---|---|
| N | 37 | 15 | 52 |
| Y | 28 | 12 | 40 |
| All | 65 | 27 | 92 |

Cell Contents: Count

## Tabulated Statistics: Shade Present?, Birds Present?, Solar Radiation Blocks

Rows: Shade Present?_0 Columns: Birds Present?_0

| | N | Y | All |
|---|---|---|---|
| N | 102 | 22 | 124 |
| | 91.71 | 32.29 | |
| Y | 94 | 47 | 141 |
| | 104.29 | 36.71 | |
| All | 196 | 69 | 265 |

*Cell Contents*
*Count*
*Expected count*

Rows: Shade Present?_10 Columns: Birds Present?_10

| | N | Y | All |
|---|---|---|---|
| N | 51 | 8 | 59 |
| | 50.17 | 8.83 | |
| Y | 57 | 11 | 68 |
| | 57.83 | 10.17 | |
| All | 108 | 19 | 127 |

*Cell Contents*
*Count*
*Expected count*

Rows: Shade Present?_20 Columns: Birds Present?_20

| | N | Y | All |
|---|---|---|---|
| N | 67 | 8 | 75 |
| | 63.10 | 11.90 | |
| Y | 55 | 15 | 70 |
| | 58.90 | 11.10 | |
| All | 122 | 23 | 145 |

*Cell Contents*
*Count*
*Expected count*

Rows: Shade Present?_30 Columns: Birds Present?_30

| | N | Y | All |
|---|---|---|---|
| N | 45 | 4 | 49 |
| | 42.693 | 6.307 | |
| Y | 43 | 9 | 52 |
| | 45.307 | 6.693 | |
| All | 88 | 13 | 101 |

*Cell Contents*
*Count*
*Expected count*

<u>Summer 2018 Data</u>

***Temperature***

Rows: Birds present?_50 Columns: Shade Present_50

| | N | Y | All |
|---|---|---|---|
| N | 8 | 8 | 16 |
| | 7.5294 | 8.4706 | |
| Y | 0 | 1 | 1 |
| | 0.4706 | 0.5294 | |
| All | 8 | 9 | 17 |

Rows: Birds present?_60 Columns: Shade Present_60

| | N | Y | All |
|---|---|---|---|
| N | 152 | 143 | 295 |
| | 136.67 | 158.33 | |
| Y | 12 | 47 | 59 |
| | 27.33 | 31.67 | |
| All | 164 | 190 | 354 |

Rows: Birds present?_70 Columns: Shade Present_70

| | N | Y | All |
|---|---|---|---|
| N | 430 | 460 | 890 |
| | 407.95 | 482.05 | |
| Y | 27 | 80 | 107 |
| | 49.05 | 57.95 | |
| All | 457 | 540 | 997 |

Rows: Birds present?_80 Columns: Shade Present_80

| | N | Y | All |
|---|---|---|---|
| N | 837 | 621 | 1458 |
| | 702.7 | 755.3 | |
| Y | 72 | 356 | 428 |
| | 206.3 | 221.7 | |
| All | 909 | 977 | 1886 |

Rows: Birds present?_90 Columns: Shade Present_90

| | N | Y | All |
|---|---|---|---|
| N | 233 | 175 | 408 |
| | 191.65 | 216.35 | |
| Y | 23 | 114 | 137 |
| | 64.35 | 72.65 | |
| All | 256 | 289 | 545 |

### *Cameras*

Rows: Birds present?_1 Columns: Shade Present_1

| | N | Y | All |
|---|---|---|---|
| N | 243 | 278 | 521 |
| | 222.84 | 298.16 | |
| Y | 44 | 106 | 150 |
| | 64.16 | 85.84 | |
| All | 287 | 384 | 671 |

Rows: Birds present?_2 Columns: Shade Present_2

| | N | Y | All |
|---|---|---|---|
| N | 156 | 168 | 324 |
| | 115.6 | 208.4 | |
| Y | 17 | 144 | 161 |
| | 57.4 | 103.6 | |
| All | 173 | 312 | 485 |

Rows: Birds present?_3 Columns: Shade Present_3

| | N | Y | All |
|---|---|---|---|
| N | 264 | 271 | 535 |
| | 238.07 | 296.93 | |
| Y | 11 | 72 | 83 |
| | 36.93 | 46.07 | |
| All | 275 | 343 | 618 |

Rows: Birds present?_4 Columns: Shade Present_4

| | N | Y | All |
|---|---|---|---|
| N | 343 | 251 | 594 |
| | 340.27 | 253.73 | |
| Y | 3 | 7 | 10 |
| | 5.73 | 4.27 | |
| All | 346 | 258 | 604 |

Rows: Birds present?_5 Columns: Shade Present_5

| | N | Y | All |
|---|---|---|---|
| N | 296 | 234 | 530 |
| | 237.8 | 292.2 | |
| Y | 32 | 169 | 201 |
| | 90.2 | 110.8 | |
| All | 328 | 403 | 731 |

Rows: Birds present?_6 Columns: Shade Present_6

| | N | Y | All |
|---|---|---|---|
| N | 358 | 205 | 563 |
| | 314.14 | 248.86 | |
| Y | 27 | 100 | 127 |
| | 70.86 | 56.14 | |
| All | 385 | 305 | 690 |

### *Time*

Rows: Birds present?_9 Columns: Shade Present_9

| | N | Y | All |
|---|---|---|---|
| N | 168 | 182 | 350 |
| | 165.22 | 184.78 | |
| Y | 1 | 7 | 8 |
| | 3.78 | 4.22 | |
| All | 169 | 189 | 358 |

Rows: Birds present?_10 Columns: Shade Present_10

| | N | Y | All |
|---|---|---|---|
| N | 159 | 172 | 331 |
| | 151.98 | 179.02 | |
| Y | 4 | 20 | 24 |
| | 11.02 | 12.98 | |
| All | 163 | 192 | 355 |

Rows: Birds present?_11 Columns: Shade Present_11

| | N | Y | All |
|---|---|---|---|
| N | 163 | 148 | 311 |
| | 145.54 | 165.46 | |
| Y | 5 | 43 | 48 |
| | 22.46 | 25.54 | |
| All | 168 | 191 | 359 |

Rows: Birds present?_12 Columns: Shade Present_12

| | N | Y | All |
|---|---|---|---|
| N | 163 | 160 | 323 |
| | 152.76 | 170.24 | |
| Y | 3 | 25 | 28 |
| | 13.24 | 14.76 | |
| All | 166 | 185 | 351 |

Rows: Birds present?_13 Columns: Shade Present_13

| | N | Y | All |
|---|---|---|---|
| N | 165 | 135 | 300 |
| | 140.68 | 159.32 | |
| Y | 1 | 53 | 54 |
| | 25.32 | 28.68 | |
| All | 166 | 188 | 354 |

Rows: Birds present?_14 Columns: Shade Present_14

| | N | Y | All |
|---|---|---|---|
| N | 160 | 144 | 304 |
| | 143.46 | 160.54 | |
| Y | 8 | 44 | 52 |
| | 24.54 | 27.46 | |
| All | 168 | 188 | 356 |

Rows: Birds present?_15 Columns: Shade Present_15

| | N | Y | All |
|---|---|---|---|
| N | 159 | 123 | 282 |
| | 132.90 | 149.10 | |
| Y | 5 | 61 | 66 |
| | 31.10 | 34.90 | |
| All | 164 | 184 | 348 |

Rows: Birds present?_16 Columns: Shade Present_16

| | N | Y | All |
|---|---|---|---|
| N | 156 | 123 | 279 |
| | 131.01 | 147.99 | |
| Y | 6 | 60 | 66 |
| | 30.99 | 35.01 | |
| All | 162 | 183 | 345 |

Rows: Birds present?_17 Columns: Shade Present_17

| | N | Y | All |
|---|---|---|---|
| N | 140 | 86 | 226 |
| | 107.40 | 118.60 | |
| Y | 23 | 94 | 117 |
| | 55.60 | 61.40 | |
| All | 163 | 180 | 343 |

Rows: Birds present?_18 Columns: Shade Present_18

| | N | Y | All |
|---|---|---|---|
| N | 108 | 62 | 170 |
| | 81.51 | 88.49 | |
| Y | 44 | 103 | 147 |
| | 70.49 | 76.51 | |
| All | 152 | 165 | 317 |

Rows: Birds present?_19 Columns: Shade Present_19

| | N | Y | All |
|---|---|---|---|
| N | 90 | 54 | 144 |
| | 69.17 | 74.83 | |
| Y | 32 | 78 | 110 |
| | 52.83 | 57.17 | |
| All | 122 | 132 | 254 |

Rows: Birds present?_20 Columns: Shade Present_20

| | N | Y | All |
|---|---|---|---|
| N | 29 | 18 | 47 |
| | 24.695 | 22.305 | |
| Y | 2 | 10 | 12 |
| | 6.305 | 5.695 | |
| All | 31 | 28 | 59 |

***Precipitation***

Rows: Birds present?_0.0 Columns: Shade Present_0.0

| | N | Y | All |
|---|---|---|---|
| N | 1394 | 1138 | 2532 |
| | 1209.7 | 1322.3 | |
| Y | 110 | 506 | 616 |
| | 294.3 | 321.7 | |
| All | 1504 | 1644 | 3148 |

Rows: Birds present?_0.1 Columns: Shade Present_0.1

| | N | Y | All |
|---|---|---|---|
| N | 81 | 78 | 159 |
| | 73.12 | 85.88 | |
| Y | 5 | 23 | 28 |
| | 12.88 | 15.12 | |
| All | 86 | 101 | 187 |

Rows: Birds present?_0.2 Columns: Shade Present_0.2

| | N | Y | All |
|---|---|---|---|
| N | 31 | 26 | 57 |
| | 28.500 | 28.500 | |
| Y | 5 | 10 | 15 |
| | 7.500 | 7.500 | |
| All | 36 | 36 | 72 |

Rows: Birds present?_0.3 Columns: Shade Present_0.3

| | N | Y | All |
|---|---|---|---|
| N | 58 | 61 | 119 |
| | 49.72 | 69.28 | |
| Y | 3 | 24 | 27 |
| | 11.28 | 15.72 | |
| All | 61 | 85 | 146 |

Rows: Birds present?_0.4 Columns: Shade Present_0.4

| | N | Y | All |
|---|---|---|---|
| N | 12 | 10 | 22 |
| | 9.862 | 12.138 | |
| Y | 1 | 6 | 7 |
| | 3.138 | 3.862 | |
| All | 13 | 16 | 29 |

(No data for 0.5 precipitation)

Rows: Birds present?_0.6 Columns: Shade Present_0.6

| | N | Y | All |
|---|---|---|---|
| N | 17 | 20 | 37 |
| | 16.553 | 20.447 | |
| Y | 0 | 1 | 1 |
| | 0.447 | 0.553 | |
| All | 17 | 21 | 38 |

(No data for 0.7 precipitation)

Rows: Birds present?_0.8 Columns: Shade Present_0.8

| | N | Y | All |
|---|---|---|---|
| N | 19 | 17 | 36 |
| | 16.941 | 19.059 | |
| Y | 5 | 10 | 15 |
| | 7.059 | 7.941 | |
| All | 24 | 27 | 51 |

Rows: Birds present?_0.9 Columns: Shade Present_0.9

| | N | Y | All |
|---|---|---|---|
| N | 14 | 20 | 34 |
| | 12.490 | 21.510 | |
| Y | 4 | 11 | 15 |
| | 5.510 | 9.490 | |
| All | 18 | 31 | 49 |

Rows: Birds present?_1.0 Columns: Shade Present_1.0

| | N | Y | All |
|---|---|---|---|
| N | 4 | 6 | 10 |
| | 3.6364 | 6.3636 | |
| Y | 0 | 1 | 1 |
| | 0.3636 | 0.6364 | |
| All | 4 | 7 | 11 |

Rows: Birds present?_1.5 Columns: Shade Present_1.5

| | N | Y | All |
|---|---|---|---|
| N | 1 | 5 | 6 |
| | 1.500 | 4.500 | |
| Y | 1 | 1 | 2 |
| | 0.500 | 1.500 | |
| All | 2 | 6 | 8 |

Rows: Birds present?_2.1 Columns: Shade Present_2.1

| | N | Y | All |
|---|---|---|---|
| N | 17 | 11 | 28 |
| | 14.424 | 13.576 | |
| Y | 0 | 5 | 5 |
| | 2.576 | 2.424 | |
| All | 17 | 16 | 33 |

***Solar Radiation***

Rows: Birds present?_0 Columns: Shade Present_0

| | N | Y | All |
|---|---|---|---|
| N | 84 | 76 | 160 |
| | 79.20 | 80.80 | |
| Y | 15 | 25 | 40 |
| | 19.80 | 20.20 | |
| All | 99 | 101 | 200 |

Rows: Birds present?_100 Columns: Shade Present_100

| | N | Y | All |
|---|---|---|---|
| N | 238 | 195 | 433 |
| | 203.54 | 229.46 | |
| Y | 29 | 106 | 135 |
| | 63.46 | 71.54 | |
| All | 267 | 301 | 568 |

Rows: Birds present?_200 Columns: Shade Present_200

| | N | Y | All |
|---|---|---|---|
| N | 278 | 236 | 514 |
| | 244.47 | 269.53 | |
| Y | 44 | 119 | 163 |
| | 77.53 | 85.47 | |
| All | 322 | 355 | 677 |

Rows: Birds present?_300 Columns: Shade Present_300

| | N | Y | All |
|---|---|---|---|
| N | 225 | 189 | 414 |
| | 191.64 | 222.36 | |
| Y | 12 | 86 | 98 |
| | 45.36 | 52.64 | |
| All | 237 | 275 | 512 |

Rows: Birds present?_400 Columns: Shade Present_400

| | N | Y | All |
|---|---|---|---|
| N | 159 | 134 | 293 |
| | 133.94 | 159.06 | |
| Y | 17 | 75 | 92 |
| | 42.06 | 49.94 | |
| All | 176 | 209 | 385 |

Rows: Birds present?_600 Columns: Shade Present_600

| | N | Y | All |
|---|---|---|---|
| N | 164 | 137 | 301 |
| | 144.14 | 156.86 | |
| Y | 6 | 48 | 54 |
| | 25.86 | 28.14 | |
| All | 170 | 185 | 355 |

Rows: Birds present?_800 Columns: Shade Present_800

| | N | Y | All |
|---|---|---|---|
| N | 106 | 94 | 200 |
| | 93.39 | 106.61 | |
| Y | 0 | 27 | 27 |
| | 12.61 | 14.39 | |
| All | 106 | 121 | 227 |

Rows: Birds present?_1000 Columns: Shade Present_1000

| | N | Y | All |
|---|---|---|---|
| N | 37 | 28 | 65 |
| | 31.645 | 33.355 | |
| Y | 0 | 11 | 11 |
| | 5.355 | 5.645 | |
| All | 37 | 39 | 76 |

Rows: Birds present?_500 Columns: Shade Present_500

| | N | Y | All |
|---|---|---|---|
| N | 145 | 124 | 269 |
| | 127.90 | 141.10 | |
| Y | 10 | 47 | 57 |
| | 27.10 | 29.90 | |
| All | 155 | 171 | 326 |

Rows: Birds present?_700 Columns: Shade Present_700

| | N | Y | All |
|---|---|---|---|
| N | 140 | 128 | 268 |
| | 127.23 | 140.77 | |
| Y | 1 | 28 | 29 |
| | 13.77 | 15.23 | |
| All | 141 | 156 | 297 |

Rows: Birds present?_900 Columns: Shade Present_900

| | N | Y | All |
|---|---|---|---|
| N | 75 | 57 | 132 |
| | 63.87 | 68.13 | |
| Y | 0 | 23 | 23 |
| | 11.13 | 11.87 | |
| All | 75 | 80 | 155 |

Rows: Birds present?_1100 Columns: Shade Present_1100

| | N | Y | All |
|---|---|---|---|
| N | 9 | 9 | 18 |
| | 7.714 | 10.286 | |
| Y | 0 | 3 | 3 |
| | 1.286 | 1.714 | |
| All | 9 | 12 | 21 |

Appendix E – OAD Survey Samples from Experiment 2

## SECTION ONE

Please read down the columns and check those words which you believe

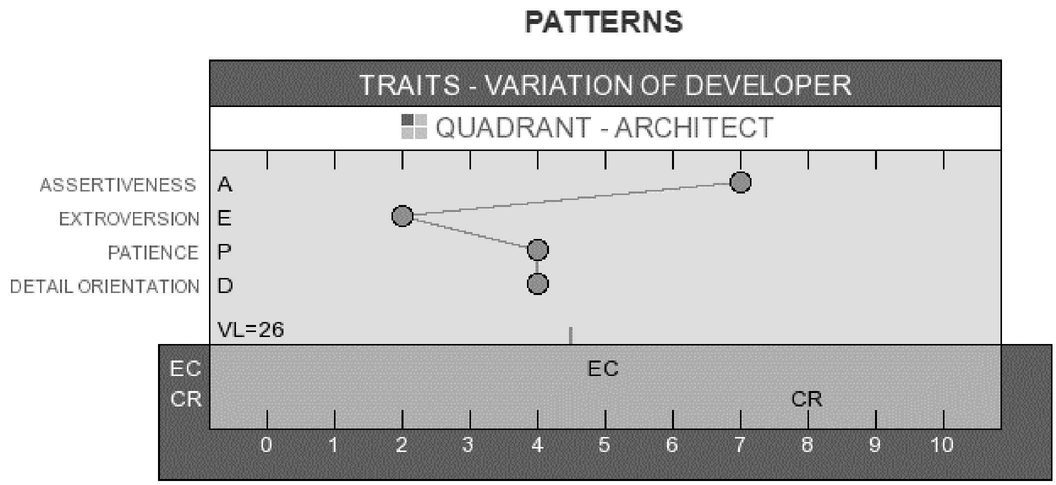
describe yourself.

Place a question mark before any word where you are uncertain of the meaning.

| | | | |
|---|---|---|---|
| ☐ Self-assured | ☐ Individualistic | ☐ Strong-willed | ☐ Venturesome |
| ☐ Friendly | ☐ Good-mixer | ☐ Cheerful | ☐ Witty |
| ☐ Easygoing | ☐ Retiring | ☐ Peaceful | ☐ Composed |
| ☐ Skilled | ☐ Cautious | ☐ Loyal | ☐ Controlled |
| ☐ Dissatisfied | ☐ Emotional | ☐ Appreciative | ☐ Fearful |
| ☐ Ingenious | ☐ Clever | ☐ Original | ☐ Inventive |
| ☐ Decisive | ☐ Opportunistic | ☐ Influential | ☐ Confrontive |
| ☐ Enthusiastic | ☐ Likable | ☐ Playful | ☐ Fashionable |
| ☐ Content | ☐ Accepting | ☐ Calm | ☐ Moderate |
| ☐ Accurate | ☐ Organized | ☐ Precise | ☐ Exacting |
| ☐ Trusting | ☐ Meek | ☐ Nervous | ☐ Immature |
| ☐ Creative | ☐ Imaginative | ☐ Innovative | ☐ Humorous |
| ☐ Determined | ☐ Self-Confident | ☐ Ambitious | ☐ Resourceful |
| ☐ Outgoing | ☐ Supportive | ☐ Talkative | ☐ Popular |
| ☐ Patient | ☐ Mild | ☐ Unhurried | ☐ Deliberate |
| ☐ Efficient | ☐ Meticulous | ☐ Worrying | ☐ Respectful |
| ☐ Egotistical | ☐ Suggestible | ☐ Moody | ☐ Impulsive |
| ☐ Reflective | ☐ Inqusitive | ☐ Analytical | ☐ Mischievous |
| ☐ Self-reliant | ☐ Daring | ☐ Demanding | ☐ Strict |
| ☐ Attractive | ☐ Sociable | ☐ Animated | ☐ Gregarious |
| ☐ Relaxed | ☐ Passive | ☐ Awkward | ☐ Methodical |
| ☐ Conscientious | ☐ Thorough | ☐ Fussy | ☐ Conservative |
| ☐ Confused | ☐ Absent-minded | ☐ Distractible | ☐ Anxious |
| ☐ Perceptive | ☐ Bright | ☐ Broad-minded | ☐ Knowledgeable |
| ☐ Casual | ☐ Tranquil | ☐ Apathetic | ☐ Indifferent |
| ☐ Punctual | ☐ Wary | ☐ Disciplined | ☐ Thrifty |
| ☐ Unconventional | ☐ Obedient | ☐ Painstaking | ☐ Modest |
| | ☐ Pessimistic | ☐ Sensitive | |

END OF SECTION ONE

Survey given to stockpeople




*Profile of Author – John Brunnquell*

SUMMARY

Analytical - technically oriented – aloof
Impatient - quick to respond to pressure - likes variety and change
Assertive and self-confident - comfortable with risk - delegates most details and follow-through
Perceives the need to be more deferential toward others and/or the job demands
Perceives the need to be more patient and systematic with work activities
Perceives the need to be even more flexible or delegative with assignments or with others

WORK ENVIRONMENT NEEDS

Authority and independence in the work environment
The opportunity to express own opinions
To be able to delegate detail or follow-up work
A work environment that is more technical in nature - analyzing, quantifying, designing, manufacturing, et al
A work environment where there is a blend of scheduled tasks and some variety and change

MOTIVATING NEEDS

Recognition for instituting or participating in change

Making difficult decisions and taking responsibility for them

Recognition for technical expertise and accomplishments rather than for selling or other "social"

activities

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VITA

John Brunnquell was born and raised in Port Washington, WI on the family homestead. He was active in 4-H and multiple High School activities graduating from Port Washington High School in 1981. John graduated with high honors and enrolled at the University of Wisconsin-Madison for an undergraduate degree in Agronomy with a minor in Poultry Science. He graduated in 1985 with his undergraduate degree. He then returned home to family farm operation and assumed management of the small 7000 hen laying flock the family owned. Having a desire to create a value-added egg John focused on cholesterol reduction of shell eggs early in his career. This pursuit brought him back to the University of Wisconsin-Madison for a master's degree in Poultry Science with a focus on nutrient manipulation of shell eggs. He studied under Dr. Art Mauer and received his master's degree in 1995.

This research led to two patents being awarded to John. One for cholesterol reduction in shell eggs and second patent for fat reduction of shell eggs. He assigned the patents to the Wisconsin Alumni Research Foundation (WARF) and licensed back the technology. John and is wife Cathy were selected as the Outstanding Young farmers in the United States by both the American Farm Bureau Federation and the National Jaycees organization. John founded Egg Innovations in 1999 and has led that organization to a national presence serving on numerous industry boards and committees. John has been recognized numerous times for his volunteer work including being inducted into the Wisconsin 4-H Hall of Fame and being named an Outstanding Alumni of the University of Wisconsin. John has served as past President of the Wisconsin Agriculture Alumni Association, The Wisconsin 4-H Foundation and Organic Egg Farmers of America.

As a non-traditional student John enrolled for Ph.D. in Poultry Science, studying under Dr. Anthony Pescatore, at the young age of 53. The focus of the research is avian ethology and behavior.