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Determination of best practice range enrichment to improve layer bird welfare.
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Executive Summary

Free range layer farms can have issues with behavioural problems such as severe feather pecking. This can lead to plumage damage and cannibalism and are considered a multi-factorial problem. In a time of changing public expectation regarding acceptable farming practices, procedures such as beak-trimming are unlikely to be allowed in the future based on welfare considerations. Therefore, further research into the management of free range laying hens and use of the range and range enrichments is essential. Opportunities to encourage birds to use of the range, and understanding the complexity of the non-cage systems in Australia, as well as the importance of key resources for hens such as overhead cover, enrichment sources, foraging and dust bathing substrates and pecking “toys” are aspects that should be considered in assessing welfare, production and health of birds within non-cage systems. It appears that only few of these issues have been addressed specifically and individually under Australia’s environmental conditions. Therefore there is potential to improve the ranging ability of birds in free range systems by improving the attractiveness of the range, and full utilisation of the range through encouraging investigation. Welfare of the birds will remain a major issue for consumers if birds are not encouraged to range, or use the range ineffectively, as well as exhibiting abnormal behaviours, such as severe feather pecking.

This project focused on levels of range enrichment to determine best practice enrichment for free range layer systems, to encourage more birds onto the range, more often throughout the day. Additionally, the research investigated practical innovations to reduce the occurrence of aggression, severe feather pecking behaviour and subsequently plumage damage, and predisposition for cannibalism in free range laying hens. Research was conducted in two components on commercial free range farms in South Australia and Victoria. Component 1 examined outdoor enrichment and was conducted by SARDI. Component 2 investigated the use of peck stones and their impact on hen performance and welfare. This component was overseen by UNE.

Component 1: Trials were run on three fixed, free range commercial layer farms in South Australia and involved four flocks. Two strategies for enrichment of the range were compared; a ‘standard’ control treatment, typical of the type of range used in the commercial industry and a ‘highly’ enriched treatment which incorporated shade cloth shelters, alongside a continuum of additional enrichment structures (e.g. artificial structures, dust baths and pecking stones etc.). The effect on feather plumage, body condition and ranging behaviours was evaluated until depopulation of each flock. The range treatments were investigated to determine the effects on motivating hens to use the range more effectively, and potentially lead to a decrease in abnormal behaviours, such as severe feather pecking and cannibalism.

Farms were visited monthly. At each visit several measures were recorded; the numbers of hens out on the range, location of hens on the range, plumage score of birds outdoors and indoors, hen live-weights and video footage of hens utilising enrichment structures on the range.

A variety and continuum of enrichment structures attracted more hens onto the range. Constructed shelters catered for the hens’ need for security and overhead protection from predators and gave them a place to dust bathe and rest. Although natural cover provided by trees had attracted the greatest number of hens. As prey animals the hens sought cover from trees and shelters and this was especially strong when they felt threatened, such as when a hawk, crows or low flying aircraft flew over-head. Heavy rain also resulted in hens retreating to shelters and then making their way back to the main shed. Hay bales were also highly utilised, even though the hen numbers attracted to them was not as high as shelters. The hay bales provided hens with the opportunity to forage by scratching and pecking. This was especially important on the fixed range farms stocked at 10,000 birds/ha as the hay bales provided a valuable foraging substrate when the range had been denuded of vegetative

ground cover. Provision of dust bathing areas was achieved simply by depositing sand directly onto the range as demonstrated on one farm in the study, it also had shown that sand pits don't need to be elaborate structures. The orange coloured attractants such as the traffic cones have the capacity to attract many hens and can be used in conjunction with other structures. Peck stones placed outdoors on the range had some utilisation, but traffic cones were observed to be more effective in attracting and occupying hens. Prevailing weather conditions and the age of the flock were strong influences on the number of hens found outdoors.

Hens on the range had significantly better plumage condition with less damage and feather loss than hens in the shed. Most of the feather damage and bare skin occurred on the neck and around the preen gland at the base of the tail. As the flocks matured the feather loss was appearing on the wing and tail.

In conclusion, more hens used the enriched side of the range and overhead cover was instrumental in enticing birds out on the range. Furthermore, hens outside on the range had better plumage with less feather loss and bare skin than those birds in the shed.

<u>Component 2:</u> The aim of this research was to investigate the effects of pecking stones, housing system and flock age on plumage condition and health parameters of free range laying hens. In total 18 flocks housed in 18 sheds (fixed sheds n=10; mobile sheds n=8) located on two commercial farms were investigated. Both farms housed Hy-line brown laying hens at different flock sizes: 19,500 hens / each fixed shed, 2,500 hens / each mobile sheds). Hens from the control flocks (n=9) were housed under the same conditions without pecking stones, whilst treatment flocks (n=9) were provided one pecking stone / 1,000 hens every ten weeks. All 18 flocks were investigated from the time of placement (16 weeks) in 10 week intervals until the end of lay (66 weeks). For each flock and time point, 50 hens per flock were randomly selected and individually evaluated for body weight, beak length and scored for feather condition. Plumage condition of individual hens was evaluated on a scale from 1 (no feathers) to 4 (full feather coverage) (Tauson et al., 2005). At each time point flock performance data (body weight, feed intake, egg production, egg weight, and cumulative mortality) were obtained. At each time point 10 hens were randomly selected and individually confined for 24 hours with 250 g feed and ad libitum water available. After 24 hours, hens were released and the left over feed was collected for investigation of particle size distribution (dMEAN) and Weende analysis.

Hens on fixed sheds significantly ($p<0.05$) produced more eggs (74.2%) with less mortality (4.49%) as compared to hens on mobile sheds (64.4% egg production and 5.63% mortality). Feather scores of the back and tail were higher ($p<0.05$) in fixed sheds (3.52 ±0.08, 3.49 ±0.09) compared to mobile sheds (3.13 ±0.16, 3.24 ±0.15). Feather scores of the neck and breast were lower ($p<0.05$) in fixed sheds (3.57 ±0.09, 2.70 ±0.15) compared to mobile sheds (3.89 ±0.02, 3.25 ±0.03). While feather score worsened from 16 to 66 weeks of age ($p<0.05$), there were no effects of pecking stones ($p>0.05$) on any parameters investigated. Significant ($p<0.05$) interactions between farm and time points were observed in feather scoring on all body parts. Cumulative mortality was significantly higher in mobile sheds (5.63 ±1.20 %) compared to fixed sheds (4.49 ±0.51 %). The farm type had also a significant effect ($p<0.05$) on beak length and feed intake: hens housed in mobile sheds had longer beaks and higher feed intake (16.0 mm; 116 g/hen/day) compared to hens housed in fixed sheds (13.9 mm; 106 g/hen/day). Subsequently, hens on both farms exhibited a statistically significantly different behaviour in feed particle selection and nutrient intake ($p<0.05$). Hens housed in mobile sheds were offered a feed with dMEAN of (1.68 mm) and selected fine particles resulting in left over feed with a higher dMEAN (1.74 mm), while hens housed in fixed sheds were offered feed with a dMEAN of 2.03 mm, and selected large particles, resulting in left over feed with a lower dMEAN (1.91 mm). Subsequently the nutrient composition of left over feed was significantly different amongst the farm types.

In conclusion, farm type and age of hens as well as their interactions were key factors affecting the parameters observed. Fixed sheds were of significant benefit to hens investigated in this study regarding egg production, feed intake, cumulative mortality and egg production. Further investigation about the use of environment enrichment such as the impact of pecking stones during rearing is warranted.

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1. Overall Introduction

This was a collaborative project that involved the South Australian Research and Development Institute (SARDI), the University of New England (UNE), and a number of commercial layer farms in South Australia and Victoria. The research focused on levels of range enrichment to determine best practice enrichment for free range layer systems, to encourage more birds onto the range, more often throughout the day. Additionally, the research investigated practical innovations to reduce the occurrence of aggression, severe feather pecking behaviour and subsequently plumage damage, and predisposition for cannibalism in free range laying hens. The project was divided into two components. Component 1 was conducted by SARDI and examined the enrichment of the outdoor range on South Australian farms. Component 2 investigated the use of peck stones on free range farms in Victoria and was undertaken by UNE. The results from both components are presented in separate chapters.

2. Objectives

<u>Component 1: Outdoor enrichment</u> – Trials were run on three fixed, free range commercial layer farms in South Australia. Two strategies for enrichment of the range were compared; a 'standard' control treatment, typical of the type of range used in the commercial industry and a 'highly' enriched treatment which incorporated shade cloth shelters, alongside a continuum of additional enrichment structures (e.g. artificial structures, dust baths and pecking stones etc.). The effects on feather plumage, body condition and ranging behaviours were evaluated until depopulation of each flock. The range treatments were investigated to determine the effects on motivating hens to use the range more effectively, and potentially lead to a decrease in abnormal behaviours, such as severe feather pecking and cannibalism.

<u>Component 2: Indoor enrichment</u> - Examined indoor enrichment of the shed by testing the use and feasibility of pecking stones on commercial free range farms. Two commercial farm types with different ranging styles (e.g. mobile and fixed shed) were the subject of this study. Pecking stones were provided and the effect on feather plumage, body condition, and feeding behaviour evaluated for the duration of the laying period. Since flock size is considerably larger in commercial farms compared to research facilities, the data obtained on the farm is extremely useful and highly warranted in order to transfer the knowledge gained to industry.

Chapter 3

Component 1 - Outdoor enrichment on commercial free range layer farms: SARDI

3.1 Introduction

Concern regarding the welfare of layers is driving change in how poultry is farmed and raises issues about the sustainability of the industry. There are increasing concerns from consumers regarding ethical and moral dilemmas associated with current commercial farming systems, whilst the farming industry has to contend with issues related to producing more food with fewer inputs. Farming systems have changed considerably in the last 60 years and initially farms consisted of low numbers of birds ranging freely. However, bird health and cost of production in outdoor systems forced farmers to shed birds intensively in cages. Many developed economies are now moving back to non-cage housing systems, such as free range, barn and aviary systems to address perceived welfare issues associated with caged housing. However, our understanding of these systems has also changed, along with increasing environmental complexity of non-cage systems. In addition, enriched cages have been introduced in some countries, such as the United Kingdom to replace conventional cages. Currently in Australia, grocery sales of cage eggs is approximately 53%, and free range and barn laid eggs at 46% (AECL 2014), whereas 10 years ago free range was considered a cottage industry. The increase in consumer demand for eggs from non-cage systems is expected to continue in the future, alongside other drivers, such as the large supermarket retailers "*plans to remove all cage eggs from supermarket shelves by 2018*" (Woolworths, 2012).

The public perception of what free range egg production entails suggests that layers have increased space allowances, perform a larger number of, and more diverse behaviours, as well as give birds the freedom to show a preference for different areas within and outside the layer shed. Additionally, access to the range allows birds to spread out to preferred distances when involved in particular behaviours, such as foraging or social interactions. This implies better welfare for the birds, and non-cage systems are perceived to be friendlier by the consumer in terms of bird welfare, as well as being of superior egg quality and safer food. However, due to the complexity of the environment and the system in question these advantages are often not proven. For example, in free range systems, the ability to freely express animal behaviour has resulted in severe feather pecking, reduced body weight, reduced performance and higher mortality compared to hens housed in conventional cages (Bilcik and Keeling 1999) (Durali 2012) (Glatz et al. 2005).

A recent review conducted in the UK assessed the welfare of hens from the main egg production systems (e.g. conventional cages, furnished cages, barn and free range) and concluded that mortality was generally lower in furnished cages, compared with conventional cages and non-cage systems, but that hens experienced stress in all housing systems (Lay et al. 2011). The authors stated that no single production system ranked highly for the welfare parameters measured in the hens, as each system had its own advantages and disadvantages for hen welfare relative to the Five Freedoms concept approach. There has been limited time to understand the requirements of modern layer birds to ensure that hens utilise the systems appropriately, particularly free range, as well as understand the types of birds that may or may not use the range. We are now in a prime position to develop and manage systems which are hen friendly, to minimize stress and safeguard welfare, whilst maintaining favorable characteristics for free range production and demand for free range eggs.

Range use

The use of the range is perceived to be beneficial to hen welfare by lowering the density of birds in the shed during daytime hours, whilst increasing their behavioural repertoire on the range. Theoretically the associated benefits, as mentioned above, also fulfil requirements by consumers for what is assumed to be a better housing system for laying birds. However, use of the range by hens is not optimal, so whilst provision of a ranging area is thought to be advantageous for welfare, the benefits of using the range are reduced due to the uneven distribution of birds using the range (Hinch and Lee 2014) and actual area of range used. Additionally, some accreditation schemes now require a larger range area in order for eggs to be branded and sold within these schemes. In some cases, this means “retro-fitting” ranges to fit the increased outdoor range area. In some cases, the additional area may not be directly outside the shed; therefore understanding whether range enrichments are able to encourage birds to more actively seek further range areas is important.

The reasoning behind the variability of range use has come from reports indicating lack of attractiveness of the range area, for example hens do not have opportunities to seek shelter from inclement weather or predators. Further research has shown a positive correlation between the presence of cover and number and dispersion of poultry on the range (Zeltner and Hirt 2003). Other factors include availability of cover (Grigor and Hughes 1993), weather conditions (Keeling et al. 1988, Hegelund 2005), flock size (Harlander-Matauschek 2001), as well as shade and overhead protection (Glatz 2010). Bright and Joret (2012) found flocks with a ranging area with a specific amount of tree cover had fewer second-quality eggs, compared with flocks housed in ranges without the specific amount of tree cover. Lower mortality was also found in those flocks with more tree cover, although this was not statistically significant. A further benefit of planting trees around layer sheds is that the provision of shade on the buildings, thereby reducing the heat load (Miao et al., 2005), particularly important in Australia where heat stress plays a major role in mortality. Therefore, there is potential to improve the ranging ability of birds in free-range systems, by getting hens out of the shed (where they tend to feather peck), encouraging them to actively range further away from the shed, as well as decreasing stocking density inside the shed and improving flock production by decreasing mortality due to abnormal behaviours.

A variety of both natural and artificial structures have been trialled on range to investigate bird preferences and to encourage their use of the range, with varying success. Nagle and Glatz (2012) found hay bales, forage, shade and shelter belts encouraged a large number of birds onto the range. These enrichments were investigated individually on an experimental basis, and with a small commercial egg producer in Queensland. Although shade was successful in attracting hens onto the range, other attractants were needed to encourage more hens out, particularly during summer months, however this was unable to be tested. The use of combinations of forage and shelter belts attracted the most number of birds onto the range, however this decreased over time, which the authors suggested was related to management of the structures being rundown over time. Thus, resource management seems to be essential to facilitate continued use of outdoor areas. Shelter belts were also used by Borland et al. (2010) (Borland et al. 2010), showing similar effects to the trials above with an increase in the number of birds using the range throughout the day. Larsen and Rault (2014) found that behaviours changed throughout the day when assessing behaviours of two flocks interacting with a specific shrub, where the birds utilised the sheltered area for different behaviours depending on the time of day. Another successful strategy to encourage poultry to use the outdoor area was provision of variety of elements on the range for hens to interact with. Zeltner and Hirt (2008) used a range of structures, including posts with hanging corks, potted trees and a box of pinecones to encourage hens out of the shed. They found that the presence of variety of structures was more effective, than the absolute number of structures in encouraging hens to use the range. Based on various research outcomes there is potential to increase the number of birds going onto the range, as well as understand the resource requirements to encourage more birds on the range, more often, which has not been tested in an Australian context.

The actual range area that birds use when on the range has also been shown to vary markedly. Research by Hirt et al. (2000) found that the majority of birds that did range outside were usually seen around the main area surrounding the shed, and the overuse of this area in itself was problematic due to nutrient load exceeding minimum acceptable levels of nitrogen (Aarnink 2006), destruction of vegetation, typically grass cover, and increased risk of intestinal parasites commonly seen on layer farms. Richards et al. (2001) showed the majority of the flock ventured into the pop hole area of the free range system at some point during the laying cycle, but the authors were unable to confirm if birds continued onto the range or how long the birds remained outside.

Not all birds utilise the outdoor run (Glatz 2010) and research conducted by Nicol et al. (2003) in Europe estimated that 20% utilization of the range by free range birds was considered high. As mentioned previously, the availability of an outdoor space is one of the perceived virtues of the free range system, however if it is not utilized by all birds, what is their welfare status and what does this mean in terms of providing a free range system? Hinch and Lee (2014) attached RFID (radio frequency identification) tags to free range hens and found individual variation in birds using the range. Three distinct populations were identified based on the birds usage of the range (outdoor, weak-outdoor, and indoor*). The authors showed that the proportion of hens never going outside did not change significantly from early to late lay. Additionally, use of the range appeared to be established very soon after range access was provided, and the proportion of hens going outside everyday increased from early to late lay. In contrast, Hegelund et al. (2006) found use of the range area decreased with increasing age, however their observations were conducted irregularly. The research reviewed above indicates that there are individual bird differences in preference for ranging and for the wide variety of structures that exist on the range, as well as other complexities, such as weather. Hegelund et al. (2010) estimated flock ranging behaviour, and on average 9% of hens used the range. However there were large variations both within and between flocks, which were mainly influenced by climatic factors. Additionally, when ranges were provided with artificial cover there were more hens on the range and the presence of the cover attracted more hens away from the area just outside the shed. Bestman et al. (2003) and Grigor and Hughes (1993) showed two particularly important factors: distance the hens needed to travel to reach cover and actual construction of the cover (speculated to relate to birds' ability to scan for aerial predators around a two- versus three-dimensional cover).

Feather pecking

Despite many years of research in an attempt to understand the underlying cause of severe feather pecking, it is still a major welfare problem in commercial egg production. The consequences of severe feather pecking can be serious for the hen and farmer, including increased feed consumption due to impaired ability of the birds to regulate their temperature, losses in egg production, pain and suffering of the bird being pecked and increased mortality from cannibalism and vent pecking (Rodenburg 2013). Additionally, once severe feather pecking starts in a flock, its management can be extremely challenging, particularly in non-cage systems. Despite this, non-cage systems in Australia have become more common with free range retail egg sales increasing from 7.8 million dozen in 2000 to 41.5 million dozen in 2011 (AECL, 2014). This trend is expected to continue in the future. It has been shown that flocks which utilise the range area better show a lower tendency to feather peck (Bestman and Wagenaar 2003). Other research has also identified a link between well-established tree cover, range use and injurious feather pecking, in that the higher the percentage of the flock ranging, the lower the percentage of injurious feather pecking (Lambton et al. 2010), (Nicol et al. 2003). List ref in one bracket separated by comma.

Blokhuis et al. (2007) collected data in Europe regarding the welfare of non-cage hens and found feather pecking occurred in 40-80% of those flocks investigated. Additionally, lower mortality and better plumage was found in beak-trimmed flocks compared with non-beak-trimmed flocks, especially in Brown genotypes, the primary layer birds used in Australia. Farmers are advised to optimise housing and management, but despite best efforts, the problem of feather pecking is persists in non-cage systems. Furthermore, several animal welfare organisations throughout the world are opposed to beak-trimming of hens, which has already resulted in a ban in several countries. Currently there is a major review underway in Australia? to address what this may mean to the industry as a whole. If beak-trimming was to be banned, understanding causes for severe feather pecking will become extremely relevant, as birds that are non-beak trimmed have significantly higher levels of cannibalism, vent pecking and cause much higher levels of plumage and skin damage than flocks that are beak-trimmed. Many studies have indicated strain differences in feather pecking behaviour and medium to high heritability for pecking. Sequencing of the chicken genome has moved the poultry industry forward with breeding companies actively enhancing breeding programs to improve selection in a number of different areas, including health and welfare (Grandin and Deesing 2014). However, poultry breeding companies have also indicated it will be many years before heritability of decreased levels of feather pecking could potentially be seen in commercial flocks. Based on information from the recent Poultry CRC survey conducted in Australia, around 50% of the free range farms contacted did not beak-trim their birds, and based on plumage scoring the vast majority were affected by severe feather pecking and/or cannibalism (Poultry CRC 2014, unpublished). Additionally, a large number of the farms surveyed were based on mobile sheds, as opposed to fixed range sheds.

Research indicates that environmental enrichment, such as foraging material or perches is accompanied by reduced feather pecking (El-Lethey et al. 2000); (Huber-Eicher and Audigé 1999)List ref in one bracket. Subsequently, dust bathing access has been implemented into national laws and regulations of several countries (TierSchNutztV 2001) (2001; 1999/74/EC, 1999). Nevertheless, in one study, perches have also been associated with increased risk of vent pecking (Lambton et al. 2015). While the addition of environmental enrichment such as hay bales or pecking stones specifically aims to reduce pecking behaviour, there are few published studies. The use of pecking stones is routine in many European poultry facilities and it is integrated as part of best practice housing for laying hens. Through pecking at the stones as part of foraging activity, the birds wear away the stone material as well as the beak tip. Thus, the beak (upper mandible) of birds with access to pecking stones should be blunted, or at least shortened. The abrasive function of the pecking stones results in beak-trimming performed by the bird itself. Therefore, the ability of the bird to damage and/or cannibalise conspecifics is minimised. However, while it is assumed that the extent of beak blunting or shortening will vary with an individual's use of the pecking stones, the effect of this kind of beak-trimming on the hen's ability of feed selection and subsequently feed intake is not known and its consideration as a 'welfare-friendly' method of beak-trimming needs further study.

Another important behaviour that seems to be associated with severe feather pecking, subsequent plumage damage and cannibalism in free range hens is dust-bathing behaviour. Dust-bathing behaviour is performed by chickens in association with preening. Together these behaviours function to maintain the health of the feathers, and thus plumage as a whole. Hens normally perform dust-bathing behaviour in the middle part of the day, on every other day (van Liere et al. 1991). If a suitable substrate is not available for dust bathing, the motivation for dust bathing increases. In the absence of dust-bathing behaviour there may be a build-up in stale lipid content in the feathers, and hens will attempt to perform longer bouts of the behaviour (van Liere and Bokma 1987). Most studies investigating the development of dust-bathing behaviour have involved rearing young chicks on wire, with or without a tray of sand for dust bathing (Huber-Eicher and Wechsler 1997, Huber-Eicher and Wechsler 1998). However, Vestergaard et al. (1997) housed hens for over two years on wire with access to none, or some, dust bathing substrates and found that the removal of substrate resulted in cessation of dust bathing and elevated stress hormone concentrations. While lack of a dust-bathing substrate altered the development of the behaviour, including the performance of sham dust bathing in cages, restricting the ability of birds to perform dust bathing also resulted in higher motivation to dust bathe. A rebound response of higher performance of the behaviour was also observed once the birds were able to dust bathe again following restriction. Although scientists believe dust bathing has an important functional role in the chickens' ethogram, there are no studies that have investigated the effects of restricting free range hens that are accustomed to performing dust-bathing behaviour, from performing the behaviour. Cronin et al. (2015) suspected that outbreaks of severe feather pecking behaviour in two flocks, with subsequent plumage damage and cannibalism, were the consequence of hens' failure to perform effective dust-bathing during prolonged wet periods due to high rainfall events. Further investigation of a possible cause and effect relationship between the quality of dust-bathing substrate and severe feather pecking, plumage damage and cannibalism is warranted. Such knowledge would enable free range egg producers to incorporate dust-bathing sites that remain dry as an easily applied method of reducing the likelihood of an outbreak of these problem behaviours, for example in covered/shaded area(s) on the range. Objective research on the importance of dust-bathing behaviour for hens on the range, with the co-provision of pecking stones for reducing severe feather pecking is lacking. Further research is clearly warranted to investigate the potential for preventing these problem behaviours through the use of adequate dust-bathing facilities, including good 'quality' litter material. However, interpretation of dust-bathing evaluations needs to be considered cautiously as hens perform other behaviours in addition to dust-bathing when outdoor. How much of the improved outcome relates to dust-bathing per se will be difficult to determine in outdoor settings.

Conclusion
Behavioural problems such as severe feather pecking can lead to plumage damage and cannibalism and are considered to be a multi-factorial problem. In a time of changing public expectation regarding acceptable farming practices, procedures such as beak-trimming are unlikely to be allowed in the future based on welfare considerations. Therefore, further research into the management of free range laying hens and use of the range and range enrichments is essential. Opportunities to encourage birds to use the range, and understanding the complexity of the non-cage systems in Australia, as well as the importance of key resources for hens such as overhead cover, enrichment sources, foraging and dust-bathing substrates and pecking "toys" are aspects that should be considered in assessing welfare, production and health of birds in non-cage systems. It appears that only few of these issues have been addressed specifically and individually in Australia. Therefore there is a potential to improve the ranging ability of birds in non-cage systems by improving the attractiveness of the range, and full utilisation of the range. Welfare of the birds will remain a major issue for consumers if birds are not encouraged to range, or use the range ineffectively, as well as exhibiting abnormal behaviours, such as severe feather pecking. Research focussing on a holistic approach of the quality and design of the range is crucial, and combining range coverage (artificial and natural), dust-bathing and pecking stones will provide a unique insight into laying hen behaviour, range utilisation and consequences on aggressive behaviour, severe feather pecking, plumage condition, cannibalism and productivity.

*Indoor: Never visit the outdoor range
Weak-Outdoor: Visit the outdoor range very rarely (visited the range ≤ 4 days)
Outdoor: Visit the outdoor range on a daily basis

3.2 Methodology

Component one investigated the demonstration of best practice range enrichment on commercial layer farms in South Australia using enrichment structures (artificial and natural), which have been evaluated from the literature to develop a continuum of range enrichment.

Three different sized commercial layer farms with a total of four flocks (Table 1) were identified and these farmers were very supportive of the on-farm trials for best practice range enrichment. All flocks studied in the project were Hy-Line Brown layers (all beak-trimmed). One shed per farm was utilized, with a split range for comparison side by side (e.g. one side of the range was enriched in comparison to the other side, which did not receive an enriched range environment (standard range environment)). A continuum of range enrichment (e.g. shade cover direct from the shed, hay bales, trees, dust baths, pecking stones and artificial shelters), provided overhead cover, diversity of range enrichment and increased the number of resources available on the range for use by the birds.

All farms were visited once a month for six months from April through to October (except farm 3, May – October).

Animal ethics approval for this project was granted through the Primary Industries and Regions South Australia Animal Ethics Committee (AEC # 13-15).

Range usage: Included the numbers of birds on the range, distribution of birds on the range, resource/bird interactions and behaviour on the range (e.g. comfort behaviours etc) and usage of pecking stones (photos and stone weight). Birds were counted in three zones on the range (within 3m of the shed, 3 -10m from the shed and beyond 10m from the shed). These counts were made in the morning shortly after pop holes were opened (15 – 20 minutes after pop holes opened) and in the early afternoon (2 – 3pm).

Feather damage/Plumage Score: Plumage score was conducted on 100 random birds throughout the shed and another 100 randomly selected birds across the different localities of the outdoor range. The AssureWel score system was used, whereby;

0 = no or minimal feather loss (no bare skin visible, no or slight wear, only single feathers missing),
1 = slight feather loss (moderate wear, damaged feathers or 2 or more adjacent feathers missing, bare skin visible <5cm maximum dimension)
2 = moderate/severe feather loss (bare skin visible ≥ 5cm maximum dimension).

This scoring system was easy to learn and found acceptable by stock people on the farms. On each farm the plumage scores were made by the same observers throughout the trial. Scores were made across five different body parts of the hen which included; head/neck, back, base of tail/around preen gland, the tail and wings. A total plumage score was calculated for each hen by adding the five body part scores together (maximum score = 10). Bare vents were also noted. Data was analysed using a t-test assuming unequal variances. The null hypothesis was no difference in the mean total score between counts/scores generated inside and outside sheds..

A fear test was conducted at the beginning of the trial, midway and prior to depopulation for three flocks, no test was made on Flock 2-2 (one of the two sheds on Farm 2). The test was done by inverting hens on their side and applying slight lateral manual restraint until the hen stopped struggling. The duration of immobility was recorded from the moment the hen stopped struggling until the hen righted itself. Twenty birds from inside the shed and 20 birds outside were randomly selected. Data was analysed using a t-test assuming unequal variances. The null hypothesis was no difference in the average time for hens to right themselves between hens scored inside and hens scored outside sheds.

Bird live weight was measured for all flocks except Flock 2-2. Fifty birds were selected at random and weighed individually. Farmer recorded bird weights were also utilized. The live weights were compared to the Hy-line Brown standards.

Production measures: All farms except Farm 3 provided egg production data.

Range vegetation ground cover : The proportion of ground cover and the plant species present on the range areas were assessed through visual scans by walking transects across the enriched range vs the standard range (two transects per range area). Transects started at the shed. Within a transect the percentage ground cover, the height of plants and the species present were recorded at 5m, 10m, 20m and 50m distances from the shed.

Environmental measures: Weather conditions were recorded during each visit (e.g. temperature at time of visit, rain, wind and cloud cover)

Video measures: Enrichment structures (shelters, hay bales, traffic cones, bark pits, sand pits and forest) were videoed for one hour in the morning shortly after pop-holes were opened and again early afternoon (2pm – 3pm). Key behaviours at each of the structures was noted and the number of hen visits in the hour counted.

Table 1. Summary of description of the farms.

Farm	Flock size	Stocking density/ha	Start ranging flock age (weeks)	Flock age (weeks) start of trial	Flock age (weeks) end of trial
Farm 1	3,000	1,500	32	32	55
Farm 2-1	10,000	10,000	26	37	63
Farm 2-2	10,000	1,500	26	49	75
Farm 3	11,700	10,000	27	50	70

Description of farms - hen shed and range areas

A variety of enrichment structures where placed on the farms and were tailored to suit the individual farm situation. It was also dependent on materials readily available on the farms as we were mindful of the cost involved in building the structures. Expensive structures are less likely to be used on commercial farms. The type of hen shed and enrichments used on each farm are described. Farm 1 and Farm 2-1 were specifically set up to compare enriched vs standard range treatments. Natural overhead cover from trees was the focus of Farm 2-2 and Farm 3.

All hen sheds in the study have raised, plastic slatted floors throughout the shed with centrally located roll-away nest boxes and automated egg collection.

Farm 1 (Enriched vs standard)
Shed: The shed is an eco-shelter with one large pop-hole located at the western end. This pop-hole remained open 24 hours a day. Drinking water is via bell drinkers and feed delivered with a chain feeder system. Ventilation is achieved by raising side curtains along the two long edges of the eco-shelter and stirrer fans inside the shelter.
Range enrichment: The range area extended out only from the western and southern sides of the shed. Enrichment structures consisted of four tractor tyres filled with sand, hay bales, shade shelters (built from besser bricks and wooden pallets), orange traffic cones and a shade sail placed directly alongside the shed. The first shade structure was placed 20m from the shed (Shelter 1) and the second 50m from the shed (Shelter 2). A large square hay bale was placed between Shelter 1 and Shelter 2 (35m from shed) and hay bale 2 placed 70 m from the shed, but only 20 m from Shelter 2. Pecking stones were placed next to the shed under

the shade sail, under Shelter 1 and under Shelter 2. The tyre sand baths were placed 20m out from the western side of the shed. There was no vegetative ground cover on the range at the start of the trial due to bushfire damage, however the low growing tree lines had remained alive on the northern and western fence lines.

Farm 2-1 (Enriched vs standard)
Shed: The shed is steel framed and the walls cladded with insulation board and a corrugated iron roof. Drinking water is via nipple and cup drinker lines and feed was delivered with a chain feeder system. Large extraction fans are used to ventilate the shed along with stirrer fans throughout the shed. Three large pop-holes are located down both long sides of the shed (total six pop-holes) so hens can access the range areas on both sides of the shed. The northern range area is narrow and only 15m wide but the southern range is approximately 1 hectare.
Range enrichment: There were 14 mature pepper-corn trees (*Schinus molle*) on the southern range with the closest tree to the shed at 20m. Bark pits, two shade structures arranged side by side and separated by 5m (placed 20m from the shed) and large round hay bales had been placed on half the range. A shade sail was also placed over one of pop-holes on the southern side of the shed. In addition, orange traffic cones, orange plastic egg fillers and orange flags had been situated close to enrichment structures. Furthermore, pecking stones were placed under the left hand side shelter and two trees.

Farm 2-2 (Natural tree cover)
Shed: The shed layout is very similar to 2-1, except the southern range is only 6 m wide and the northern range opens out onto a one hectare olive plantation.
Range enrichment: No additional enrichment was added to the range. This range has natural shade provided by an established olive plantation with some trees directly adjacent to the shed and the majority starting within 20 m from the shed. Trees were arranged 7m apart. In total there were 485 trees. Beyond the olive plantation there was an outer paddock area allowing for a stocking density of 1,500 hens/ha. To reach the outer paddock the birds firstly needed to travel approximately 250 m through the olive plantation.

Farm 3 (Natural tree cover)
Shed: The shed had similar construction and ventilation to the sheds on Farm 2. The seven pop-holes down one side of the shed opened out onto a northern outdoor range. Inside the shed the drinking water is delivered by nipple and cup drinker lines and feed via pan feeders.
Range enrichment: The range area on this farm extended into a small pine forest area. Between the shed and the forest there was an open area with only two trees. These trees were 10m from the shed and the pine forest started 40m from the shed. Numerous trees surrounded this farm, therefore even the open areas of the range have some shade throughout the day. Additional enrichment structures were hay bales, pecking stones and traffic cones. Pecking stones were placed under an olive tree (10m from shed) at the edge of the forest (40m from shed) and middle forest (60m from shed). Sand baths were not considered necessary as the locality has very sandy soils.

Pop-holes on farms 2 and 3 were usually opened between 10.00am – 11am and closed around dusk.

The variety of enrichments used in the study are shown in photos 1 – 6.

Photo 1: Examples of shelters used on the farms (Left, besser bricks & pallets; Right, simple A frame)

Photo 2: Traffic cones and orange flags where used as attractants on the range.

Photo 3: Hay bales used on the range

Photo 4: Left, tractor tyre filled with sand used as a dust bath (this created a problem with egg laying under the tyre rim) and Right, a simple mound of soil on the range used for effective dust bathing.

Photo 5: Pecking stones placed on the range under trees

Photo 6: Natural overhead cover provided by olive trees

3.3 Results

Range usage – number of birds on the range

The percentage of the flock on the range was influenced strongly by the weather conditions and the age of the flock. Overcast conditions with no wind and light drizzle led to the greatest numbers of birds outdoors (e.g. Farm 2 when the two flocks were 50 and 62 weeks of age respectively, and Farm 3 when the flock was 58 weeks)(Figure 1, Appendix Table 1). On these visits well over 60% of the flock ventured outdoors in the morning. Farm 1 had the least percentage of birds outdoors during our visits (Figure 1). This farm had the pop hole open 24 hours a day so there were no great differences between the morning and the afternoon bird counts. Young flocks had fewer birds outdoors.

The proportion of outdoor hens ranging at <3m, 3 – 10m and >10m from the shed was calculated by pooling the hen counts from the morning and afternoon at each flock age. Age of the flock strongly influenced where on the range the birds were found. Younger flocks had a higher proportion of birds staying within 3m of the shed (Figure 2, Farm 1 and Farm 2-1). For mature flocks at least 50% of those birds outdoors were ranging greater than 10m from the shed.

Irrespective of hen age and time of day, the enriched side of the outdoor range attracted significantly more birds (Figure 3). This was demonstrated on Farm 1 and Farm 2-1 whereby one side of the range (southern aspect) was enriched with shade shelters, hay bales, traffic cones, orange flags, pecking stones, bark pits and sand pits.

Bird Measures

Plumage scores – The average total plumage damage increased as the flocks matured on Farm 1 and 3. Whereas plumage damage stabilised for both flocks on Farm 2 and showed a slight decrease. Furthermore, outdoor birds had significantly less damage than those birds in the shed for most flock ages (Figure 4). The most severely affected body part was the neck and over time the base of tail and back had progressively more damage (Figures 5-8). Plumage damage at the base of the tail was greatest for the flock on Farm 3. But across all farms on most visits birds found on the range had significantly less damage at the base of the tail than those found indoor. The disappearance of wing and tail feathers occurred later as the flocks matured, however the age at which it began to show did vary according to the flock. Bare vent areas appeared on the hens from Farm 1 and 3. On farm 1 the hens were 55 weeks old when 3% of birds in the shed had some bare vents, however no birds on the range had bare vents. Hens on Farm 3 had a higher incidence of bare vents but at 70 weeks of age, whereby 17% of range birds and 24% of shed birds had shown some signs of bare vents. Despite the bare vents appearing there were no signs of cannibalism. All the flocks in the study were beak-trimmed.

At the end of the study the total plumage score was categorized for the level of damage for each flock (Figure 9). Well over 50% of birds on the range had no to low damage across all farms. Furthermore, Flock 2-2, the oldest flock, had 80% of birds on the range with no or low plumage damage. Conversely, proportionally less range birds had medium and severe plumage damage. Farm 1 had the highest level of birds with medium damage, most of which can be attributed to neck and base of tail damage. Farm 2 flocks followed a similar pattern to one another. Farm 3 had the most birds with severe damage. This may be due to birds having to be kept indoors because of frequent storm activity during September and October in the locality of Farm 3.

Bird weights- Live weights were measured on Farm 1 and 3 and they were comparable to the Hy-Line Brown performance standards for alternative systems (Table 1). The coefficient of variation was below 10%.

Table 1: Average hen live weights (kg) and CV% for Farm 1 and 3 as compared to the Hy-Line Brown performance standard (kg) for alternative systems 2016.

Farm /flock age	**(kg)**	**CV%**	**Hy-Line Brown standard (kg)**
Farm 1 (42 weeks)	2.04	8.05	1.88 – 2.00
Farm 1 (55 weeks)	2.02	6.89	1.90 – 2.02
Farm 3 (70 weeks)	2.02	9.30	1.91 – 2.03

Fear measures- The level of fear was determined by inverting the bird on its side and timing how quickly it righted itself. The quicker the time to recover the less fear. The hypothesis was that outdoor birds show less fear than indoor birds. However, there were no statistical differences in responses between inside birds and range birds. However, there is a trend toward quicker response times as the flock matured (Table 2).

Table 2: Average time in seconds for Hy-line Brown layers to right themselves after they had been inverted on their side at different ages, comparing birds from the shed and range on three commercial layer farms in South Australia.

	Early trial		**Midway trial**		**Finish trial**	
	Shed	Range	Shed	Range	Shed	Range
Farm1	-	-	0.94	0.52	0.34	0.28
	Not measured		Age 42 weeks *P= 0.1394*		Age 55 weeks *P= 0.0532*	
Farm 2-1	2.34	1.14	0.32	0.42	0.24	0.25
	Age 37 weeks *P= 0.0663*		Age 50 weeks *P=0.0784*		Age 63 weeks *P=0.3334*	
Farm 3	0.89	1.05	-	-	0.22	0.22
	Age 50 weeks *P=0.1739*		Not measured		Age 70 weeks *P=0.4713*	

Production

Egg production data was provided by farms 1 and 2 (Table 3). Percentage hen day for the Farm 1 flock was always lower than the Hy-Line Brown standard, whereas flock 2-2 had the best performance. However, flock 2-2 was below the Hy-line standards at 75 weeks of age (close to depopulation).

Table 3: Egg production expressed as % hen day for Farm 1 and 2 flocks compared with the Hy-Line Brown standard 2016. Yellow high-light indicates those weeks whereby the farm flock was performing at or higher than the Hy-Line standard.

Farm/flock	Age (weeks)	% hen day	% hen day Hy-Line brown standard 2016
Farm 1	32	90.1	94 - 95
	36	92.0	93 - 94
	40	86.2	92 - 93
	42	85.1	91 - 92
	48	78.6	88 - 90
	51	75.1	87 - 89
	55	82.3	86 - 88
Farm 2-1	29	92.7	95 - 96
	37	88.4	93 - 94
	41	92.5	91 - 93
	50	90.1	88 - 89
	55	85.6	86 - 88
	57	84.0	85 - 87
	63	81.0	83 - 85
Farm 2-2	41	87.7	91 - 93
	49	91.7	88 - 90
	53	90.3	87 - 88
	62	85.8	83 - 86
	67	81.2	81 - 84
	69	79.1	81 - 82
	75	72.3	76 - 79

Range vegetation ground cover:

The majority of the ground cover plant species found growing on the range were weeds (Table 4). Percentage ground cover on the range was influenced by the stocking density. Those flocks stocked at 10,000/ha had denuded the entire vegetative cover on the range by the time they had reached the age of 50 weeks (Farm 2-1 and Farm 3). The 3,000 bird flock stocked at 1,500/ha had totally cleared the area around the shed to approximately 5m, but the remainder of the range maintained cover that varied between 35% to 94% cover (Farm 1). This range had to be mown to maintain the height around 10cm because at one stage marshmallow weed had grown away quickly and hens were using this tall coverage to lay eggs within. Further out on the range, at 50m from the shed, the grasses and annual medic were more commonly found. Farm 2-2 was also stocked at 1,500/ha but was a larger flock (10,000 birds). These birds had cleared the ground cover around the olive trees and had progressively made their way to the open paddock section of their range by the age of 67 weeks. Here the birds were targeting lucerne, barley grass (before it ran to flower head), annual ryegrass and wild mustard. Horehound was commonly found on most of the farms in the study and proved to be unpalatable to hens. Horehound plants would grow into large plants, untouched even in areas of greatest grazing pressure from hens. Soursob on the other hand was highly palatable despite being high in oxalic acid content. Hens were eating soursob on Farm 2-2 but could not reach those plants growing within the prickly roly poly plants.

Table 4: List of ground cover plant species found growing on the range of three commercial layer farms in South Australia.

Farm/flock	Plant species/ P = pasture plant, N = native, W = weed
Farm 1	Marshmallow *(Malva parviflora)* W Horehound (*Marrubium vulgare)* W Capeweed (*Arctotheca calendula)* W Wireweed (*Polygonum aviculare)* W Barley grass (*Hordeum leporinum)* W Roly poly (*Scleroleana muricata)* N, W Wild mustard (*Sinapsis arvensis)* W Annual medic (*Medicago sp.)* P Winter grass (*Poa annua*) W
Farm 2-1	Unidentified ground cover W? Horehound (*Marrubium vulgare*) W Blue bush (*Maireana brevifolia*) N Roly poly (*Scleroleana muricata*) N, W Marshmallow (Malva parviflora) W Potato weed (*Heliotropium europaeum*) W
Farm 2-2	Soursob (*Oxalis pes-caprae*) W Horehound (*Marrubium vulgare*) W Blue bush (*Maireana brevifolia*) N Lucerne *(Medicago sativa)* P Barley grass (*Hordeum leporinum)* W Annual ryegrass *(Lolium rigidum)* P or W Wild mustard (*Sinapsis arvensis)* W Stinging nettle *(Urtica dioica)* W Roly poly (*Scleroleana muricata*) N, W
Farm 3	Range denuded, no species were found growing on the range when the trial commenced.

Environmental measure

Weather data at the time of farm visits are presented in Appendix Table 1. The highest temperature during a visit was 25^{o}C during the afternoon in April at Farm 1. Not many birds were out on this occasion as they had only been ranging for a week at the time of the visit. The lowest temperature was 5^{o}C one morning in July on Farm 1. Low temperatures during this trial did not impact bird numbers on the range. For example, Farm 2, had the greatest percentage of birds out on the range during the morning with a 9^{o}C temperature (July visit). The day was overcast, with light breeze and light drizzle.

Video measures

The forest on Farm 3 attracted the largest number of hen visits in the hour (Figure 10). On average, there were 1,500 hen visits to the forest during the hour of videoing with no differences between the morning and the early afternoon. Constructed shelters on the range and sand pits had the next highest number of visits. With respect to distance from shed for the same structure, the more distant shelter from the shed (Farm 1, Shelter 2, 50m from shed) did have fewer visits than the shelter closest to the shed (Farm 1,Shelter 1, 20m from shed). Similarly, the more distant hay bale had fewer visits (Farm 1). Shelters placed at 20m from the shed had similar levels of visitation irrespective of the size of flock and the farm (Farm 1 and Farm 2-1). Traffic cones attracted over 100 birds on Farm 1 and over 400 birds on Farm 3. Bark pits had the lowest level of visits by hens. At any one time, some birds remained in the forest and under shelters. In contrast, bird numbers around hay bales and traffic cones were more transient. The behaviours exhibited did vary depending on the structure. Birds at the shelters were mostly dust-bathing, sunbathing, standing and sometimes perching on top of the structure. Hay bales and traffic cones led to scratching and pecking at the object or the ground surrounding the object. In the forest, the two main behaviours observed were dustbathing and scratching/ pecking at the ground. Furthermore, usually one behaviour was more dominant on the day of the visit.

Peck stones on the range

The peck stones on Farm 1 and Farm 2-1 had similar levels of usage with much of the stones still remaining at the end of the study after 21 – 22 weeks (Table 5). In contrast, the hens on farm 3 had almost totally eaten the peck stones placed on their range.

Table 5: The amount of peck stone remaining (kg) 22 weeks after placement in three locations on the range of three commercial free range egg layer farms in South Australia.

Location on the range	Distance from shed (m)	Amount peck stone remaining (kg)
Farm 1		
Shade sail	3	7.42
Shelter 1	20	6.02
Shelter 2	50	8.00
Farm 2-1		
Shelter (left hand side)	20	7.06
Tree # 1	20	6.40
Tree # 2	50	5.05
Farm 3		
Olive tree	15	0.00
Edge of forest	40	3.90
Middle forest	60	0.00

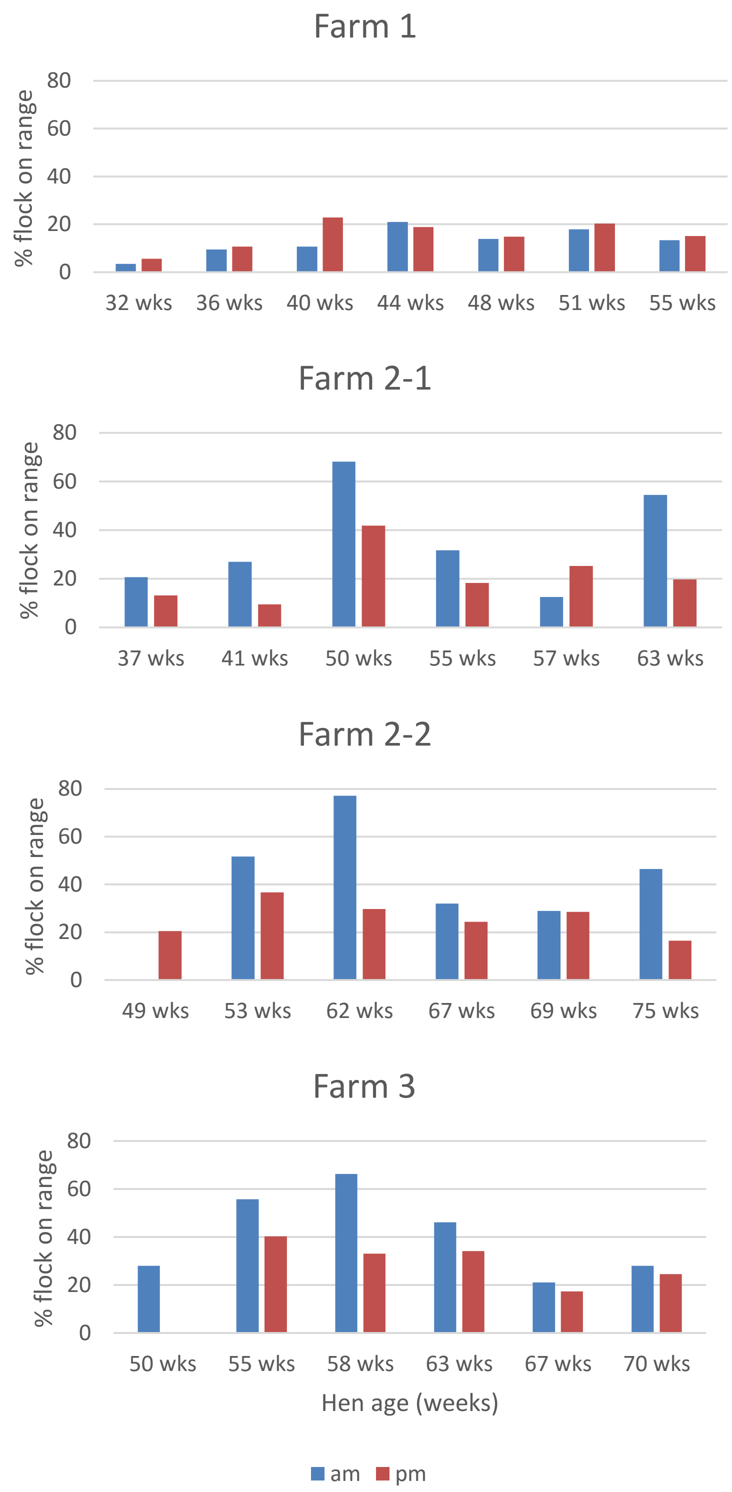

Figure 1: Percentage of the total flock outdoors by hen age (weeks) in the morning (shortly after pop holes opened) and early afternoon (2 – 3pm) on three commercial egg layer farms in South Australia.

Figure 2. The proportion of outdoor hens at <3m, 3 – 10m and >10m from the shed on three commercial egg layer farm in South Australia.

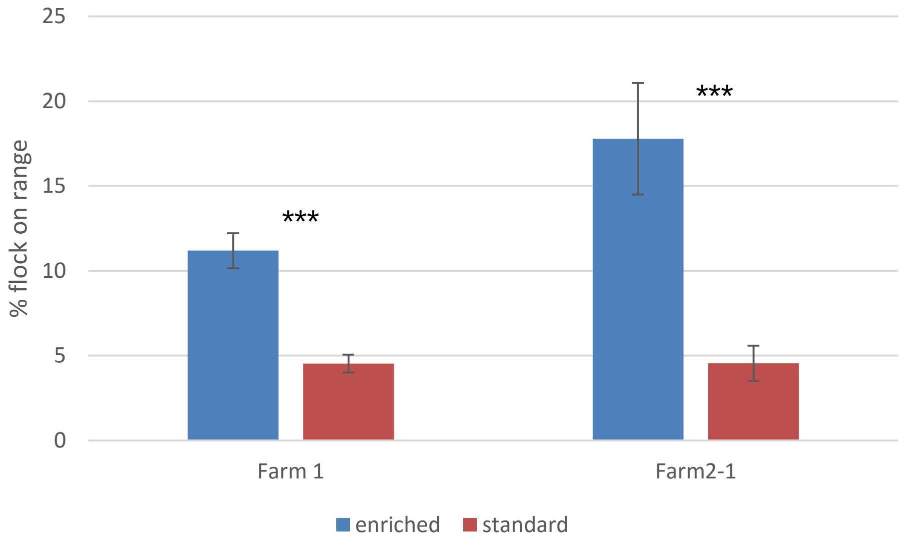

Figure 3: The average percentage of the flock found on the enriched side of the range compared to the standard side of the range for two commercial egg layer flocks in South Australia. The statistical difference between enriched and standard for each farm is highly significant *** P ≤ 0.001.

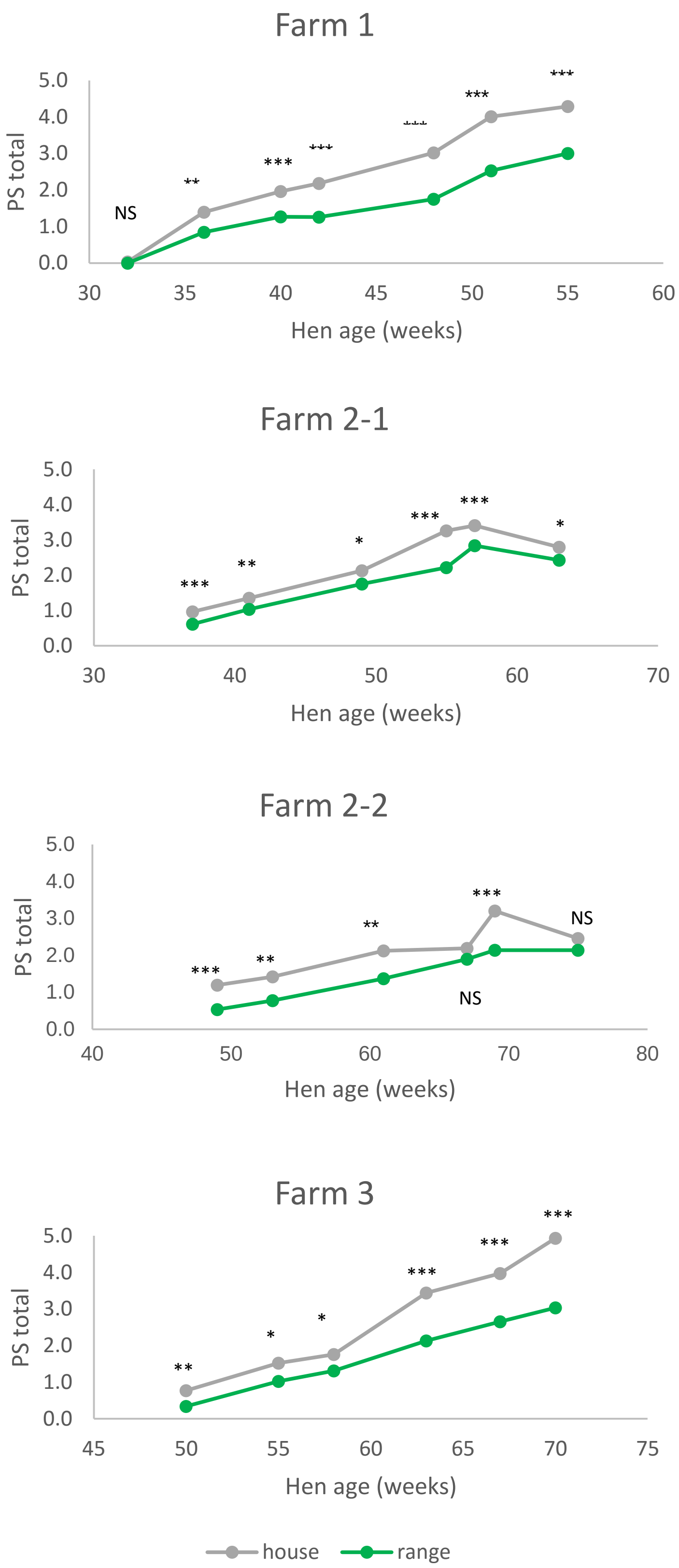

Figure 4: Average total plumage score (PS) for birds outdoors on the range and birds in the shed on three commercial egg layer farms in South Australia. Significance levels between range and shed birds; NS = Not Significant, * P<0.05, ** P<0.01 and *** P<0.001

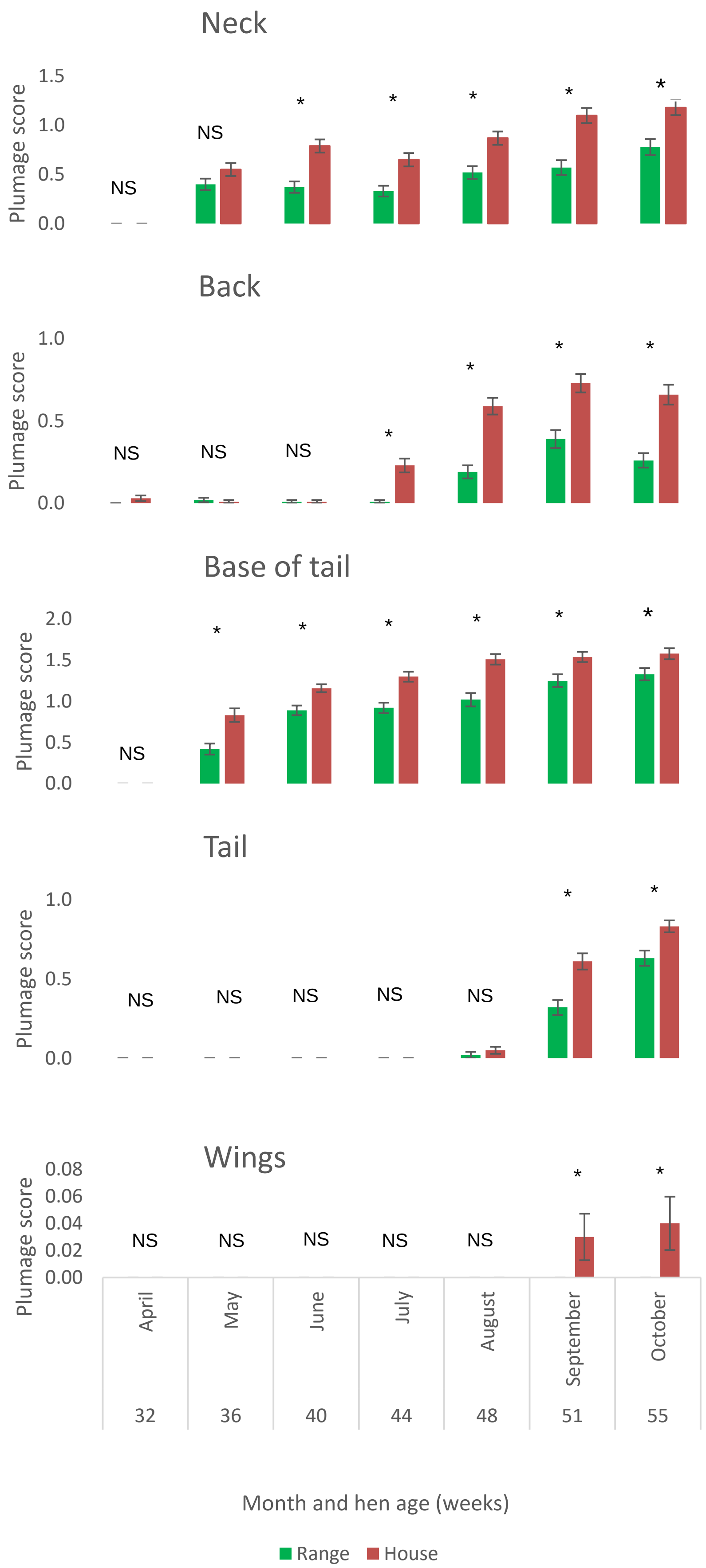

Figure 5: **Farm 1** average plumage scores across five body parts on hens for range birds vs shed birds from April – October 2016; neck, back, base of tail, tail and wings. Statistical significance between shed and range indicated with * P<0.05 and NS = Not Significant.

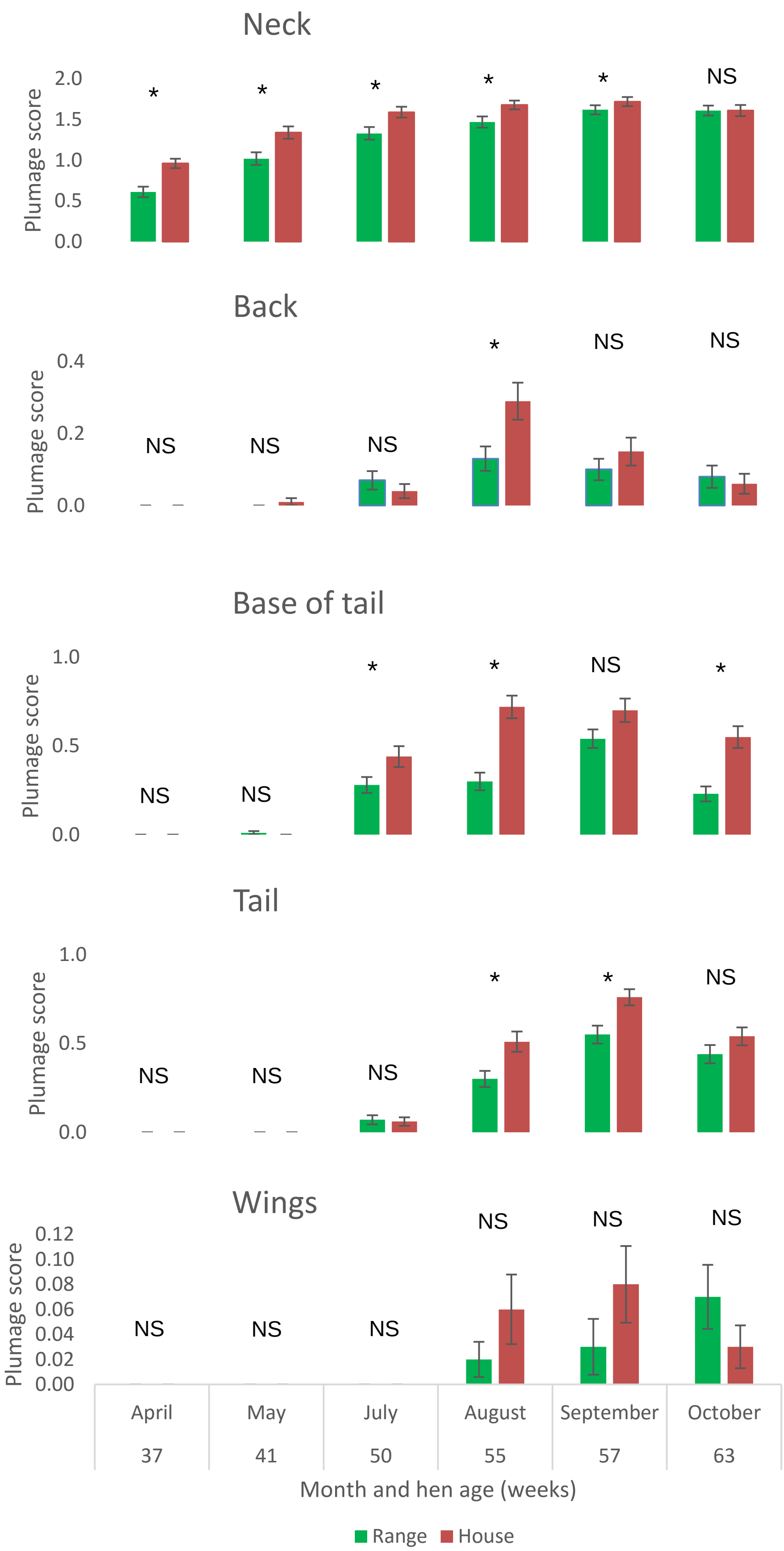

Figure 6: **Farm 2-1** average plumage scores across five body parts for range hens vs shed hens from April – October 2016; neck, back, base of tail, tail and wings. Statistical significance between shed and range indicated with * P<0.05 and NS = Not Significant.

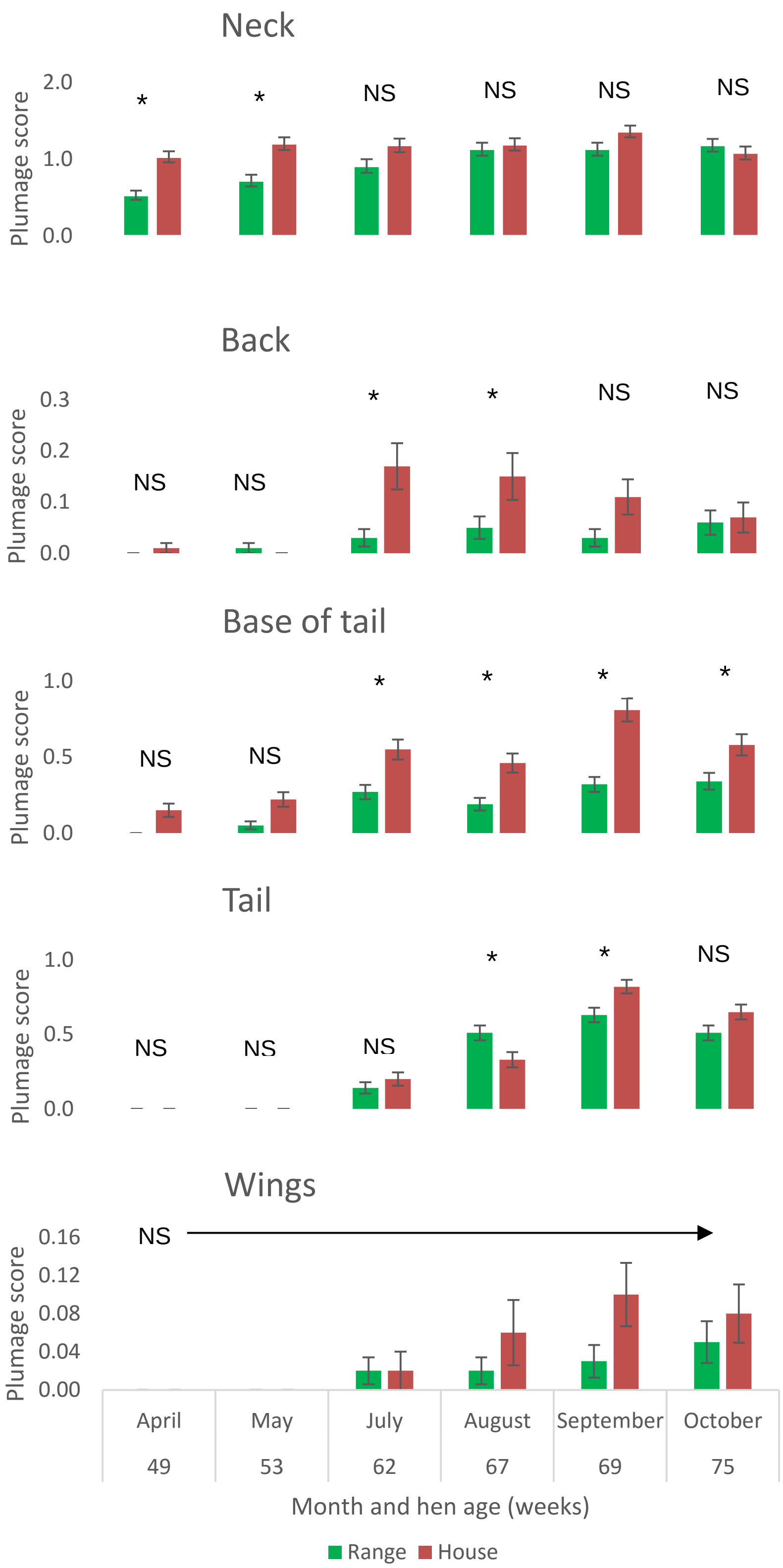

Figure 7: **Farm 2-2** average plumage scores across five body parts for range hens vs shed hens from April – October 2016; neck, back, base of tail, tail and wings. Statistical significance between shed and range indicated with * P<0.05 and NS = Not Significant.

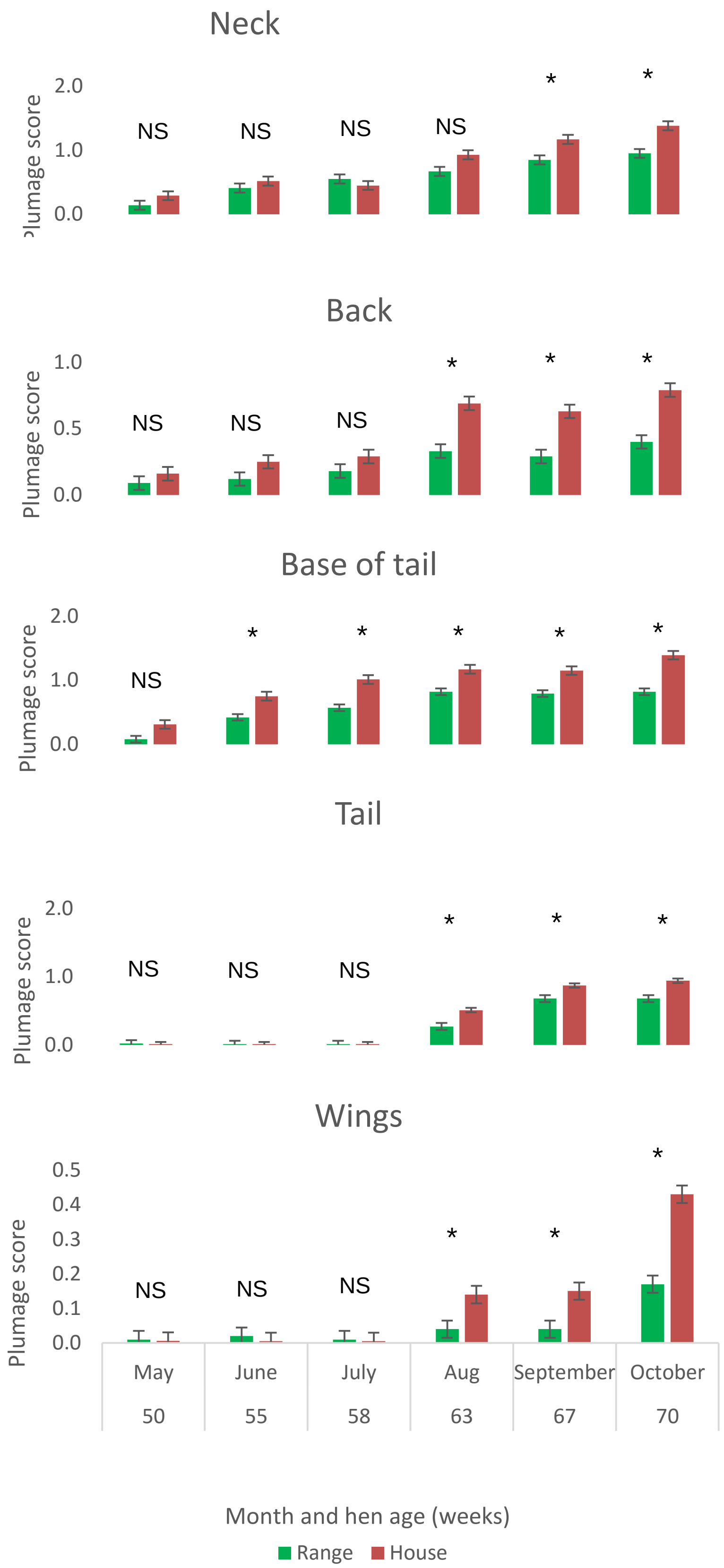

Figure 8: **Farm 3** average plumage scores across five body parts for range hens vs shed hens from April – October 2016; neck, back, base of tail, tail and wings. Statistical significance between shed and range indicated with * P<0.05 and NS = Not Significant.

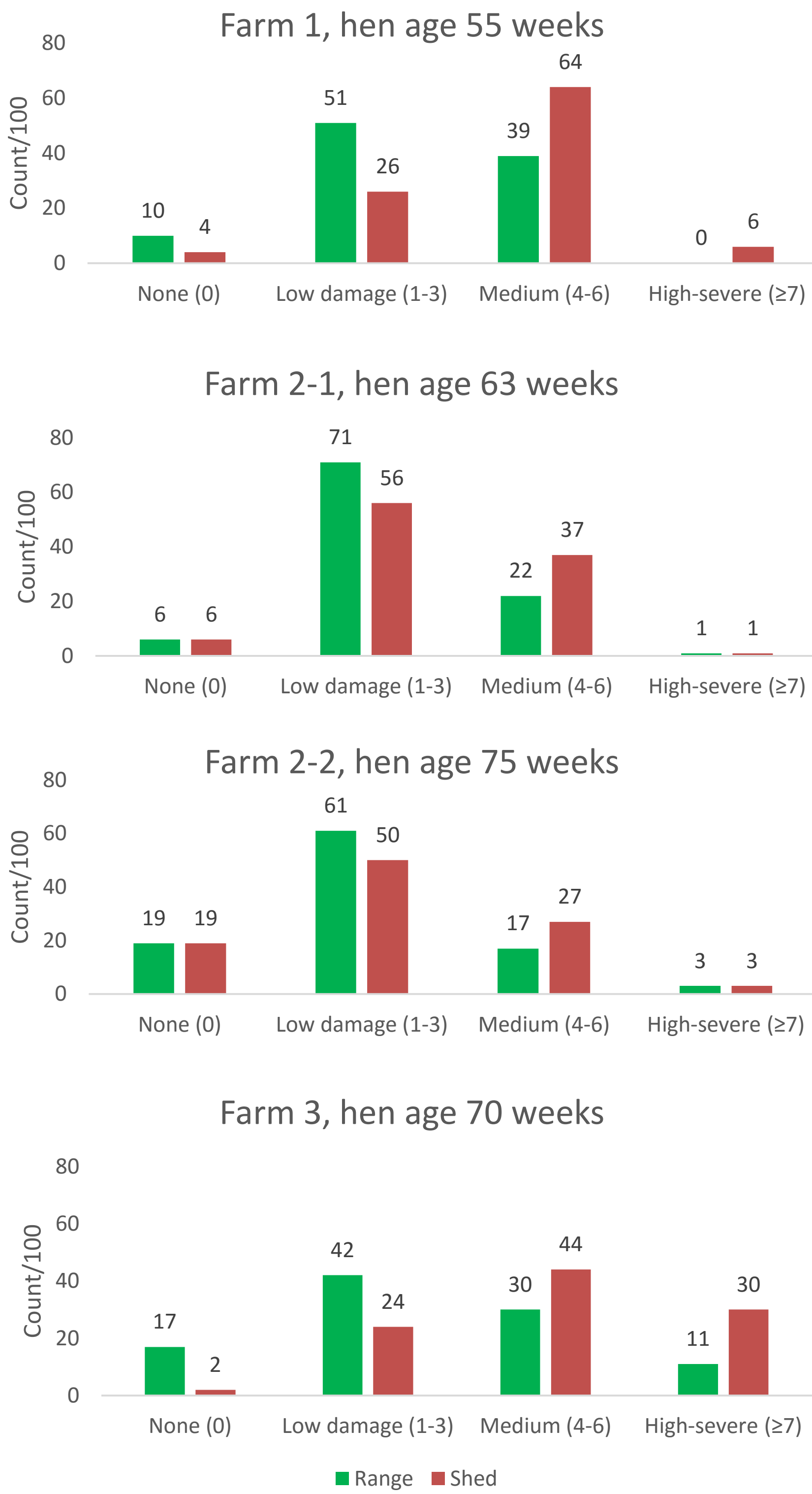

Figure 9: Total plumage scores at the end of the study categorized into different levels of damage for each flock. The number of hens in each damage category per 100 range birds and 100 shed birds (level of plumage damage; none =0, Low damage = 1-3, Medium damage = 4-6 and High/severe damage ≥7).

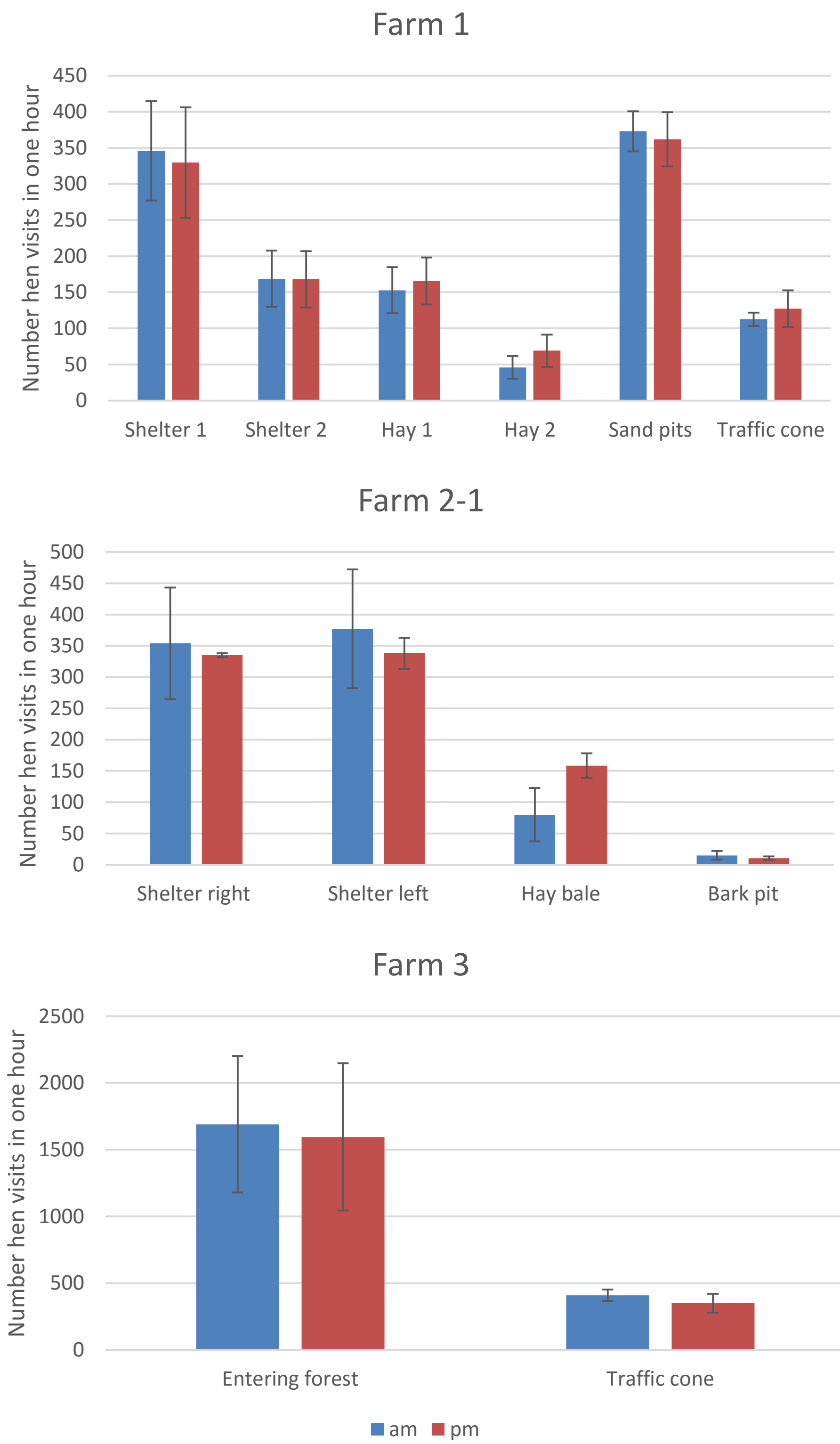

Figure 10: The number of hen visits in one hour of video footage entering the forest and various enrichment structures on the range of three commercial egg layer farms in South Australia.

3.4 Discussion of Results

A variety and continuum of enrichment structures attracted more hens onto the range (Photo 7). It is therefore essential to provide enrichment structures on range areas which have no or minimal natural over-head coverage from trees. Constructed shelters catered for the hens' need for security and overhead protection from predators and gave them a place to dust bathe and rest. Although natural cover provided by trees had attracted the greatest number of birds, the trees themselves may need protection from excessive dustbathing and scratching activity from hens as this can expose tree roots. This was particularly evident on the farm with the very sandy soil as the hens found it easy digging. As prey animals the hens sought cover from trees and shelters and this desire for cover was especially strong when they felt threatened, such as when a hawk, crows or low flying aircraft flew over-head. Heavy rain also resulted in hens retreating to shelters and then making their way back to the main shed. Hay bales are also essential for range enrichment, even though the hen numbers attracted to them was not as high as shelters. The hay bales provided hens with the opportunity to forage by scratching and pecking. This was especially important on the fixed range farms stocked at 10,000 birds/ha as the hay bales provided a valuable foraging substrate when the range had been denuded of vegetative ground cover. We had observed some egg laying around hay bales, therefore they will need to be checked regularly. Even though the tractor tyres filled with sand were very popular for dustbathing, they did create a major problem with egg laying. As the level of sand in the tyres dropped hens were able to get underneath the rim and found convenient egg laying sites. A better solution was to deposit the sand directly onto the range as demonstrated on one farm in the study. This study has also shown that sand pits don't need to be elaborate structures. The orange coloured attractants such as the traffic cones have the capacity to attract many hens and can be used in conjunction with other structures. Peck stones placed outdoors on the range had some utilisation, but traffic cones were observed to be more effective in occupying hens and in the long run will be more cost effective. Yellow/orange dyed peck stones?

The video footage from our study had shown the movement of birds over the range was very dynamic. Different areas of the range and structures had promoted particular behaviours. Observed behaviours for the forest area were mostly dustbathing or scratching/pecking. In contrast, Larsen and Rault (2014) did not observe dustbathing during their study of hens utilising groves of Kangaroo apple (*Solanum laciniatum*). At the time of their study the soil was moist and they had postulated this was not conducive to dustbathing. However, on pre-trial visits to their site they had seen dustbathing divots and observed dustbathing. Farm 3 in our study has very sandy soil and would not stay wet for long after rain, therefore the soil conditions for dustbathing would be favourable most of the time. On one occasion we saw up to 3,600 birds in the forest most of which were dustbathing at the same time. Larsen and Rault (2014) had also observed social facilitation, where individuals within a group were performing the same behaviour.

Hens on the range had better plumage condition with less damage and feather loss than hens in the shed. The recent study by Rodriguez-Aurrekoetxea and Estevez (2016) had also found birds on the range had lower plumage damage. The flock with the least plumage damage in our study also had access to a range area with the greatest level of overhead cover (approx. 30%). In this situation it was provided by olive trees and we postulate this high level of overhead cover played a significant role in enticing large numbers of hens outdoors resulting in less plumage damage. Other studies have shown more birds ventured outdoors when overhead cover was available. For example, meat chickens ventured furthest from the poultry shed with olive trees on the range compared to no trees (Dal Bosco, et al., 2014). Similar results were shown with Hy-Line layers, where when shelter belts were provided on the range, more hens were found outside compared to non-shelter belt ranges (Borland, et al., 2010; Nagle and Glatz, 2012). The numbers of hens found outdoors will still be modified by the prevailing weather conditions.

At the start of the trials, minor plumage damage on the neck front is likely due to mechanical damage probably from chain feeders. Farms 1 and 2 had chain feeders and the neck damage was rated higher on these two farms early in the study compared with farm 3 with pan feeders. Once damage had begun on the neck and bare skin was exposed, the site probably became the focus for other birds to peck leading to severe feather loss over the entire neck, such birds looked as though they were "ring-barked".

In conclusion, more hens used the enriched side of the range and overhead cover was instrumental in enticing birds out on the range. Furthermore, hens outside on the range had better plumage with less feather loss and bare skin than those birds in the shed.

Photo 7: A continuum of enrichment structures encouraged birds further onto the range, these structures were spaced approximately 10 – 15 m apart.

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Chapter 4

Component 2 – Indoor enrichment of the shed on commercial free range layer farms: UNE

4.1 Introduction

Free range farming is a rapidly growing sector in the Australian layer industry, with an estimated retail market share value of 49% and 17% annual increase in growth rate (AECL, 2015). Compared to conventional caged facilities, free range systems provide greater opportunity for hens to articulate a broader range of behavioural expressions (Lunam et al. 1996; Kjaer and Sørensen, 2002). This freedom can be associated with a wide range of health, performance, and welfare problems (Glatz et al., 2005; Ruhnke et al., 2015). Vigorous or severe feather pecking (SFP) is a persistent multifactorial behaviour with a broad range of causative agents including environment, genetics and social engagement (Hartcher et al., 2015). While SFP is a serious threat to animal welfare leading to injuries and increased mortality, economical losses such as reduced production and impaired feed intake of de-feathered birds are also of concern (Huber-Eichler and Wechsler, 1998; Lambton et al., 2010). Blokhuis et al. (2007) collected data in Europe regarding the welfare of non-cage hens and found severe feather pecking in 40-80% of flocks investigated. Additionally, lower mortality and better plumage was found in beak trimmed flocks compared with non-beak trimmed flocks, especially in brown genotypes, the primary layer birds used in Australia (Grandin and Deesing 2014). Farmers are advised to optimise housing and management, but despite best efforts, the problem of feather pecking is on-going. Furthermore, several animal welfare organisations throughout the world are opposed to beak-trimming of hens, which has already resulted in a ban in several countries (Petek and McKinstry, 2010, Gilani et al., 2013). The reason for this is that the beak has very developed linkages with the trigeminal nerve and the Herbst and Merkel Corpuscles specialised dermal papillae on the tip of the beak have a number of free nerve endings (Gentle, 1986a). In respect to the sensory innervation, beak-trimming, especially hot-blade trimming, can result in a loss of sensory to the animal. Thus the removal of sensory receptors can lead to a reduction in feed consumption, pecking efficiency, and touch response (Gentle, 1986b). Poor beak-trimming can result in poor beak conditions (crossed beak, bubble beak, short beaks, split beaks), thus leading to difficulty in feeding especially when feeding a mashed diet.

Currently, a major review of the Australian code of welfare for laying hens is under investigation. If beak-trimming was to be banned, understanding causes for severe feather pecking will become even more relevant, as birds that are non-beak trimmed have significantly higher levels of cannibalism, vent pecking and cause much higher levels of plumage and skin damage than flocks that are beak trimmed. Based on information from the recent Poultry CRC survey conducted in Australia, around 50% of the free range farms contacted did not beak trim their birds, and based on plumage scoring the vast majority were affected by severe feather pecking and/or cannibalism (Poultry CRC 2014, unpublished). Additionally, a large number of the farms surveyed were based on mobile sheds, as opposed to fixed range sheds.

Research indicates environmental enrichment, such as foraging material or perches is accompanied with reduced feather pecking (El-Lethey et al., 2000; Huber-Eicher and Audigé 1999). While the addition of environmental enrichment such as hay bales or pecking stones specifically aims to reduce pecking behaviour, there are few published studies. However, the use of pecking stones is routine in many European poultry facilities and integrated as part of best practice housing for laying hens. While pecking at the stones can be seen as part of the hen's ‘natural’ behaviour, the hens wear away the abrasive stone material as well as the beak tip. Thus, the beak of hens with access to pecking stones may get blunted or at least shortened. The abrasive function of the pecking stones may result in beak-trimming performed by the bird itself. Therefore the ability of the bird to damage and/or cannibalise conspecifics is minimised. However, while it is assumed that the extent of beak blunting or shortening will vary with an individual’s use of the pecking stones, the effect of this kind of beak-trimming on the ability of feed selection and subsequently feed intake is not known and requires investigation as a ‘welfare-friendly’ method of beak-trimming.

This study was conducted to evaluate the impact pecking stones and the interaction of pecking stones with the housing style (fixed or mobile sheds) and the age of the hens on pecking and feeding behaviour in free range laying hens. Aspects of behaviours investigated included feather pecking and cannibalism, body weight, feed selection, feed intake, and laying performance.

4.2. Methodology

4.2.1. Animal experiment

The experimental procedure was reviewed and approved by the University of New England Animal Ethics Committee (AEC15-008). Two commercial free-range egg producers were subject of this experiment. Both farms represented different but common housing conditions: fixed and mobile free range sheds. A total of 18 flocks were examined on both farms (fixed sheds n = 10; mobile sheds n = 8). On each farm, commercial egg laying flocks were equally divided into control and treatment groups. Treatment flocks were offered one pecking stone (approx. 10 kg) per 1000 birds every ten weeks. Hens of the control group were housed under the exact same conditions, but not exposed to pecking stones. These paired control and treatment groups were placed on the same day with hens of the same age (16 weeks) and breed (Hy-line brown). Variations of hen behaviour due to different rearing were taken into account by evaluating control and treatment flocks from the same batch of reared pullets. This mean that pullets were reared together and then split up into two flocks (control vs. treatment) when placed in two identically equipped layer sheds. These layer flocks were then randomly assigned to a treatment and a control group respectively. Hens of the associated control and treatment groups were evaluated on exactly the same time point throughout the experiment with an interval of ten weeks (16, 26, 36, 46, 56, and 66 weeks of age). Due to economic decisions, the farm with mobile sheds was closed down before any flock could be evaluated at 66 weeks of age. Flocks on this farm could only be evaluated until 56 weeks of age.

4.2.2 Pecking stones usage

Pecking stones were introduced to the flocks of the treatment groups when the hens were 16 weeks of age. One pecking stone/1000 hens, weighing 10 kg, was placed inside the shed (figure 1). Hence, hens on farm A, with 20,000 hens/flock, were exposed to 20 pecking stones, while hens on farm B, with 2000 hens/shed, were exposed to 2 pecking stones. Every 10 weeks an additional pecking stone/1000 hens was placed inside of the shed regardless of whether the pecking stones from previous time points had diminished or not. In order to determine the pecking stone usage, all stones were weighed at the evaluation time points (when hens were 26, 36, 46, 56, 66 weeks of age).

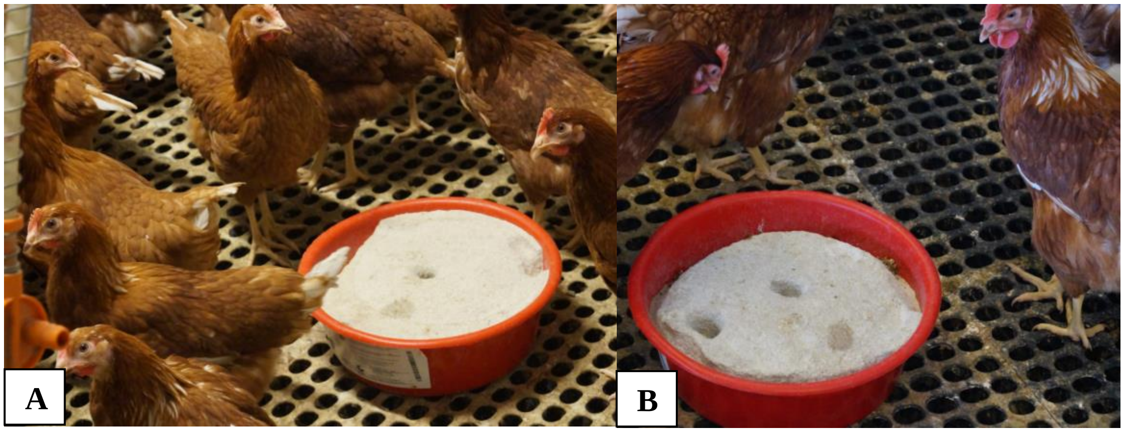

Figure 1: Pecking stones inside the housing facilities of a treatment flock two days (A) and 10 weeks (B) after being placed.

4.2.3 Performance of the flocks

At each time point data regarding feed intake, body weight, egg production, egg weight, and cumulative mortality of each flock was obtained from the farm managers. This data was used to investigate the overall effect of age, farm type/management and pecking stone on the performance parameters and liveability of birds, and to validate data obtained by the researchers with the overall flock data.

4.2.4 Feather pecking and plumage deterioration

At each time point (starting from 16th and ending at 66th weeks of age), 50 hens from each flock were randomly selected from 5 different shed locations and were evaluated for body weight (Mini crane scale, Model OCS_L, Anyload Llc, New Jersey, USA), toenail length (measuring tape) and beak length (Vernier callipers Supatool®, Kincrone Pty Ltd, Scoresby, VIC). The plumage condition of individual hens was evaluated on a scale from 1 (no feathers) to 4 (full feather coverage) following the method described by Tauson *et al.* (2005).

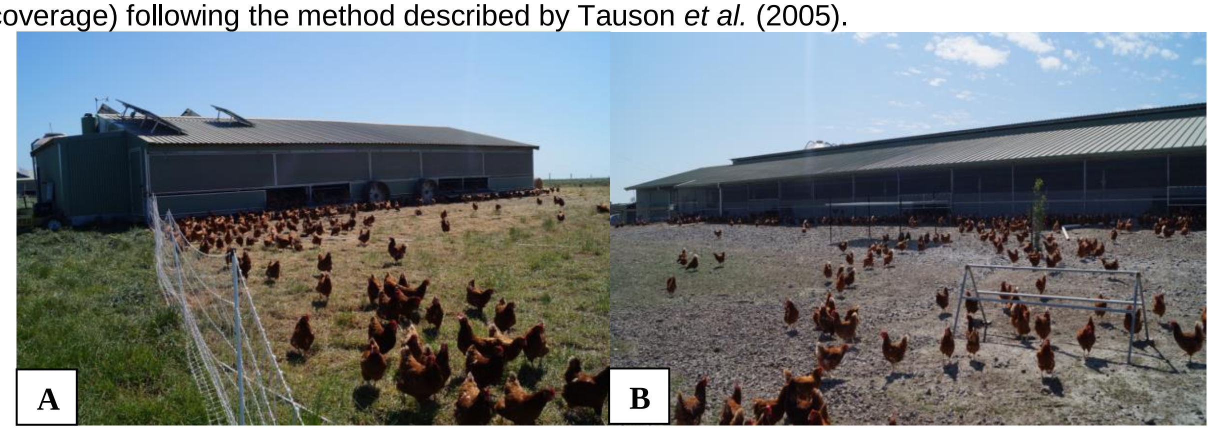

Figure 2: Pecking stones were investigated in mobile sheds housing 2,000 hens/flock (A), and fixed sheds housing 20,000 hens/flock.

Figure 3: Laying hen being feather pecked on back, vent, and tail.

4.2.5 Individual feed intake, feed selection and feeding behaviour

At each time point (starting form 16th and ending 66th weeks of age) 10 birds were randomly selected from each control and treatment group, and individually placed in a cage which was present in each shed during the entire housing period (figure 4). Each hen was offered 250g mash feed (their commercial diet collected straight from the silo) and water (figure 5). Feed intake and feed selection was then monitored for 24 hours. Once the 24-hour period had elapsed, leftover feed from each hen was removed and weighed to calculate feed intake, and collected for feed particle size distribution (dMEAN), as well as weende analysis. Feed samples from the silo were also used for analysis of DMEAN and weende. In order to evaluate the impact of stress on the hen, the individual body weight per hen was evaluated immediately before and after the 24 hour period using a mobile scale (Mini crane scale, Model OCS_L, Anyload Llc, New Jersey, USA). In order to correlate feed intake and feed selection the individual hen beak length was measured using Vernier callipers (Supatool®, Kincrone Pty Ltd, Scoresby, VIC).

Figure 4: Cage system to evaluate individual feed intake and feed selectivity during a 24-hour observation period. In order to minimise stress on the hens, and to monitor feed intake and feed selection as accurately as possible, the cage was placed into the shed before populating it and was continuously present. On the left side of this picture, the automatic scale for monitoring flock weight is visible.

Figure 5: Hens being placed in the cage unit for evaluation of individual feed intake and feeding behaviour. The white feeder cups shown in this pre-trial set up were later replaced with custom-made deep metal feeders that prevented any feed spillage and wastage.

The collected left over feed samples, as well as the original feed sampled were used for sieving and particle size distribution following the method described by Herrera et al. (2016) and as indicated by ASAE (Standard) by using a mechanical sieve shaker (Retsch AS 200 digit CA, Retsch GmbH, Haan, Germany) at Amplitude 3.0 for the duration of 5 minutes. Sieve diameters used were 4.0 mm, 2.8 mm, 2 mm, 1.6 mm, 1.25 mm, 1 mm, 500 µm, and 250 µm. For weende analysis, samples were also processed using a 0.50 mm mesh size grinder. Protein analysis was performed using nutrient nitrogen estimation with the the Leco trueSpec series. The method is based on dumas method of combustion which consist of three steps, purge, burn and analyser. Briefly, 0.1 g sample encapsulated in aluminium foil was placed in the head, sealed and vacuumed. During the burning phase, the sample dropped into the primary furnace (950 ^{o}C) and flushed with pure oxygen for rapid combustion. Afterwards, the combustion product was passed through the after burner furnace, the furnace filter, pre cooler and thermoelectric cooler before being collected into the ballast volume. During the analyser phase, combusted gases in the ballast were homogenised by passive mixing. A series of infra-red detectors measured the evolved gases for carbon and hydrogen and aliquots were captured for final results. Mineral estimation was performed using the Ultrawave Microwave digestion technique (Milestone UltraWave, Sorisole, Italy).

4.2.6 Statistical analysis

Data were analysed using a general linear model with 2 (fixed shed vs mobile shed) x 2 (treatment vs control) x 6 (time point) arrangement. Outliers were detected and removed using Grub's Test (Grubbs, 1950) for outliers. Means were compared using Tukey's range test. All statistical analyses were performed using SPSS version 2.0 (IBM, Chicago, IL, USA).

4.3. Results

4.3.1 Performance

Flocks performance data was obtained from farm manager at each time point and is shown in table 1. Data analysis showed a significant effect ($p<0.05$) of farm type on pecking stone consumption. Hens on mobile sheds consumed higher amount (19.7 kg/1000 hens) of pecking stones as compared to fixed sheds (13.9 kg/1000 hens). Farm type (fixed shed vs. mobile sheds) had a significant effect ($p<0.05$) on average egg production and cumulative mortality. A significantly higher egg production (74.2 %) was observed in hens housed in fixed sheds compared to hens housed in mobile sheds (64.4 %). A significantly higher cumulative mortality (5.63 %) was observed in mobile sheds compared to fixed sheds (4.49 %). The age of hens had a significant effect ($p<0.05$) on pecking stone consumption (at the beginning of the evaluation period: 5.93 kg/1000 hens vs. 28.1 kg/1000 hens at the end of the evaluation period), egg production, cumulative mortality (1.31% vs. 9.65 %) and average egg weight (56.6 g vs. 61.6 g).

4.3.2 Plumage deterioration

Pecking stones had no significant effect ($p>0.05$) on plumage condition on any part of the body. The effect of pecking stones, farm type and hen age on feather pecking is indicated in table 2. Farm type had a significant effect ($p<0.05$) on neck, back, breast, and tail feather cover. Significantly lower feather scores neck (3.57) and breast (2.70) were recorded on hens housed in fixed sheds compared to hens housed in mobile sheds (3.89 and 3.25, respectively). In contrast, lower scores of back (3.13) and tail (3.24) feathers were recorded on hens housed in mobile sheds compared to hens housed in fixed sheds (3.52 and 3.49, respectively). The age of the hens had a significant ($p<0.05$) effect on feather score neck, back, vent, breast, wing, and tail feather score. A higher feather score neck (3.99), back (3.99), vent (4.00), breast (3.97), wings (4.00), and tail (3.99) was at hen placement, which worsened and decreased with age reaching the lowest score of 2.70, 2.51, 2.60, 1.25, 2.57 and 2.35 of neck, back, vent, breast wings and tail respectively at 66 weeks of age. A significant farm/time point interaction was observed on the feather scores of all body parts. There was no significant interaction between time points / pecking stone or farm / time point / pecking stone on feather score of any parts of the body.

4.3.3 Individual feed intake and feed selection

Feed intake of hens observed for 24 hours did not differ from overall feed intake of the flock, and individual body weight before and after the 24 hour period was consistent (data not shown). Pecking stone did not show any significant ($p>0.05$) effect on any feed parameters investigated (table 3 and 4). Data analysis showed significant effect ($p<0.05$) of farm type on feed intake, beak length, and mean diameter particle size (dMEAN) of leftover feed. Hens housed in mobile sheds had significantly ($p<0.05$) longer beaks (16.0 mm) and consumed higher amount of feed (116g/hen/day) compared to hens housed in fixed sheds (13.9 mm, and 106 g/hen/day, respectively). The different beak lengths could be associated with a significant ($p<0.05$) different feed particle selection. Although hens housed in fixed sheds were offered feed with relatively higher dMEAN particle size (2.03 ±0.02 mm) compared to hens housed in mobile sheds (1.68 ±0.03 mm), they left relatively smaller feed particles (dMEAN 1.74 ±0.05 mm) compared to hens housed in mobile sheds (1.91 ±0.05 mm). A significant interaction of farm type and time of age was observed in dMEAN of feed leftovers. Age of the hens had a significant effect on feed intake and toe nail length. A lower feed intake (87.2 g/hen/day) was recorded at the age of 16 weeks, compared to an increased amount (108 g/hen/day) at the age of 66 weeks. Toe nail length showed a parabolic effect with respect to age. Length was short (1.61 mm) at 16 weeks, but increased

(1.74 mm) at 26 weeks and reduced again at 46 weeks (1.69 mm), and 56 weeks (1.69 mm) of age, before reaching a final length of 1.83 mm at the age of 66 weeks.

In table 4, crude protein (CP) and mineral intake of hens are indicated. The farm type had a significant effect ($p<0.05$) on CP and minerals intake. Hens housed in fixed shed hens consumed a significantly higher amount of calcium (Ca) as indicated by less amounts detectable in feed leftovers (4.18 g/100 g respectively), compared to hens housed in mobile sheds (5 g/100 g). However, fixed shed hens consumed less CP and iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), and sodium (Na) compared to mobile sheds as indicated by higher amounts of CP (21.1 g/100 g vs. 18.5 g/100 g), Fe (38.5 mg/100 g vs. 27.4 mg/100 g), K (0.079 g/100 g vs 0.062 g/100 g), Mg (0.023 g/100 g vs 0.019 g/100 g), Mn (19.3 mg/100 g vs 15.1 mg/100 g), and Na (0.25 g/100 g vs 0.18 g/100 g) in leftover feed. Age of the hens also showed a significant effect ($p<0.05$) on some minerals intake. Less intake at the age of 16 weeks as indicated by higher amount in leftover feed of K (0.73%), Mn (190 ug/g), and P (0.79) was decreased to K (0.62 g/100 g), Mn (171 ug/g), and P (0.44 g/100 g) at the age of 66 weeks in feed leftovers. A significant farm/pecking stone and farm/time point interaction was observed for Na and K intake respectively.

Table 1. The effect of pecking stone, farm type and age of the birds on pecking stone intake, cumulative mortality, egg production, and egg weight[1]

Parameters		Pecking stone intake (kg /1000 hens)	Cumulative mortality (%)	Egg production (%)	Egg weight (g)
Farm (F)[2]	**A**	13.9^{b} ±2.02	4.49^{a} ±0.51	74.23^{a} ±4.27	49.8 ±3.02
	B	19.7^{a} ±2.51	5.63^{b} ±1.20	64.37^{b} ±2.54	-----
Treatment (TR)[3]	**control**	-----	5.03 ±0.82	72.9 ±4.47	49.8±4.31
	pecking stone	16.0 ±1.62	4.36 ±0.71	70.6 ±4.93	49.9 ±4.31
Time point[4] (T)	**16 weeks[α]**		1.31^{a} ±0.67	0.00^{a}	-----
	26 weeks[β]	5.93^{a} ±1.38	3.14^{ab} ±1.17	81.5^{ab} ±3.58	56.6^{a} ±0.37
	36 weeks[γ]	12.0^{a} ±2.45	4.05^{ab} ±0.82	77.0^{b} ±4.38	60.4^{b} ±0.33
	46 weeks[Ω]	19.0^{b} ±3.38	6.31^{bc} ±0.60	84.3^{b} ±2.16	61.6^{b} ±0.30
	56 weeks[ε]	23.5^{bc} ±1.59	7.85^{c} ±0.57	84.4^{b} ±2.40	61.6^{b} ±0.26
	66 weeks[π]	28.1^{c} ±2.78	9.65^{c} ±0.87	80.8^{b} ±0.79	61.0^{b} ±0.27
P-value	**F**	0.00	0.00	0.00	-----
	TR	-----	0.40	0.46	0.94
	T	0.00	0.00	0.00	0.00
	FxTR	-----	0.84	0.91	-----
	FxT	0.09	0.85	0.15	-----
	TRxT	-----	0.93	0.42	0.97
	FxTRxT	-----	0.58	0.67	------

[1] mean values

[2] Farm: n = 2 A = fixed sheds, flock size 20,000 hens/shed; B = mobile sheds, flock size 2,000 hens/shed,

[3] Treatment: after every 10 week, 10 kg pecking stone/1000 birds were placed in all treatment flocks. A total of 5 control and 5 treatment flocks in fixed sheds and 4 control and 4 treatment flocks in mobile sheds were investigated

[4] Time point α = 9 replicates per treatment/control group; β = 9 replicates per treatment/control group; **γ** = 9 replicates per treatment/control group; **Ω** = 9 replicates per treatment/group; **ε** = 9 replicates per treatment/group; π = 8 replicates per treatment/group

Table 2: The effect of pecking stone, farm type and age on plumage deterioration of free range egg laying hens[1]

Parameters		Feather scoring[2]					
		Neck	**Back**	**Vent**	**Breast**	**Wings**	**Tail**
Farm (F)[3]	**A**	$3.57^{b}\pm0.09$	$3.52^{a}\pm0.08$	3.66 ± 0.07	$2.70^{b}\pm0.15$	3.57 ± 0.08	$3.49^{a}\pm0.09$
	B	$3.89^{a}\pm0.02$	$3.13^{b}\pm0.16$	3.53 ± 0.12	$3.25^{a}\pm0.03$	3.68 ± 0.05	$3.24^{b}\pm0.15$
Treatment (TR)[4]	**control**	3.60 ± 0.10	3.34 ± 0.11	3.61 ± 0.08	2.85 ± 0.16	3.54 ± 0.10	3.34 ± 0.12
	pecking stone	3.78 ± 0.06	3.43 ± 0.12	3.62 ± 0.10	2.92 ± 0.15	3.69 ± 0.06	3.46 ± 0.12
Time point (T)[5]	**16 weeks[α]**	$3.99^{a}\pm0.00$	$3.99^{a}\pm0.00$	$4.00^{a}\pm0.00$	$3.97^{a}\pm0.01$	$4.00^{a}\pm0.00$	$3.99^{a}\pm0.00$
	26 weeks[β]	$3.99^{a}\pm0.00$	$3.70^{ab}\pm0.13$	$3.95^{ab}\pm0.03$	$3.85^{a}\pm0.02$	$3.98^{a}\pm0.01$	$3.99^{a}\pm0.00$
	36 weeks[γ]	$3.91^{a}\pm0.03$	$3.28^{ab}\pm0.24$	$3.58^{ab}\pm0.17$	$3.08^{b}\pm0.14$	$3.78^{a}\pm0.07$	$3.39^{b}\pm0.20$
	46 weeks[Ω]	$3.67^{a}\pm0.11$	$3.33^{ab}\pm0.16$	$3.62^{ab}\pm0.16$	$2.52^{c}\pm0.13$	$3.70^{a}\pm0.05$	$3.28^{b}\pm0.18$
	56 weeks[ε]	$3.19^{b}\pm0.24$	$3.06^{bc}\pm0.16$	$3.42^{b}\pm0.12$	$1.69^{d}\pm0.16$	$2.94^{b}\pm1.70$	$2.86^{b}\pm0.16$
	66 weeks[π]	$2.70^{b}\pm0.29$	$2.51^{c}\pm0.23$	$2.60^{c}\pm0.23$	$1.25^{d}\pm0.06$	$2.57^{c}\pm0.22$	$2.35^{bc}\pm0.27$
P value	**F**	0.04	0.01	0.07	0.00	0.562	0.00
	TR	0.06	0.47	0.83	0.62	0.18	0.30
	T	0.00	0.00	0.00	0.00	0.00	0.00
	FxTR	0.30	0.98	0.25	0.38	0.00	0.98
	FxT	0.02	0.02	0.00	0.00	0.00	0.01
	TRxT	0.45	0.97	0.81	0.91	0.26	0.95
	FxTRxT	0.83	0.97	0.77	0.79	0.03	0.77

[1] In each flock 50 birds were randomly selected every 10 weeks, results are reported as means values

[2] Feather scoring was performed by scoring individual hens on a 1-4 scale with 1: no feather cover, 4: full feather cover

[3] Farm: n = 2, A= fixed sheds, flock size 20,000 hens/shed; B = mobile sheds, flock size 2,000 hens/shed

[4] Treatment: after every 10 week, 10 kg pecking stone/1000 birds were placed in all treatment flocks. A total of 5 control and 5 treatment flocks in fixed sheds and 4 control and 4 treatment flocks in mobile sheds were investigated

[5] Time point α = 9 replicates per treatment/control group; β = 9 replicates per treatment/control group; **γ** = 9 replicates per treatment/control group; **Ω** = 9 replicates per treatment/group; **ε** = 9 replicates per treatment/group; **π** = 8 replicates per treatment/group

Table 3: Effect of pecking stone, farm type and age on feeding behavior in free range laying hens[1]

Parameters		Body weight (kg)	Feed intake (g/hen/day)	Upper beak length (mm)	Toe nail length (mm)	dMEAN of offered feed (mm)	dMEAN of leftover feed (mm)
Farm (F)[2]	**A**	1.84±0.02	106^{b} ±2.31	13.9^{b} ±0.10	1.70 ±0.02	2.03^{a}±0.02	1.91^{a}±0.05
	B	1.88±0.04	116^{a} ±2.41	16.0^{a} ±0.31	1.67 ±0.01	1.68^{b}±0.03	1.74^{b}±0.05
Treatment (TR)[3]	**control**	1.85±0.03	110 ±2.24	14.7 ±0.25	1.72 ±0.02	1.88±0.04	1.77±0.04
	pecking stone	1.87±0.02	109 ±2.83	14.6 ±0.22	1.66 ±0.01	1.90±0.04	1.92±0.06
Time point (T)[4]	**16 weeks$^{\alpha}$**	1.50^{a}±0.03	87.2^{a} ±4.26	14.3^{a} ±0.55	1.61^{a} ±0.02	1.86±0.06	1.77±0.07
	26 weeks$^{\beta}$	1.79^{b}±0.04	118^{b} ±4.78	14.1^{a} ±0.39	1.70^{a} ±0.01	1.86±0.06	1.89±0.11
	36 weeks$^{\gamma}$	1.92^{c}±0.01	114^{b} ±3.20	14.8^{b} ±0.44	1.69^{a} ±0.03	1.80±0.06	2.01±0.09
	46 weeks$^{\Omega}$	1.98^{c}±0.02	114^{b} ±3.11	15.2^{b} ±0.37	1.69^{a} ±0.03	1.86±0.07	1.74 ±0.06
	56 weeks$^{\varepsilon}$	1.97^{c}±0.02	108^{b} ±1.47	14.8±0.15	1.65^{a}±0.03	2.04 ±0.06	1.79 ±0.11
	66 weeks$^{\pi}$	1.96^{c}±0.01	108^{b} ±3.21	14.2±0.31	1.83^{b}±0.05	2.10±0.06	1.85±0.04
P-value	**F**	0.07	0.02	0.00	0.61	0.00	0.01
	TR	0.51	0.70	0.73	0.05	0.94	0.13
	T	0.00	0.00	0.15	0.01	0.30	0.19
	FxTR	0.80	0.38	0.54	0.53	0.41	0.29
	FxT	0.01	0.59	0.03	0.15	0.37	0.04
	TRxT	0.00	0.61	0.99	0.67	0.51	0.26
	FxTRxT	0.00	0.77	0.98	0.67	0.95	0.89

[1]In each flock and for each me point, 10 hens were individually investigated, mean values of those 10 hens are presented

[2] Farm: n = 2, A = fixed sheds, flock size 20,000 hens/shed; B= mobile sheds, flock size 2,000 hens/shed

[3] Treatment: after every 10 week, 10 kg pecking stone/1000 birds were placed in all treatment flocks. A total of 5 control and 5 treatment flocks in fixed sheds and 4 control and 4 treatment flocks in mobile sheds were investigated

[4] Time point α = 9 replicates per treatment/control group; β = 9 replicates per treatment/control group; γ = 9 replicates per treatment/control group; Ω = 9 replicates per treatment/group; ε = 9 replicates per treatment/group; π = 8 replicates per treatment/group

Table 4: Effect of pecking stone, farm type and age on CP and mineral content of feed leftover[1]

Parameters		Nutrients in leftover feed[2]									
		CP (g/100 g)	**Ca** (g/100 g)	**Cu** (mg/100 g)	**Fe** (mg/100 g)	**K** (g/100 g)	**Mg** (g/100 g)	**Mn** (mg/100 g)	**Na** (g/100 g)	**P** (g/100 g)	**Zn** (mg/100 g)
Farm (F)[3]	**A**	21.1^{a}	4.18	1.36	38.5^{a}	0.79^{a}	0.23^{a}	19.3^{a}	0.25^{a}	0.69	13.3
	B	18.5^{b}	5.00	1.24	27.4^{b}	0.62^{b}	0.19^{b}	15.1^{b}	0.18^{b}	0.73	12.4
Treatment (TR)[4]	**control**	20.4	4.59	1.32	33.1	0.73	0.21	17.7	0.22	0.70	13.8
	pecking stone	19.9	4.42	1.32	34.5	0.72	0.21	17.4	0.22	0.70	12.2
Time point(T)[5]	**16 weeks$^{\alpha}$**	20.1	4.37	1.42	33.3	0.73^{ab}	0.210	19.0^{a}	0.22	0.79^{a}	12.6
	26 weeks$^{\beta}$	22.9	4.22	1.46	31.7	0.77^{ab}	0.21	18.5^{a}	0.23	0.80^{a}	12.9
	36 weeks$^{\gamma}$	21.1	4.26	1.23	33.0	0.79^{a}	0.22	18.0^{ab}	0.23	0.77^{a}	13.3
	46 weeks$^{\Omega}$	18.8	4.81	1.36	35.1	0.69^{ab}	0.21	14.9^{b}	0.21	0.71^{ab}	13.5
	56 weeks$^{\varepsilon}$	18.6	5.16	0.99	37.3	0.65^{ab}	0.22	17.0^{ab}	0.22	0.61^{bc}	12.4
	66 weeks$^{\pi}$	17.8	4.58	1.36	34.8	0.62^{b}	0.21	17.1^{ab}	0.22	0.44^{c}	12.5
	SEM	0.38	1.25	0.06	1.16	0.01	0.00	4.36	59.0	0.01	0.36
P-value	**F**	0.01	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.38	0.27
	TR	0.13	0.60	0.82	0.09	0.80	0.40	0.97	0.47	0.31	0.10
	T	0.19	0.11	0.32	0.72	0.00	0.98	0.00	0.38	0.00	0.87
	FxTR	0.29	0.87	0.99	0.50	0.52	0.57	0.51	0.03	0.15	0.18
	FxT	0.04	0.70	0.83	0.89	0.00	0.43	0.71	0.54	0.06	0.31
	TRxT	0.26	0.05	0.53	0.20	0.75	0.05	0.13	0.17	0.39	0.36
	FxTRxT	0.89	0.95	0.89	0.92	0.84	0.80	0.39	0.36	0.78	0.98

[1]In each flock and for each me point, 10 hens were individually investigated, mean values of those 10 hens are presented

[2] CP = crude protein; Ca = calcium; Cu = copper; Fe = iron; K = potassium; Mg = magnesium; Mn = manganese; Na = sodium; P = phosphorus; Zn = zinc,

[3] Farm: n = 2, A = fixed sheds, flock size 20,000 hens/shed; B= mobile sheds, flock size 2,000 hens/shed

[4] Treatment: after every 10 week, 10 kg pecking stone/1000 birds were placed in all treatment flocks. A total of 5 control and 5 treatment flocks in fixed sheds and 4 control and 4 treatment flocks in mobile sheds were investigated

[5] Time point α = 9 replicates per treatment/control group; β = 9 replicates per treatment/control group; γ = 9 replicates per treatment/control group; Ω = 9 replicates per treatment/group; ε = 9 replicates per treatment/group; π = 8 replicates per treatment/group

4.4 Discussion of results

4.4.1 Performance data

Performance data of each flock obtained from farm manager at each time point showed that hens on mobile shed consumed relatively larger amounts of pecking stone, had higher egg production and higher cumulative mortality. Hens housed in mobile sheds demonstrated a relatively larger number of aggressive peckers resulting in severe feather pecking (SFP) which may explain the higher cumulative mortality which was up to 14.1 % in individual flocks at the age of 56 weeks. These high mortalities were especially observed in flocks where hens had relatively longer beaks (16.0 mm) and low feather score on back and tail. One can only speculate what mortality and egg production data could have been observed when hens were 66 weeks of age, but as age was a significant factor influencing these parameters, the performance indicators can be expected to decrease. Hens housed in mobile sheds had numerically, but not significantly shorter toe nail length. Short toe nails can resulting from the abrasive action of ranging. Thus it may be speculated, that ground pecking can be redirected to feather pecking in hens hat range less (Huber-Eicher and Wechsler, 1997; Blokhuis, 1986). Once SFP is introduced to a flock, the habit can be transmitted through social behaviour (Zeltner et al., 2000). Severe feather pecking can result in higher energy demands to regulate body temperature, increased stressed and fearfulness, thus leading to deteriorated egg production on these farms (Sommer and Vasicek, 2000). The results of the present study are in line with the findings of Nagle et al., (2008) who reported feather pecking, vent pecking and cannibalism as the major causes of high mortality, low profitability, and economical losses in egg laying hens in all states across Australia. It was further confirmed by Ruhnke et al. (2015) who performed a survey in which farmers indicated cannibalism as one of the major causes of high mortality in free range hens in Australia.

4.4.2 Plumage deterioration

The term feather pecking can be defined as the pulling out and, in some cases, consumption of feathers from different body parts (Bilčík and Keeling, 2000). As described in results (table 5), the farm type had a significant effect on feather pecking behaviour of hens. In hens housed in fixed sheds, neck and breast were scored significantly lower than neck and breast of hens housed in mobile sheds. Some studies reported that damage to plumage covering breast is mainly caused by abrasive action such as usage of a specific feeding system instead of feather pecking behaviour (Kjaer and Sørensen, 2002). With that having been said, the hens on mobile sheds did show a significantly lower feather score on the back and tail which can be associated with severe feather pecking leading to cannibalism (Kjaer and Sørensen, 2002). These hypothesis can be supported by the fact that flocks of this housing system had also higher cumulative mortalities. One possible reason of the difference in pecking behaviour is the beak length and the ranging activity: hens housed on both type of farms had significantly different beak length. Hens that were housed in mobile sheds had relatively longer beaks in comparison to hens housed in the fixed sheds with higher ranging and ground pecking which was redirected to feather pecking.

The results of the present study disagrees with past studies that reported pecking behaviour linked with flock size. Hughes and Duncan (Hughes and Duncan) reported higher feather pecking in large flock size. However, feather pecking, being a social behaviour, depends on the number of aggressive peckers within the flock, irrespective of flock size. It is highly volatile and many large commercial flocks might not have feather pecking problems at all (Bilčík and Keeling, 2000). Increasing flock size does not necessarily increase size of aggressive peckers either. Pagel and Dawkin (1997) proposed that birds in large groups employ an alternative strategy in establishing relations with flock mates. Large flocks have less aggressive peckers (Lindberg and Nicol, 1996, Hughes et al., 1997) when compared to small flocks. This was true in the present study, and higher feather pecking in smaller flocks was observed. Age had a significant impact on plumage deterioration with an onset at 26 weeks of age leading to the lowest scoring at 66 weeks of age.

4.4.3 Individual feed intake and feed selection

The beak length of hens is an important factor in feed particle selection. In addition, a significantly lower feed intake has been reported in hens with shorter beaks compared to those with longer beaks even though shorter beaked hens would peck more frequently on feeders and spent more time feeding than longer beaked hens (Glatz, 2003, Portella et al., 1988). In the current study, hens housed in mobile sheds had significantly longer beaks than hens housed in fixed sheds. Results of feed intake on both farms and particle selection can be explained through different beak length and may be a result of reduced pecking efficiency and touch response n hens with shorter beaks (Gentle et al., 1982, Gentle, 1986a, Glatz and Lunam, 1994). The results of the present study also indicated that hens housed in fixed sheds 'scooped' feed particles, resulting in a non-selective eating while hens housed in mobile sheds selected specifically smaller feed particles, resulting in a higher dMEAN in the left over diet than in the diet that was initially offered. Subsequently, hens with shorter beaks ingested more minerals and vitamins, as the micro ingredients and the premix are usually present in the smaller fraction of the particle sizes. Thus these hens modified their offered diets which may lead to imbalanced in the long term, which maybe one of the reasons for the reduced egg production observed I these flocks (table 1). In the present study, the feeding behaviour of larger particle selection in long beaked hens had a pronounced effect on nutrient intake. Longer beaked hens housed in mobile sheds consumed significantly more CP, Fe, K, Mg, Mn, and Na, as less amounts of these minerals were present in leftover feed. It has been stated that non trimmed hens used to peck while beak trimmed hens employed a scooping method for feeding (Persyn et al., 2004). In detail, hens with a beak lengths of 10-11 mm have been shown to scoop feed while hens with longer beaks (13-15 mm) length use pecking (Glatz, 2003). While the beaks of hens in the present study can be both considered as long (the average beak length of hens housed in fixed sheds was 13.9 mm and average beak length of hens housed in mobile sheds was 16.0 mm), we still observed significant different feed selection. Regression analysis of the beak length, and Δ dMEAN would be useful to investigate further.

4.4.5. Conclusion

Feather pecking is a highly detrimental social behaviour in free range laying hens that leads to serious welfare, health and economical losses. This study investigated the use of environmental enrichment (pecking stones), housing systems, and age of hens on hen production, feather pecking and feeding behaviour. Based on the results obtained, the use of 10kg pecking stones/1000 hens, had no impact on hen performance, beak length and feed intake. It has been demonstrated that in this study the housing system played a major role in hen welfare and was a key factor in hen mortality, feeding behaviour and egg production. Fixed sheds may be preferred to mobile sheds as they may be easier to manage and provide a more protective environment. The equivocal results of pecking stones and housing system on feather pecking may lead to the conclusion that key factors of feather pecking behaviour may be predisposed during earlier life stages. In conclusion, investigating of environmental enrichment during rearing is highly warranted.

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5. Implications

- A continuum of enrichment structures on the range did result in more hens on the range.

- Our results confirm that outdoor birds have less feather damage than those birds in the shed.

- A combination of various structures are required on the range to cater for the hens' strong sheltering instincts along with their foraging, exploration and dustbathing behaviours. These can be provided mainly in the form of shelters, hay bales and sand bathing pits.

- Orange traffic cones can be used to attract hens.

- Trees on the range are highly utilised for cover while hens dustbathe, scratch and peck at the ground underneath trees.

- Trees can be damaged by all the hen activity around their root zone and this damage is more likely to occur on sandy textured soils.

- Peck stones used in the shed as enrichment had no impact on hen performance, beak length and feed intake

- The type of housing system (fixed vs mobile) had played a major role in hen welfare and was a key factor in hen mortality, feeding behaviour and egg production.

- Fixed sheds were of significant benefit to hens investigated in this study regarding egg production, feed intake, cumulative mortality and egg production.

6. Recommendations

- It would be highly worthwhile to construct a map showing the location of any existing trees on the range. Shelters can then be placed in the large open areas providing a bridge to trees further out on the range.

- Shelters can be simple and inexpensive and placed at regular intervals, probably no more than 15 -20m apart and can start close to the shed at 20m.

- A combination of shelters, hay bales, attractants are required to fulfil a range of behaviours.

- Dust bathing pits can be simple piles of sand deposited on the range.

- We do not recommend sand filled tyres as they can create attractive egg laying sites.

- Long term overhead cover can be provided by planting small forested areas. Although there is some concern with trees attracting wild birds.

- Further investigation about the use of environment enrichment such as the impact of pecking stones during rearing is warranted.

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POULTRY CRC

Plain English Compendium Summary

Sub-Project Title:	Determination of best practice range enrichment to improve layer bird welfare.
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Sub-Project Overview	The project was conducted in two components on commercial layer farms in South Australia and Victoria. Component 1 examined the outdoor range enrichment by comparing a continuum of enrichment structures vs the standard. The main aim was to attract more hens outdoors and utilise the range more effectively. Structures consisted of shelters, hay bales dust bathing pits and attractants such as traffic cones and peck stones. Component 2 tested the use and feasibility of pecking stones. Two commercial farms with different ranging styles (e.g. mobile and fixed shed) that frequently face severe feather damage and cannibalism were the subject of this study. Pecking stones were provided and the effect on feather plumage, body condition, and feeding behaviour evaluated for the duration of the laying period.
Background	Behavioural problems such as severe feather pecking can lead to plumage damage and cannibalism and are considered a multi-factorial problem. In a time of changing public expectation regarding acceptable farming practices, procedures such as beak-trimming are unlikely to be allowed in the future based on welfare considerations. Therefore, further research into the management of free range laying hens and use of the range and range enrichments is essential. Opportunities to encourage birds to use of the range, and understanding the complexity of the non-cage systems in Australia, as well as the importance of key resources for hens such as overhead cover, enrichment sources, foraging and dust bathing substrates and pecking "toys" are aspects that should be considered in assessing welfare, production and health of birds within non-cage systems. It appears that only few of these issues have been addressed specifically and individually under Australia's environmental conditions. Therefore there is potential to improve the ranging ability of birds in free range systems by improving the attractiveness of the range, and full utilisation of the range through encouraging investigation. Welfare of the birds will remain a major issue for consumers if birds are not encouraged to range, or use the range ineffectively, as well as exhibiting abnormal behaviours, such as severe feather pecking. Research focussing on a holistic approach of the quality and design of the range is crucial, and combining range coverage (artificial and natural), dust bathing and pecking stones will provide a unique insight in laying hen behaviour, range utilisation and consequences on aggressive behaviour, severe feather pecking, plumage condition, cannibalism and productivity.
Research	Component 1 revealed more hens used the enriched side of the range and overhead cover was instrumental in enticing birds out on the range. Furthermore, hens outside on the range had better plumage with less feather loss and bare skin than those birds in the shed. Component 2 had shown peck stones used in the shed as enrichment during lay had no impact on hen performance, beak length and feed intake. In addition, the type of housing system (fixed vs mobile) had

	played a major role in hen welfare and was a key factor in hen mortality, feeding behaviour and egg production.
Sub-Project Progress	All milestones were completed.
Implications	• A continuum of enrichment structures on the range did result in more hens on the range. • Our results confirm that outdoor birds have less feather damage than those birds in the shed. • A combination of various structures are required on the range to cater for the hens' strong sheltering instincts along with their foraging, exploration and dustbathing behaviours. These can be provided mainly in the form of shelters, hay bales and sand bathing pits. • Orange traffic cones can be used to attract hens. • Trees on the range are highly utilised for cover while hens dustbathe, scratch and peck at the ground underneath trees. • Trees can be damaged by all the hen activity around their root zone and this damage is more likely to occur on sandy textured soils. • Peck stones used in the shed as enrichment during lay had no impact on hen performance, beak length and feed intake. • The type of housing system (fixed vs mobile) had played a major role in hen welfare and was a key factor in hen mortality, feeding behaviour and egg production. • Fixed sheds were of significant benefit to hens investigated in this study regarding egg production, feed intake, cumulative mortality and egg production.
Publications	We intend to publish two papers, one from each component.

Appendix

Table 1: Prevailing weather conditions at the time of each visit to the three commercial egg layer farms in South Australia, April – October 2106.

Date 2016	Hen age (weeks)		Time (am /pm)	Temp. (ºC)	Description
Farm 1					
Apr 18	32		am	19	Partly cloudy, light wind
			pm	25	Partly cloudy, light wind
May 16	36		am	14	Overcast, light intermittent rain, no wind
			pm	21	Sunny, no cloud, moderate to strong wind
Jun 14	40		am	17	Sunny, very light breeze
			pm	20	Sunny, light breeze
Jul 8	44		am	5	Overcast, light breeze
			pm	14	Mostly sunny, no wind
Aug 8	48		am	14	Partly cloudy, light wind
			pm	20	Sunny, light wind
Sep 5	51		am	14	Mostly sunny, light breeze
			pm	17	Mostly sunny, light breeze
Oct 6	55		am	19	Sunny, moderate to strong wind, gusting
			pm	24	Sunny, moderate wind
Farm 2					
	Flock 2-1	Flock 2-2			
Apr 21	37	49	am	23	Overcast, no wind
			pm	21	Sunny, no wind
May 19	41	53	am	18	Sunny, light wind
			pm	18	Overcast, light wind
Jul 14	50	62	am	9	Mostly cloudy, light breeze, light drizzle
			pm	12	Overcast, light breeze, occasional shower
Aug 25	55	67	am	12	Sunny, no wind
			pm	13	Sunny, light breeze
Sep 8	57	69	am	17	Overcast, steady rain, no wind
			pm	16	Overcast, light breeze
Oct 21	63	75	am	13	Overcast, rain over night, moderate wind
			pm	14	Mostly cloudy, short sunny breaks, moderate wind
Farm 3					
May 24	50		am only	16	Sunny, no cloud, light wind
Jun 28	55		am	12	Partly cloudy, light wind
			pm	14	Partly cloudy, light wind
Jul 19	58		am	14	Overcast, no wind, drizzle
			pm	16	Mostly cloudy, short sunny breaks, no wind
Aug 23	63		am	13	Partly cloudy, light breeze
			pm	15	Partly cloudy, short sunny breaks, light breeze
Sep 21	67		am	13	Overcast, light wind
			pm	14	Mostly cloudy, short sunny breaks, light wind, gusting
Oct 11	70		am	13	Mostly cloudy, light breeze
			pm	12	Mostly cloudy, light to moderate breeze