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# Frequent range visits further from the shed relate positively to free-range broiler chicken welfare

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*Little is known about the implications of accessing an outdoor range for broiler chicken welfare, particularly in relation to the distance ranged from the shed. Therefore, we monitored individual ranging behaviour of commercial free-range broiler chickens and identified relationships with welfare indicators. The individual ranging behaviour of 305 mixed-sex Ross 308 broiler chickens was tracked on a commercial farm from the second day of range access to slaughter age (from 16 to 42 days of age) by radio frequency identification (**RFID**) technology. The radio frequency identification antennas were placed at pop-holes and on the range at 2.7 and 11.2 m from the home shed to determine the total number of range visits and the distance ranged from the shed. Chickens were categorised into close-ranging (**CR**) or distant-ranging (**DR**) categories based on the frequency of visits less than or greater than 2.7 m from the home shed, respectively. Half of the tracked chickens (n=153) were weighed at 7 days of age, and from 14 days of age their body weight, foot pad dermatitis (**FPD**), hock burn (**HB**) and gait scores were assessed weekly. The remaining tracked chickens (n=152) were assessed for fear and stress responses before (12 days of age) and after range access was provided (45 days of age) by quantifying their plasma corticosterone response to capture and 12 min confinement in a transport crate followed by behavioural fear responses to a tonic immobility (**TI**) test. Distant-ranging chickens could be predicted based on lighter BW at 7 and 14 days of age ($P=0.05$), that is before range access was first provided. After range access was provided, DR chickens weighed less every week ($P=0.001$), had better gait scores ($P=0.01$) and reduced corticosterone response to handling and confinement ($P<0.05$) compared to CR chickens. Longer and more frequent range visits were correlated with the number of visits further from the shed ($P<0.01$); hence distant ranging was correlated with the amount of range access, and consequently the relationships between ranging frequency, duration and distance were strong. These relationships indicate that longer, more frequent and greater ranging from the home shed was associated with improved welfare. Further research is required to identify whether these relationships between ranging behaviour and welfare are causal.*

**Keywords:** outdoor, pasture, poultry, meat, technology

## Implications

Despite an increase in consumer demand for free-range chicken meat, there is limited evidence about the welfare implications of accessing an outdoor range for chicken welfare, particularly at the individual chicken level. We identified relationships between ranging and BW, suggesting that individual characteristics of the chicken may be important for distance ranging. This study provides evidence that ranging further from the shed has positive relationships with chicken welfare, including better leg health and a reduced physiological stress response. Animal-based parameters may be predictive of later range access and possibly bird welfare; hence free-range systems need to be considered as a whole system.

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## Introduction

Chickens prefer to range close to their home shed (Rivera-Ferre *et al.*, 2007; Dal Bosco *et al.*, 2010; Fanatico *et al.*, 2016). However, the aggregation of chickens in range areas close to the shed can have detrimental effects on the range environment and chicken welfare due to accumulation of excreta and nutrient load, reduced vegetation and increased pathogens (van de Weerd *et al*., 2009). Therefore, encouraging more widespread ranging distribution in free-range flocks is important to safeguard chicken welfare and environment sustainability. Ranging distance can be encouraged by providing range enrichment, both natural structures such as trees and bushes (Mirabito *et al*., 2001; Dawkins *et al*., 2003; Stadig *et al*., 2016) or artificial structures such as roosts, screened shelters and wigwams (Gordon, 2002; Fanatico *et al*., 2016). Despite the success of the aforementioned range enrichments to encourage chickens to range further from the shed, studies indicate that the majority of broiler chickens within a flock still preferred to range close to the shed (Mirabito *et al*., 2001; Gordon, 2002; Dawkins *et al*., 2003; Fanatico *et al*., 2016; Stadig *et al*., 2016).

Individual characteristics may significantly impact on the willingness of a chicken to range further from the shed, and therefore may play an important role in promoting more widespread ranging distribution. Stadig *et al.* (2016) found evidence that general fearfulness before range access, measured via a TI test, was negatively related to the number of chickens that ranged further than 5 m from the shed, suggesting that the propensity to be frightened impeded ranging distance. Furthermore, particular health characteristics may also impede ranging further from the shed.

Ranging greater distances may require good mobility, either due to good leg health, lower body weight (BW) or a combination of both (Taylor *et al*., 2018). Poor leg health has arguably been seen as the greatest historic risk to broiler chicken welfare. Although decades of selection for improved leg health have resulted in genetic improvements (Kapell *et al*., 2012), a wide range of leg disorders are still present in modern broiler flocks, albeit less prevalent. Rodriguez-Aurrekoetxea *et al.* (2014) showed that the provision of perches altered tibial morphological characteristics and increased ranging distance. Although there has been some investigation into the relationships between mobility and ranging behaviour, none of the studies have assessed leg health prior to range use (Kestin *et al*., 1992; Weeks *et al*., 1994; Fanatico *et al*., 2008; Durali *et al*., 2014; Zhao *et al*., 2014). It therefore remains unknown whether poor leg health inhibits ranging further from the shed or is positively affected by distant ranging. Of note, practical assessments of leg health are subjective, and the impact of increased BW and poor leg health on mobility is often difficult to disentangle.

Few studies have assessed chicken welfare both before and after range access is provided, and so it is difficult to ascertain cause and effect between ranging behaviour and chicken welfare, such as whether leg health is affected by, or conversely encourages, ranging. Therefore, in this study on a commercial farm, we assessed welfare both before and after range access, on the basis of general fearfulness and chicken health, and we tracked individual broiler chicken ranging behaviour through Radio Frequency Identification (RFID) technology, with a focus on distance ranged from the shed. Radio frequency identification technology wirelessly detects electromagnetic signals from a uniquely coded electronic transponder when it is within range of an antenna (Domdouzis *et al*., 2007). As such, each chicken carried a unique identification electronic chip within a silicone leg band that registered as it passed over antennas strategically placed at the pop-holes of the shed and at various locations within the range. Thus, the RFID technology utilised in this study permitted an understanding of range access and ranging distance by individual chickens during hours of range access.

We hypothesised that chickens would exhibit inter-individual differences in ranging distance, and that chickens that prefer to range further from the shed would be less fearful, have better leg health and lower BW than chickens that ranged closer to the shed.

## Materials and methods

### *Study site and subjects*

This study was conducted on one flock on a commercial farm in South Australia during summer. A tunnel-ventilated shed (160 m×16 m) with evaporative cooling pads and range areas (160 m×17.3 m) located on both sides of the shed contained approximately 39 740 mixed-sex Ross 308 broiler chickens placed at 1 day old with a stocking density kept below 28 kg/m$^2$. Radio frequency identification equipment was used to track individual chicken ranging behaviour. Due to a finite amount of RFID equipment, a study area within the commercial shed was partitioned off. The study area (96 m$^2$) was located in the middle of the shed, partitioned with mesh fencing 0.5 m high, extending 8 m from the south wall of the shed and 12 m wide (Figure 1). Range access in the experimental area was provided via two south facing range doors (3.8 m wide), hereafter referred to as 'pop-holes', which were spaced 3.8 m apart. The experimental range area (17.3 m×12 m) contained a 0.8 m high, 12 m×3.5 m rectangle horizontal shade cloth that covered the range area 6.1 to 9.6 m from the shed width wise (Figure 1). Two 0.3 m high immature trees were present 12 m from the shed, close to the experimental fence. The experimental area housed approximately 1580 chickens that were randomly caught at 4 days of age from various areas within the shed, based on location relative to the front of the shed and distance from pop-holes. Chickens were caught by corralling approximately 50 to 100 individuals at predetermined sampling location using portable fencing. Chickens were then chosen randomly, placed in a crate, transported and released in the experimental area. Stocking density was consistent with the rest of the commercial flock (28 kg/m$^2$) and was maintained by depopulating (removing approximately one-third of the flock for slaughter, also referred to as 'thinning') at 35 days of age. Chickens were depopulated from the commercial flock by removing the chickens from the front of the shed indiscriminate of sex or weight. Chickens in the experimental flock were

**Table 1** *Commercial broiler chicken ranging conditions during each week of range access, including availability of range and range weather conditions. Morning weather conditions were measured at 0900 h by an Australian Government Bureau of Meteorology weather station located 0.6 km from the farm*

| Ranging conditions | Mean±SEM | | | |
|---|---|---|---|---|
| | Week 3 | Week 4 | Week 5 | Week 6 |
| Number of days the range was available | 5 | 7 | 4 | 3 |
| Total number of hours of range availability | 28.6 | 45.1 | 19.8 | 11.5 |
| Hours of daily access | 5.7±1.6 | 6.4±1.0 | 5.0±0.7 | 3.8±0.7 |
| Time of day range was available | 0748 h to 1212 h | 0651 h to 1317 h | 0540 h to 1020 h | 0600 h to 1320 h |
| Morning temperature (°C) | 19.9±2.3 | 18.5±1.4 | 23.3±1.8 | 19.9±0.8 |
| Morning relative humidity (%) | 55.4±7.9 | 61.0±7.2 | 50.3±3.4 | 87.0±6.1 |
| Morning wind speed (km/h) | 12.0±4.9 | 8.2±0.8 | 5.5±2.9 | 4.0±0.0 |
| Minimum daily temperature (°C) | 15.8±2.1 | 13.6±1.0 | 17.1±1.7 | 17.9±0.6 |
| Maximum daily temperature (°C) | 30.9±2.5 | 31.4±1.1 | 36.7±0.8 | 29.9±0.6 |

SEM=standard error of the mean.

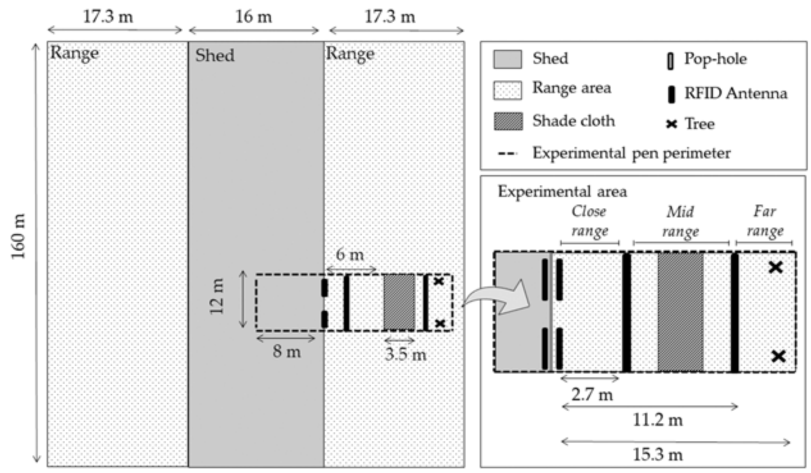


**Figure 1** Commercial broiler chicken shed and experimental pen dimensions and layout. Experimental range area indicates range areas separated by radio frequency identification (RFID) antennas differing in distance from the shed wall, defined as close-range (<2.7 m from shed wall), mid-range (2.7 to 11.2 m from the shed wall) and far-range (11.2 to 15.3 m from the shed wall).

depopulated by removing unmarked chickens from the experimental flock into the commercial flock. The litter was turned manually in the experimental area at 14 and 36 days of age at the same time as the rest of the shed litter using machinery for litter management purposes.

Chickens were permitted range access from 15 days of age. Management provided access to the range at their discretion, often dictated by the shed environment (e.g. increased relatively humidity) which was difficult to control during extreme external weather conditions when the pop-holes were open. Due to the climate in South Australia in summer (maximum temperature variation: 25.7 to 29.1°C; minimum temperature range: 12.3 to 14.3°C), pop-holes were typically open at sunrise (0600 h) when temperature was lower and closed as temperature and humidity increased (1200 h). Tunnel ventilation is an effective system to ensure temperature and humidity remain at appropriate levels within the shed (Kaur *et al.*, 2017). However, when pop-holes are open, the environmental control of the tunnel ventilation system is compromised. Therefore, pop-holes were open only when temperatures and humidity within the shed were within a safe range and did not compromise the welfare of chickens within the shed. Range access was provided an average of 4.8±0.9 days weekly for 5.5±0.6 h daily. However, range availability varied each week, dictated by weather conditions (Table 1). In the final week of the study, increased temperature and thunderstorms subsequently increased humidity, and opening pop-holes became a welfare risk to chickens inside the shed, and consequently range access was not permitted between 39 and 42 days of age.

*Tracking individual range use*

Range use was tracked on a subpopulation ($n$=305) within the experimental pen. Chickens were randomly selected from 10 areas evenly spread throughout the experimental area specifically related to the width of the experimental area and distance from pop-holes (e.g. adjacent to pop-holes, near pop-holes and furthest away from the pop-holes).

Individual range use was tracked by the Gantner Pigeon RFID System (2015 Gantner Pigeon Systems GmbH, Benzing, Schruns, Austria), with a bespoke programme Chicken Tracker that was developed for the use of tracking chickens, previously validated and used on a commercial farm to track laying hens (Gebhardt-Henrich *et al.*, 2014) and broiler chickens (Taylor *et al.*, 2017a and 2017b). Chickens were fitted with a silicone leg band that automatically loosened with growth (Shanghai Ever Trend Enterprise, Shanghai, China). Each leg band contained a unique ID microchip (Ø4.0/34.0 mm Hitag S 2048 bits, 125 kHz) that registered as the chickens walked over the antenna (26 cm×56 cm×2.7 cm; for images of the antenna refer to Gebhardt-Henrich *et al.*, 2014). Antennas were attached to both sides of each pop-hole (i.e. indoor and outdoor) to determine the direction of movement by each tagged chicken, hence permitting calculation of ranging frequency and duration. In addition, two rows of RFID antennas were placed in the range at 2.7 to 11.2 m from the shed wall (Figure 1). The placement of antennas in single rows at various distances from the shed permitted identification of the maximum distance for each range visit. Antennas were placed in the shed before placement of the chickens to minimise disturbance. Antennas were checked each morning before range access was provided by running a 'test' RFID chip over each antenna; faulty antennas were replaced immediately. Chickens were marked with blue or green stock paint (FIL Tell Tail, GEA, New Zealand) on tail and wing feathers to identify tagged chickens in order to retrieve leg bands at the end of the study. Chickens were excluded from analysis if tags were not recovered or functional at the end of the trial.

Because of technical problems on the first day, chickens were tracked from the second day of range access until depopulation for slaughter (from 16 to 42 days of age).

Throughout the study 97% of tagged chickens were successfully tracked, indicated by functioning tags recovered after the experimental period. Four chickens were found dead during the study, two tags were dysfunctional and three tags were never recovered. Ranging and welfare data from these nine chickens were excluded from analysis.

### *Welfare indicators*

To investigate relationships between ranging distance and welfare, we included assessments of BW, health and fear responses. To minimise the effects of handling before measuring indicators of fear responses, tracked chickens ($n$=305) were randomly allocated to either the BW and health ($n$=153) or fear ($n$=152) assessment group. A full set of welfare data was not collected on a small population of tracked chickens (fear group $n$=2; health group $n$=9) for various reasons; subsequently these chickens were included in the analysis of ranging behaviour but not welfare. Chickens were randomly selected from 10 areas evenly spread throughout the experimental area specifically related to the width of the experimental area and distance from pop-holes (e.g. adjacent to pop-holes, near pop-holes and furthest away from the pop-holes), at 7 and 11 days of age for the health and fear assessment groups, respectively. All experimenters that handled and scored chickens for welfare and fear assessments were blind to an individual chicken's ranging behaviour.

*Body weight and health.* At 7 days of age, chickens were weighed by placing an individual on a small-animal scale (SR instruments, Tonawanda, NY, USA), tagged with wing band with a unique identification number (Jiffy Wing Bands 893, National Band and Tag, Newport, KY, USA), sprayed with blue stock paint (FIL Tell Tail, GEA, New Zealand) and released into the flock. At 14 days of age, wing bands were removed and replaced with a leg band containing a unique ID microchip to monitor range use. Gait, FPD and HB were scored, and chickens were weighed each week from 14 to 42 days of age. At all ages, focal chickens were identified by the coloured paint marks and manually caught by experimenters. Gait was scored immediately after catching, following by FPD and HB scores then **BW**. After assessments, chickens were placed in a temporary holding pen until all chickens were tested, to avoid catching the same chicken twice.

Gait scores were assessed by standing directly behind the chicken and when required encouraging the chickens to walk by slow human approach and gentle tactile contact with a clip board. Gait scores were assessed in less than 30 s using a six-point gait score scale (Kestin *et al.*, 1992) and later condensed into three scores; normal=score 0, affected=score 1 or 2 or lame=score 3 or 4 or 5.

Foot pad dermatitis and HB were scored using a five-point scale (Welfare Quality®, 2009), recording the highest score from either foot/leg. The foot pad dermatitis scores were later condensed into four scores, only three chickens had the maximum score of 5 and therefore scores 4 and 5 were pooled. Hock burn scores were later condensed to a three-point scale, only one chicken had a HB score of 4 and no chicken had the maximum score of 5; therefore scores of 3, 4 and 5 were pooled.

*Fear responses.* Chickens ($n$=152) were caught the night before testing (12 and 45 days) and segregated in a smaller pen within the shed with *ab libitum* access to food and water. On the day of testing, chickens were randomly chosen from six evenly distributed areas of the holding pen and placed in a transport crate in groups of three in a quiet room adjacent to the shed. Exactly 12 min later, chickens were removed from the crates, and a blood sample was collected from the brachial wing vein. To collect the blood sample, chickens were placed on their side on a table with legs extended and the handler lightly covered the chickens head with one hand. Approximately, 2 ml of blood was collected from the brachial wing vein with an S-monovette (Sarstedt AG & Co, Nümbrecht, Germany). All chickens were bled within 2 min of removing the chicken from the crate to avoid an acute stress response to handling associated with blood sampling (Broom and Johnson, 1993): thus this plasma sample will reflect the physiological stress response to 12 to 16 min of confinement, depending on the order of blood collecting of the three chickens crated. After collection, blood samples were spun on site at 10 000 rpm for 5 min. The supernatant was collected, stored on ice and frozen at –20°C for later analysis. Plasma corticosterone concentrations were measured using a commercially available double antibody radioimmunoassay kit (MP Diagnosistics, Orangeburg, NY, USA) as per manufacturer's instructions with the exception of the dilution factor of 1:4 to fall within an optimal part of the standard curve, with duplicates with a coefficient of variation lower than 5%.

Immediately after blood samples were obtained, each chicken was transported by researchers 5 to 10 m to one of three isolated rooms to conduct a TI test. During transportation, chickens were carried close to the experimenter's body with two hands and were never inverted. All three TI testing rooms were temperature controlled, isolated from weather extremities and identically designed. The chicken was inverted and restrained gently on its back in a U-shaped cradle with light pressure applied to the sternum, and the head was lightly covered by the handlers hand for 15 s. A maximum of three attempts were made to induce the TI state. A successful induction was considered when the chicken remained in TI for more than 15 s after the handler released pressure. The length of time chickens remained in TI was recorded. Chickens were permitted to remain in a TI state for a maximum of 360 s after which they were gently righted. If TI was not induced after three attempts, that chicken was given a score of zero. If breathing appeared laboured or restricted the chicken was brought out of TI immediately and excluded from analysis ($n$=2 post-range access at 45 days). Experimenters remained out of the chicken's field of view after TI was induced. A white noise recording played continuously in each of the TI rooms and crating room to minimise any outside sound disturbance.

Following the TI test, each chicken was weighed, marked with green livestock spray marker (FIL Tell Tail, GEA, New Zealand) and returned to the experimental flock.

### *Statistical analysis*

All statistical analysis was performed with SPSS statistical software (v22, IBM Crop, Armonk, NY, USA). Normality of data was assessed by Kolmogorov–Smirnov and Shapiro–Wilk normality test statistics unless otherwise stated.

### *Ranging behaviour*

Ranging behaviour of focal chickens from the BW and health and fear parts of this study were compared with non-parametric Kruskal Wallis tests. The total number of range visits, the number of range visits to the close-range (<2.7 m), mid-range (between 2.7 and 11.2 m) and far-range (>11.2 m) areas did not differ between focal chickens from the two sub-populations (total number of range visits: $P$=0.78; total time spent on the range: $P$=0.57; first day the range was accessed: $P$=0.13; number of visits to the close-range: $P$=0.30; number of visits to the mid-range: $P$=0.57; number of visits to the far-range: $P$=0.11). Therefore, ranging behaviour data from all tracked chickens ($n$=296) were pooled for analysis and are presented together.

The relationships between percentage of visits to close-, mid- and far-range areas and overall range use (frequency and duration) were analysed with Spearman's correlation analysis. The peak number of weekly range visits was analysed with a generalised linear model (**GLIM**). The number of birds that displayed increased, decreased or stabilised maximum ranging distance each week from the preceding week was analysed with chi-square analysis with the Bonferroni correction method to account for multiple comparisons. The effect of sex on the total number of range visits and overall percentage of visits to the close- and mid-range areas were analysed using a general linear model (**GLM**). Sex was included as a fixed factor and final BW as a covariate. Due to minimal far-range visits, binary GLIM comparisons (accessed far-range *v.* did not access far-range) were used to compare sex.

*Categorising ranging chickens.* To identify relationships between ranging distance and welfare indicators, chickens were categorised into groups based on the maximum distance ranged from the shed per visit. Chickens that accessed the close-range (maximum 2.7 m from the shed) more frequently (>50% of total visits) than the mid- or far-range areas (greater than 2.7 m from the shed) throughout the study were categorised as 'close rangers' (**CR**). Conversely, chickens that accessed the mid- and far-range areas (greater than 2.7 m from the shed) more frequently (>50% of total visits) were classified as 'distant rangers' (**DR**). Few chickens never accessed the range ($n$=16), and they were excluded from all analysis.

*Comparisons between close- and distant-ranging chickens.* Relative growth rate was calculated by dividing the difference in **BW** from the previous week, by the previous week's **BW**.

*Analysis of pre-range access data.* Relative growth rate, weight at 7 and 14 days of age and acute plasma corticosterone concentrations were analysed with GLM to determine differences between CR and DR chickens, including sex and weight as random factors where appropriate. Ordinal and binary data, such as gait, FPD and HB scores, the number of TI attempts, failure to induce a TI state (maximum attempts) and the number of chickens remaining in TI for the maximum duration were analysed with generalised linear mixed models (**GLIMM**) to determine differences between CR and DR chickens. Due to the censored nature of TI duration (maximum 360 s) data were analysed with Cox regressions, with ranging category as a fixed factor, handler, sex and number of attempts to induce TI as random factors, and time of day and weight as covariates. Binary logistic regressions were used to predict CR and DR chickens. Pre-ranging data were included in a binary logistic regression if $P$ values were $\leq$0.1. A variable was removed from the regression model if it was strongly correlated with another variable (≥0.7) with a maximum of three variables included. The most parsimonious models are reported with statistically useful variables in the model, confirmed by goodness of fit tests calculated by Omnibus model coefficients and Hosmer and Lemeshow tests and the amount of variation the model accounted for, determined by Nagelkerke $R$ square values.

*Analysis of post-range access data.* Post-ranging gait, FPD and HB scores and number of TI attempts were analysed with an ordinal logistic generalised estimating equation (**GEE**) accounting for repeated measures with a robust estimator autoregressive working correlation matrix; Wald statistics are reported. Post-ranging weight and acute plasma corticosterone responses were analysed with a general linear mixed model (**GLMM**), accounting for weekly repeated measures with an autoregressive covariance structure and individual as the subject. All GLMM and GEE models included ranging distance category (CR or DR), week and the interaction between ranging distance category and week as fixed factors and sex, weight and handler as random variables where appropriate. Furthermore, pre-ranging weight (14 days of age) and number of range visits were included as covariates in all GLMM and GEE models to control for any differences before range access and frequency of range use, respectively. Non-significant interactions were removed from models ($P>0.05$).

Failure to induce a TI state and the number of chickens remaining in the TI state for maximum duration were analysed with a binary logistic GLIMM. Post-ranging TI duration censored data were analysed with Cox regressions, with handler, sex and number of attempts to induce TI included as random factors and time of day, weight and pre-ranging TI duration included as covariates. Raw means ± SEM are reported unless otherwise noted.

## Results

*Ranging behaviour*

Most, but not all, of the chickens accessed the range (non-rangers: 5.4% ($n$=16) tracked chickens; Figure 2) and those that never accessed the range were excluded from all analyses. On average, individuals accessed the range 12.9±0.2 days, 52.5±1.3 times, for a total duration of 8.9±0.2 h during the study (Table 2).

Some ranging chickens (13.2%, $n$=37) were never detected at the RFID antenna 2.7 m from the shed (Figure 2). The majority of tracked chickens (62.5%, $n$=175) visited close-range areas more frequently (more than 50% of range visits were a *maximum* distance of 2.7 m). Less than half of the tracked chickens (37.5% of tracked chickens, $n$=105) visited the mid-range area more frequently (more than 50% of range visits greater than 2.7 m but less than 11.2 m). No chicken visited the far-range area more frequently than the close or mid-range areas (more than 50% of all range visits greater than 11.2 m); the maximum

**Table 2** *Ranging behaviour (mean ± SEM) of focal chickens (n=296) throughout the study period*

| | Mean±SEM | Minimum | Maximum |
|---|---|---|---|
| Number of days the range was accessed | 12.9±0.2 | 0 | 18 |
| Total number of range visits | 52.5±1.3 | 1 | 185 |
| Total time spent on the range (h) | 8.9±0.2 | 0.02 | 44.5 |
| Days the range was accessed (% available) | 67.9±1.1 | 5.3 | 94.7 |
| Visits to close-range (% range visits) | 61.9±0.8 | 8.1 | 100 |
| Visits to mid-range (% range visits) | 41.3±0.7 | 1.1 | 83.2 |
| Visits to far-range (% range visits) | 5.7±0.2 | 0.7 | 17.1 |

SEM=standard error of the mean.

**Table 3** *Mean (± SEM) BW at 7 and 14 days of age and pre-ranging growth rate (mean±SEM) and prevalence of gait, food pad dermatitis and hock burn scores at 14 days of age, before range access for close-ranging (CR, n=86) and distant-ranging (DR, n=47) chickens*

| | Mean±SEM | | |
|---|---|---|---|
| Measure | CR | DR | *P*-value |
| Day 7 weight (g) | | | |
| Mixed-sex | 190.5±3.5[a] | 178.3±5.0[b] | 0.02 |
| Male | 200.2±2.7 | 193.9±4.3 | 0.21 |
| Female | 195.6±2.2[a] | 186.0±3.5[b] | 0.05 |
| Day 14 weight (g) | | | |
| Mixed-sex | 508.5±7.9[a] | 490.0±10.3[a] | 0.02 |
| Male | 561.9±6.1[a] | 541.7±7.0[b] | 0.04 |
| Female | 534.0±6.0 | 515.3±7.3 | 0.16 |
| Growth rate | | | 0.38 |
| Mixed-sex | 1.6±0.1 | 1.8±0.0 | |
| Male | 1.8±0.1 | 1.8±0.1 | |
| Female | 1.7±0.1 | 1.8±0.1 | |
| Gait score % | | | 0.25 |
| 1 – normal | $61.9_{(52)}$ | $72.3_{(34)}$ | |
| 2 – affected | $38.1_{(32)}$ | $27.7_{(13)}$ | |
| 3 – lame | $0_{(0)}$ | $0_{(0)}$ | |
| Foot pad dermatitis % | | | 0.35 |
| 1 – none | $86.9_{(73)}$ | $89.4_{(42)}$ | |
| 2 – slightly affected | $11.9_{(10)}$ | $8.5_{(4)}$ | |
| 3 – moderate | $0_{(0)}$ | $2.1_{(1)}$ | |
| 4 – severe | $1.2_{(1)}$ | $0_{(0)}$ | |
| Hock burn % | | | 0.79 |
| 1 – none | $86.9_{(73)}$ | $89.4_{(42)}$ | |
| 2 – slight | $13.1_{(11)}$ | $10.6_{(5)}$ | |
| 3 – severe | $0_{(0)}$ | $0_{(0)}$ | |

CR=close ranger, chickens that accessed the range area close to the shed more frequently; DR=distant ranger, chickens that accessed areas further from the shed more frequently; SEM=standard error of the mean.

The number of chickens for each body condition score is indicated in parenthesis.

[a,b] Values within a row with different superscripts differ significantly at $P<0.05$.

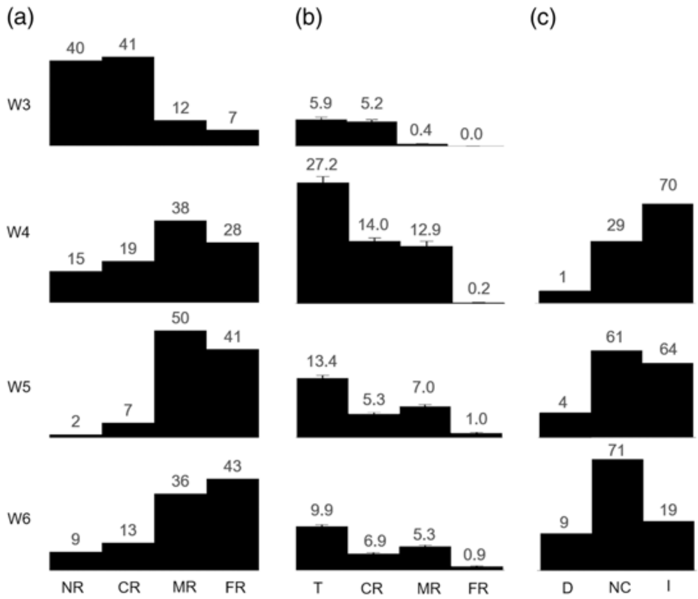


**Figure 2** Ranging behaviour each week (week 4 to week 5) when range access was provided: (a) percentage of tracked chickens ($n$=296) that accessed the close- (CR), mid- (MR) and far-range (FR) areas or did not access the range (NR) each week (week 3 to week 6); (b) the average number of range visits (± SEM) in total (T), to the CR, MR and FR areas; (c) the number of chickens that decreased (D), increased (I) or did not change (NC) the maximum ranging distance from one week to the next.

percentage of an individual's range visits to the far-range area was 17.1%. More visits to the mid- and far-range areas were observed when more chickens were on the range (mid-range: $r_{(109)}$=0.84, $P \leq 0.001$; far-range $r_{(109)}$=0.48, $P \leq 0.01$). Chickens accessed the mid- and far-range areas more if they accessed the range more frequently (mid-range: $r_{(280)}$=0.62, $P<0.001$; far-range: $r_{(280)}$=0.60, $P<0.001$) and for a longer period of time (mid-range: $r_{(280)}$=0.78, $P<0.001$; far-range: $r_{(280)}$= 0.73, $P<0.001$).

The number of weekly range visits and visits to the close- and mid-range areas peaked at 4 weeks of age (total range visits: $\chi^2_{(3,\ 280)}$=255.9, $P<0.001$; close-range visits: $\chi^2_{(3,\ 280)}$=189.8, $P<0.001$; mid-range visits: $\chi^2_{(3,\ 280)}$=303.3, $P<0.001$; Figure 2). The number of visits to the far-range area peaked at 5 and 6 weeks of age ($\chi^2_{(3,\ 280)}$=168.4, $P<0.001$; Figure 2). Almost all of the tracked chickens (98%) continued to access the range every week after their first range visit. Only 2% of chickens ($n$=6) accessed the range during 1 week but not again for the remainder of the study ($n$=2 each week, excluding week 6). An individual's maximum ranging distance rarely decreased between weeks; 9.3% of chickens ($n$=27) reduced their maximum ranging distance from one week to the next throughout the study (Figure 2).

The number of females and males tracked throughout the study was similar (females $n$=142, males $n$=136, unknown $n$=18). There were no differences between the sexes in the likelihood of accessing the far-range ($P$=0.93), the proportion of CR or DR ($P$=0.89), the total number of range visits ($P$=0.40) or percentage of visits to the close-, mid- or far-range areas (close-range visits: $P$=0.20; mid-range visits: $P$=0.14; far-range visits: $P$=0.27). There was no interaction between sex and week on total weekly range visits ($P$=0.11), mid-range visits ($P$=0.19) or far-range visits ($P$=0.30). However, there was an interaction between sex and week on the number of close-range visits ($F_{(93,198)}$=3.08, $P$=0.03) indicating that at 3 weeks of age males visited the close-range area more frequently than females but between 4 and 6 weeks of age females visited the close range more frequently than males.

*Body weight, health and fear assessments before range access*

The body weight of DR chickens ($n$=47 chickens) was lower than CR chickens ($n$=86 chickens) before range access, specifically females at 7 days of age ($F_{(1,128)}$=5.70, $P$=0.02; Table 3) and males at 14 days of age ($F_{(1,127)}$=5.74, $P$=0.02; Table 3). Before range access at 14 days of age, gait, FPD and HB scores did not differ between CR and DR chickens ($P>0.05$), but high (worse) gait, FPD and HB scores were rare at 14 days of age (Table 3).

*Predicting the likelihood of distant-ranging with pre-ranging variables*

Weight before range access predicted CR and DR chickens at both 7 days of age ($\chi^2_{(1,\ 133)}$=5.6, $P$=0.02) and 14 days of age ($\chi^2_{(1,\ 133)}$=5.2, $P$=0.02) correctly classifying 67.2% and 65.4% of cases, respectively. Pre-ranging growth rate or sex did not predict CR and DR chickens ($P>0.05$).

*Body weight and health after range access*

Four chickens were found dead inside the shed during the study between 17 and 35 days of age. Two of the four chickens had accessed the range before death for 2 to 10 visits on 2 days, spending a total of 6.5 min to 1.8 h on the range. Two of the chickens found dead never accessed the range. All four birds were excluded from analysis. Every week of the study,

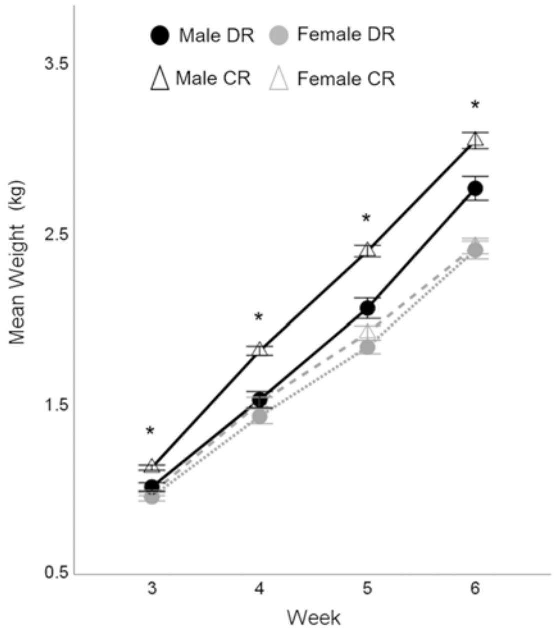


**Figure 3** Mean BW (kg)±SEM for close-ranging (triangles, $n$=86) or distant-ranging (circles, $n$=55) chickens from the first week of range access (week 3) to the final week of range access (week 6). Data are separated into sex: female (dotted lines) and males (solid lines). Significant BW differences ($P$<0.01) between close-ranging (CR) and distant-ranging (DR) chickens each week are indicated by *. Close ranger (CR) denotes chickens that accessed the range area close to the shed more frequently; distant ranger (DR) denotes chickens that accessed areas further from the shed more frequently.

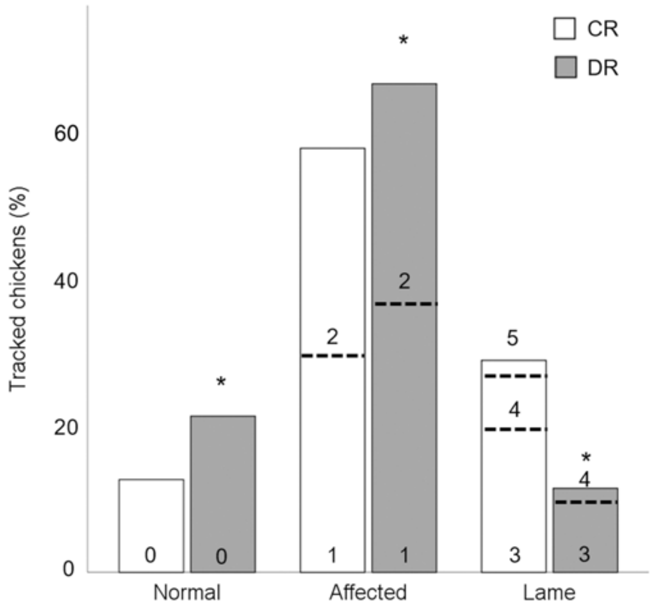


**Figure 4** Percentage of close-ranging (CR, white bars, $n$=86) and distant-ranging (DR, grey bars, $n$=55) chickens with normal, affected or lame gait scores pooled from weeks 3 to 6. Dotted lines within bars indicate the percentage of gait scores. *indicates significant difference between close- and distant-ranging chickens at $P$≤0.01. Close ranger (CR) denotes chickens that accessed the range area close to the shed more frequently; distant ranger (DR) denotes chickens that accessed areas further from the shed more frequently.

BW was lower for DR chickens than CR ($F_{(3,130)}$=5.6, $P$=0.001; Figure 3). In addition, more range visits, lower pre-ranging weight and females were associated with reduced weekly BW (number of weekly range visits $F_{(1,130)}$=10.9, $P$=0.001; sex $F_{(1,130)}$=27.5, $P$<0.001; pre-ranging weight $F_{(1,130)}$=4.8, $P$<0.001).

There was a significant three-way interaction between ranging distance, week and sex on relative growth rate ($F_{(3,362)}$=4.97, $P$<0.01): male DR chickens grew 14.6% slower the first week of range access (2 to 3 weeks of age) compared to male CR chickens ($F_{(1,63)}$=13.7, $P$<0.001) but 7% faster during the final week of range access ($F_{(1,59)}$=5.56, $P$=0.02). Ranging distance was not related to the relative growth rate of females ($F_{(1,124)}$=1.96, $P$=0.16). More range visits were associated with lower relative growth rate, regardless of sex ($F_{(3,320)}$=17.0, $P$<0.001).

Overall, DR chickens had lower (better) gait scores than CR chickens ($\chi^2_{(1,132)}$=6.9, $P$≤0.01; Figure 4). Increased BW was associated with higher (worse) gait scores ($\chi^2_{(1,132)}$=43.7, $P$<0.001). Foot pad dermatitis and HB scores increased over time (FPD: $\chi^2_{(3,132)}$= 40.1, $P$≤0.001; HB: $\chi^2_{(3,130)}$=32.7, $P$<0.001; Table 4) but did not differ between CR and DR chickens (FPD: $P$=0.51; HB: $P$=0.20; Table 4), even when data from the final week (when range access was restricted) were removed ($P$=0.61). However, higher FPD scores were associated with more range visits and lower weight (total number of range visits: $\chi^2_{(1, 132)}$=8.6, $P$<0.01; weight $\chi^2_{(1, 132)}$=8.1, $P$≤0.01). Conversely, higher HB scores were associated with increased BW ($\chi^2_{(1,130)}$=21.3, $P$<0.001).

*Fear assessments*

There was no difference in any TI measure between CR ($n$=79 chickens) and DR ($n$=52 chickens) before or after range access ($P$>0.05, Table 5). The corticosterone response to handling and confinement before ranging did not differ between CR and DR chickens (CR: 2.9±0.1 ng/ml, DR 3.2±0.1 ng/ml, $P$=0.16). There was no effect of BW or sex on any fear response measure ($P$>0.05). The corticosterone response was lower in all chickens after range access, but a greater reduction was observed in DR chickens than CR chickens (CR: 1.2±0.2 ng/ml, DR 0.8±0.1 ng/ml; interaction between time of data collection and ranging distance: $F_{(1,130)}$=4.3, $P$=0.04).

## Discussion

*Relationships between ranging frequency/distance, body weight and welfare*

Monitoring the ranging distance of individual broiler chickens on a commercial free-range farm over time revealed that chickens that accessed the range area more frequently and further from the shed had lower BW than chickens that stayed closer to the shed, both before and after range access. Furthermore, distant-ranging chickens had better gait scores and lower corticosterone response to handling and

**Table 4** *Prevalence of food pad dermatitis (FPD) and hock burn (HB) scores after range access at 3, 4, 5 and 6 weeks of age for close-ranging (CR) and distant-ranging (DR) chickens*

| | Category | Week 3 | Week 4 | Week 5 | Week 6 |
|---|---|---|---|---|---|
| FPD score $\%_{(n)}$ | | | | | |
| 1 – none | CR | $88.2_{(75)}$ | $88.1_{(74)}$ | $75.9_{(63)}$ | $57.8_{(48)}$ |
| | DR | $82.6_{(38)}$ | $82.2_{(37)}$ | $63.0_{(29)}$ | $30.4_{(14)}$ |
| 2 – slightly affected | CR | $9.4_{(8)}$ | $6.0_{(5)}$ | $15.7_{(13)}$ | $15.7_{(13)}$ |
| | DR | $13.0_{(6)}$ | $6.7_{(3)}$ | $19.6_{(9)}$ | $26.1_{(12)}$ |
| 3 – moderate | CR | $0.0_{(0)}$ | $3.6_{(3)}$ | $6.0_{(5)}$ | $15.7_{(13)}$ |
| | DR | $2.2_{(1)}$ | $6.7_{(3)}$ | $8.7_{(4)}$ | $21.7_{(10)}$ |
| 4 – severe | CR | $2.4_{(2)}$ | $2.4_{(2)}$ | $2.4_{(2)}$ | $10.8_{(9)}$ |
| | DR | $2.2_{(1)}$ | $4.4_{(2)}$ | $8.7_{(4)}$ | $21.7_{(10)}$ |
| HB score $\%_{(n)}$ | | | | | |
| 1 – none | CR | $84.7_{(72)}$ | $91.7_{(77)}$ | $72.3_{(60)}$ | $36.1_{(30)}$ |
| | DR | $95.7_{(44)}$ | $84.4_{(38)}$ | $84.8_{(39)}$ | $56.5_{(26)}$ |
| 2 – slight | CR | $15.3_{(13)}$ | $15.6_{(7)}$ | $16.9_{(14)}$ | $65.4_{(17)}$ |
| | DR | $4.3_{(2)}$ | $4.3_{(2)}$ | $15.2_{(7)}$ | $19.6_{(9)}$ |
| 3 – severe | CR | $0.0_{(0)}$ | $1.2_{(1)}$ | $10.8_{(9)}$ | $43.4_{(36)}$ |
| | DR | $0.0_{(0)}$ | $0.0_{(0)}$ | $0.0_{(0)}$ | $23.9_{(11)}$ |

CR=close ranger, chickens that accessed the range area close to the shed more frequently; DR=distant ranger, chickens that accessed areas further from the shed more frequently; FPD=Food pad dermatitis; HB=Hock burn.
The number of chickens for each body condition score is indicated in parenthesis.

**Table 5** *Tonic immobility (TI) measures for close-ranging (CR, n=81) and distant-ranging (DR, n=55) chickens before and after range access was provided*

| Tonic immobility measure | CR | DR | *P*-value |
|---|---|---|---|
| Before range access | | | |
| Failure to induce TI (%) | $25.6_{(20)}$ | $34.5_{(19)}$ | 0.33 |
| Inductions required to induce TI | 2.0±0.1 | 2.3±1.1 | 0.25 |
| Duration of TI (s) | 119.1±13.8 | 135.9±20.5 | 0.56 |
| Maximum TI duration (%) | $10.0_{(6)}$ | $13.9_{(5)}$ | 0.74 |
| After range access | | | |
| Failure to induce TI (%) | $21.1_{(16)}$ | $20.0_{(10)}$ | 0.54 |
| Inductions required to induce TI | 2.0±0.1 | 2.0±0.1 | 0.23 |
| Duration of TI (s) | 203.9±14.5 | 198.0±19.1 | 0.60 |
| Maximum TI duration (%) | $19.4_{(12)}$ | $19.5_{(8)}$ | 1.00 |

CR=close ranger, chickens that accessed the range area close to the shed more frequently; DR=distant ranger, chickens that accessed areas further from the shed more frequently.
The number of chickens is indicated in parenthesis for each variable.

confinement after range access. These results suggest that ranging further from the shed can be associated with better broiler chicken welfare outcomes. However, individuals from only one flock on one farm were investigated, and causation cannot be inferred from these relationships. Furthermore, ranging distance was correlated with the frequency of range visits.

Body weight before range access was predictive of ranging further from the shed, and distant-ranging chickens weighed less at all time points than close-ranging chickens, even before range access was provided. Lighter birds may be restricted from accessing resources inside the shed due to social competition and subsequently access the range in search of feed or water. However, Estévez *et al.* (1997) provide evidence that monopolisation of feeders by a few chickens does not occur in broiler flocks. Rather, weight differences may reflect temperament differences such as activity or motivation to explore, or individual fitness or energy levels. However, we also provide some limited evidence that frequently ranging further from the shed may impact BW; the only week that distant-ranging male chickens grew faster than close-ranging male chickens coincided with range restrictions. As such, we provide evidence to suggest that BW may be an important factor for ranging behaviour, but is also impacted by ranging.

Pre-ranging gait, HB and food pad dermatitis scores were not related to, or predictive of, ranging distance. Of note, poor gait scores and HBs are usually rare at this young age (Vestergaard and Sanotra, 1999; Knowles *et al.*, 2008; Bassler *et al.*, 2013). After range access, chickens that ranged further from the shed more frequently had better gaits scores than chickens that ranged closer to the shed. However, it is difficult to identify the reason for poor mobility/locomotion with the gait scoring methodology, that is leg health *v.* growth morphology (Skinner-Noble and Teeter, 2009; Sandilands *et al.*, 2011; Caplen *et al.*, 2012; Caplen *et al.*, 2013). Although, foot-pad dermatitis scores were not related to ranging distance, chickens that accessed the range more frequently had worse foot-pad dermatitis scores. As we could not disentangle the relationships between ranging distance and frequency of ranging, the improvements to mobility may be related to frequency of ranging, or overall activity levels rather than ranging distance per se. Therefore, although we provide evidence that ranging distance was related to better mobility, we cannot determine the causal factor of this relationship, for example, BW, leg health, ranging behaviour or another factor that was not assessed.

General fearfulness, assessed with TI before and after range access, was not related to ranging distance. Fear and anxiety are emotional and motivational states induced by actual or perceived danger (Boissy, 1995). Fear may be induced by a variety of extrinsic factors including unfamiliar environments or stimuli (neophobia) (Jones, 2002), evolutionary dangers (Jones, 1996), human contact (Barnett, Hemsworth and Newman, 1992), social interactions (Jones and Merry, 1988), social isolation for gregarious species (Forkman *et al.*, 2007) and conditioned stimuli (Gray, 1987). The combination of intrinsic factors leads to variation between naive individuals in the propensity to be frightened; this trait is broadly referred to as general fearfulness (Boissy, 1995; Hemsworth and Coleman, 2011; Jones, 1996; Price, 1984). We attempted to measure general fearfulness with the TI test. Tonic immobility is an innate antipredator response of a catatonic-like state and can be induced by physical restraint (Jones, 1986). Of note, TI responses can be affected by fear responses associated with human handling, social isolation and novel experiences. Our results contradict Stadig *et al.* (2016) who report a reduction in general fearfulness, measured by TI, when more chickens ranged further from the shed (>5 m), although they did not assess individual ranging behaviour. However, pre-test handling, including confining chickens overnight in a pen and in a transport crate for 12 min, various forms of human contact and collecting blood samples, likely impacted our TI results (Jones, 2002). Indeed, the average duration of TI in the current study was greater than previously reported in free-range broiler chickens studies (Zhao *et al.*, 2014; Stadig *et al.*, 2016). Regardless, there were no differences between DR and CR chickens in their responses to the TI test suggesting that general fearfulness is not related to distance ranging. However, the greater reduction of the physiological stress response to capture and confinement for DR chickens compared to CR chickens contradicts the TI results, and does support the Stadig *et al.* (2016) findings. The relationship between fearfulness and ranging distance clearly warrants further investigation. However, the physiological data from the current study together with the behavioural results from Stadig *et al.* (2016) suggest that a reduction in fearfulness may be an important component of ranging further from the shed for broiler chickens.

### *Ranging behaviour*

This study provides evidence that broiler chickens ranged relatively far from the shed, and highlighted an important impact of age and/or experience, in agreement with Rodriguez-Aurrekoetxea *et al.* (2014). Yet, Fanatico *et al.* (2016) found that ranging distance of chickens decreased with age and Weeks *et al.* (1994) showed no consistent trend in ranging distance with age. Such inconsistencies between studies are likely related to the strain of broiler chicken, ranging opportunities (age of exposure and length), maximum ranging distance permitted (14 m to greater than 50 m), flock size, housing conditions, stocking density, provision and type of range resources present, weather variation and geographical location. Using a faster growing broiler chicken strain under southeastern Australian commercial free-range conditions, we provide evidence of a relationship between age and ranging distance. Furthermore, we provide the only description of ranging distance of continuously tracked individual chickens.

Visits to the far-range area peaked during 5 and 6 weeks of age, and few chickens (≤9%) decreased their maximum ranging distance from week to week. This suggests that the first visit further from the shed may be the biggest impediment for broiler chickens. It may be that once the range area further from the shed is reached, the far-range is rewarding for chickens and thus reinforcing use. In addition, the number of chickens that ranged further from the shed was related to the number of chickens on the range, which suggests an increase in perceived safety with a larger group size, motivation for individual space or simply physical pressure to move further from the shed as crowding increased. This may be specifically reflective of the far-range; if the mid-range was the most attractive due to the shade cloth provided, chickens may have been hesitant to move further than the mid-range unless it became crowded over time.

The number of tagged chickens that never accessed the range (5.2%; $n$=16) throughout the study was lower than previously reported in commercial flocks that were not separated (18% to 68% – Taylor *et al.* 2017a) but similar to local reports on segregated flocks (for the purpose of experimental study) (5%, Durali *et al.* 2012). The early age of first range access (15 days) compared to previous studies (21 days (Durali *et al.*, 2012; Taylor *et al.*, 2017a) may have positively affected ranging behaviour, as the number of chickens that accessed the range increased overtime. Alternatively, the subsequent effects of segregating the experimental flock from the commercial flock, such as decreased flock size and fencing in the range, may also have increased range use, as previously reported in laying hens (Rault *et al.*, 2013; Gebhardt-Henrich *et al.*, 2014). Nevertheless, the aim of this experiment was not to provide descriptive ranging behaviours on commercial farms, but to identify the relationships between ranging distance and indicators of welfare.

### *Limitations*

The repeated measure data on individual chickens in this study provide a detailed description of the relationship between individual ranging behaviour and welfare. However, it should be recognised that while this study on 305 chickens sampled from one flock of almost 40 000 chickens was conducted under commercial conditions, factors such as climate, housing, management practices, design of the shed and range and genetics are likely to have differed from other commercial farms not only in Australia but internationally. Furthermore, chickens were categorised based on their overall ranging behaviour. Categorising chickens was required for statistical analysis due to the relatively low number of range visits. The method of categorisation did not mean that a close-ranging chicken never accessed the far-range, and clearly the DRs had to cross the close-range area to reach the mid- and far-range areas. As technology advances, the exact location and ranging behaviour may be tracked at an individual level permitting a better insight into the relationships observed. Furthermore, the frequency of range visits was positively related to the number of visits to the mid- and far range, but could not disentangle the effects of ranging frequency and ranging distance on welfare.

### *Conclusions*

Monitoring individual chicken ranging behaviour over time in relation to distance ranged from the shed provided evidence that ranging further from the shed may be positively associated with broiler chicken welfare, including better gait scores and a reduced stress-induced corticosterone response. Furthermore, we identified relationships between ranging behaviour and BW both before and after ranging, suggesting that BW may influence ranging behaviour but may also be affected by the activity of ranging. These results suggest that practical on-farm interventions that increase ranging distance are likely to improve chicken welfare.


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## Declaration of interest

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses or interpretation of data; in the writing of the manuscript and in the decision to publish the results.

## Ethics statement

This experiment was approved by the South Australian Research and Development Institute Animals Ethics Committee in accordance with the Australian Code of Practice for the Care and User of Animals for Scientific purposes (ethics approval number 3-16).

## Software and data repository resources

None of the data were deposited in an official repository.

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