

PREPRINT

Understanding individual range use in free-range chickens - a systematic review

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27 & editing.

Abstract

Every year, over 50 billion chickens are raised globally for meat and eggs. Increasing consumer demand has driven a shift towards free-range and organic systems. These systems allow chickens outdoor access aimed to improve behavioural diversity, and consequently, welfare. However, studies show that only a portion of a flock use the outdoor range. What causes these individual differences, the consequences of this variation and potential interventions to improve ranging have become an important research focus especially in the last decade. In this systematic review we synthesise the results of 107 studies on ranging behavior in layers and broilers to highlight patterns and draw general conclusions regarding the factors influencing ranging. Due to the breadth of our focus, we grouped research together covering (i) causes of individual differences, (ii) the consequences of individual differences in ranging for welfare and production, and (iii) interventions that can change ranging behaviour. Overall, some important patterns emerged. On the one hand, environmental factors, such as weather and temperature may predictably affect ranging across the year, particular strains ranged more and ranging increased over time. On the other hand, the results assessing ranging in relation to behaviour and cognition were less clear. Although some evidence showed better spatial cognition in indoor-preferring birds, no clear relationship to fear was evident. While the effect of outdoor access on welfare in layers was rather mixed, the effects on broilers were more straightforward, sometimes indicating better condition in outdoor-preferring individuals. In regard to production, only a few studies focused on the effects of individual ranging level on production traits finding little effect on egg quality in layers and mostly negative effects on weight, but some positive effects on meat quality in broilers. Finally, changes in management, rearing and the structure of the outdoor range show promise to improve ranging behaviour but these come with a financial cost. Overall, many knowledge gaps still remain and for some sections results are based on only a few studies limiting how well we can draw robust conclusions. We provide some suggestions on how to proceed with future investigations. Together, integrating the perspectives presented in this review will help

55 to understand and manage variation in free-range behaviour shown by both layer and broiler
56 chickens.

57

58 *Key words:* behaviour, cognition, enrichment, Gallus gallus domesticus, production, welfare

59

1 Introduction

Every year, over 50 billion chickens (*Gallus gallus domesticus*) are reared to keep up with the global demand for eggs and meat (CIWF, 2025). In the last decade, changing consumer perception has led to an increase in free-range and organic farming (with decreased flock size and stocking density for organic production) and a move away from cage and purely indoor floor or barn systems. In free-range and organic chicken farming, domestic fowl selected for egg laying (layers) and meat production (broilers), are reared indoors for the first weeks of life, but have access to an open outdoor area called the range later in life. Consumers believe that chickens from free-range systems experience better welfare (an animal's quality of life, Bray & Ankeny, 2017; Heng, Peterson, & Li, 2013; Pettersson et al., 2016) and produce better tasting and healthier eggs and meat (Bray & Ankeny, 2017; Fanatico et al., 2005; Pettersson et al., 2016).

Good animal welfare is generally assumed if animals are healthy and free from fear, pain, or suffering, if they are able to express their natural behaviours and thrive by experiencing positive mental states (Fraser et al., 1997; Rault et al., 2025). Compared to conventional systems (i.e. cage and floor systems), an outdoor range provides increased space per bird and the opportunity to express a range of natural behaviours not easily achievable inside (Fiorilla et al., 2024; Knierim, 2006; Lay et al., 2011; Pettersson et al., 2016). The space indoors is typically limited and too small for comfort behaviours such as wing stretching, and flapping, feather ruffling, preening, and ground scratching (Dawkins & Hardie, 1989). Chickens show such comfort behaviours more frequently outside (wing flapping: Ahmad et al., 2021, Jones et al., 2007; head shaking: Jones et al., 2007; dust and sun-bathing: Diep, Larsen, & Rault, 2018; Hartcher & Jones, 2017). Furthermore, compared to indoors, chickens exhibit more foraging and exploration when outside (Abouelezz et al., 2014; Chielo, Pike, & Cooper, 2016; Diep, Larsen, & Rault, 2018; Fanatico et al., 2016; Jones et al., 2007; Taylor et al., 2015; Thuy Diep, Larsen, & Rault, 2018) and lower gentle feather pecking (Diep, Larsen, & Rault, 2018); all indicators of improved welfare.

87 Despite the potential large positive outcomes associated with outdoor range access
88 available to individual chickens, observational studies that count the number (proportion or
89 percent) of birds outside show that only a portion of the flock that has access to the range
90 occupies it at any given timepoint (reviewed by Pettersson, Freire, & Nicol, 2016) (layers: 3-
91 99%, mean = 37.94; broiler chickens: 4.2-95%, mean = 35.99; Appendix Table S1).
92 Furthermore, of those chickens that do access the range, many stay close to the barn rather
93 than using the whole outdoor area which leads to increased local stocking density and
94 increased disease transmission and environmental degradation (Bubier, 1998; Chielo, Pike,
95 & Cooper, 2016; Dawkins et al., 2003; Göransson et al., 2021; Hegelund, Sørensen, &
96 Hermansen, 2006; Tainika, Sekeroglu, & Abaci, 2024). While one might expect chickens to
97 display a relatively uniform behavioural profile due to being domesticated, reared, and housed
98 under identical conditions, it is intriguing to observe such variation exhibited by flocks and
99 individuals, leading to variation in welfare and production.

100 Apart from the increased space and improved foraging opportunity, the range does
101 also pose risks to chicken. Individuals may choose not to use the range because it can expose
102 them to welfare-reducing factors (Bonnefous et al., 2022) such as predation (by predominantly
103 aerial predators; Dal Bosco et al., 2014; Göransson et al., 2023; Hübner et al., 2024), parasites
104 (Bari et al., 2020b; Bestman et al., 2023; Sherwin et al., 2013; Sibanda et al., 2020c), and
105 other diseases such as spotty liver disease (Sibanda et al., 2020c) which can increase
106 mortality (Fossum et al., 2009; Knierim, 2006; Lay et al., 2011). Despite potential exposure to
107 risks, given the scope for improved welfare from access to the range, it is important to
108 understand why there is variation in its use and how all individuals can be managed to use
109 this resource.

110 Our aim is to understand how and why chickens, as individuals or as a population,
111 differ in the extent that they use available outdoor facilities. We do this through a systematic
112 review of the literature. This is a rapidly developing field. Our search resulted in 107 relevant
113 studies while in a similar review conducted a decade ago only 14 of these were included
114 (Pettersson, Freire, & Nicol, 2016). Our review also extends some more recent reviews in

breadth and scope (Ferreira, Guesdon, & Calandreau, 2021; Miao, Glatz, & Ru, 2005; Rault, 2018). Due to the breadth of our focus, we grouped research together across three sections covering (i) causes of individual differences in ranging such as environmental factors, genotype, age and individual cognitive or behavioural factors, (ii) the consequences of individual differences in ranging on welfare and production, as well as (iii) interventions that can change ranging behaviour such as management interventions and enrichment (Figure 1). We differentiated studies using layers versus broilers as these have been selected for different production parameters, leading to differences in behaviour and welfare needs. Layers, selected for egg production, are kept up to 70 weeks and typically receive access to the range from the start of laying when 16–18 weeks of age. Broiler chickens, on the other hand, selected for meat production and fast growth, are processed around 80–90 days of age (slow growing broiler strains are preferentially used for free-range production, fast growing strains are killed around 42–47 days of age) and receive access to the range from around 30 days of age (sometimes earlier, Appendix Table S1; Dawkins et al., 2003). Therefore, results might not be directly comparable (Dawkins et al., 2003). We critically summarise the existing knowledge to help researchers quickly find relevant information and make comparisons between studies and scenarios as easy as possible. To finish up each section, we provide a succinct summary to highlight patterns and inconsistencies. Together, this enabled us to identify knowledge gaps for future research to improve chicken management and housing on farm founded in empirical results (also see Bonnefous et al., 2022).

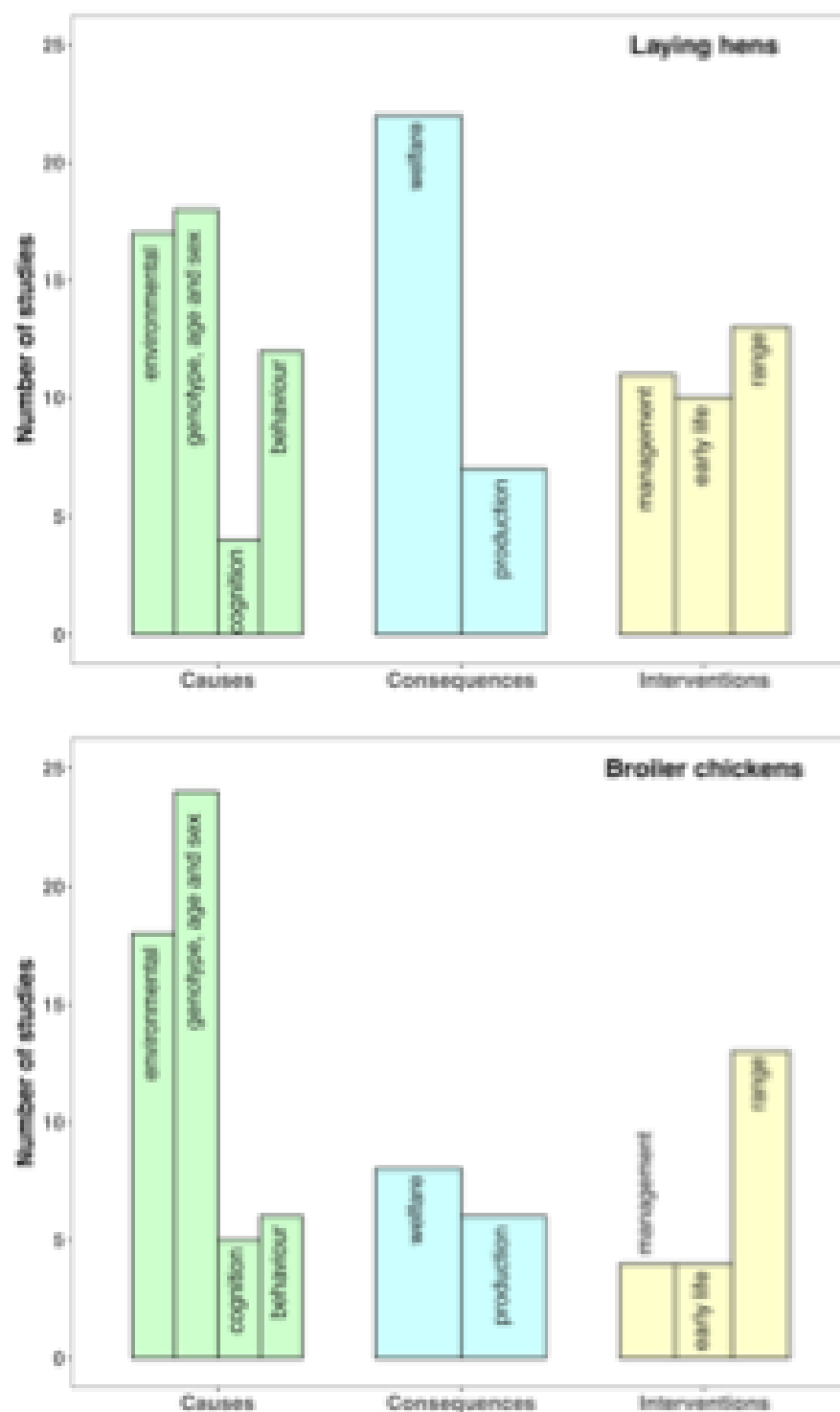


Figure 1. Number of studies investigating causes, consequences and interventions of individual ranging in both layers and broilers. The four studies using dual purpose breeds were merged with the data on broilers.

2 Methods: systematic literature compilation

We conducted a systematic literature search using the Web of Science, Core Collection. We used the search term "chicken" OR "fowl" OR "poulet" AND "ranging" (all fields) accounting for differences in spelling and included results between 1900-2024. This search resulted in 3526 records from which we removed 3 duplicates (Figure 2). We then continued to screen the titles of these records for inclusion based on the following criteria: (1) the study must be conducted in domesticated, free-range chickens (2) and must mention welfare, cognition, behaviour or production. Based on these criteria, we identified 47 records for inclusion (few studies were identified during the initial search due to unrefined search terms which was compensated for by the backward and forward searches). Next, we further narrowed down the selection based on the information provided in the abstract. We added a third criterion for inclusion, namely, (3) that the study needed to quantify ranging either on the flock or individual level. Of the 47 records selected based on title, 30 were selected for inclusion based on the information in the abstract. To ensure completeness of our sample, we proceeded to conduct forward and backward searches which led to the inclusion of a further 91 references (forward search = 46, backward search = 45). In total we collected 122 references (for 3 no full text was available). We then proceeded to read the full text of these 119 references and excluded another 12 references (conference abstract = 8, ranging not assessed = 3, review = 1). Our final sample of studies included in this review is 107 studies (Figure 2). The whole systematic search was performed between the 7th of November 2024 and the 24th of February 2025.

Across studies, two methods were generally used to collect data on ranging: flock level counts (scan sampling) of chickens found on the range at a given point in time (single or multiple sampling points; e.g. Castellini et al., 2016; Chielo, Pike, & Cooper, 2016; Dawkins et al., 2003; Rodriguez-Aurrekoetxea & Estevez, 2016) and continuous tracking for days to weeks using Radio Frequency Identification technology (RFID) (e.g. Campbell et al, 2018a; Richards et al., 2012; Taylor et al., 2023b). A minority of studies used scan sampling of small flocks in which all individuals were individually identified (e.g. Ferreira et al., 2021; 2022; 2024). Differences in the tracking methods as well as duration of tracking (RFID studies) seem

to influence the reported percent of the flock found on the range as studies using individual tracking report higher use of the range (Appendix Table S1). For example, when counting the percentage of chickens in a flock that ranged at least once using individual tracking, Taylor and colleagues (2017a) found that 87.3% of chickens used the range at some point during the tracking period, but only 36.7% were found to be on the range at any given point in time. This suggests that when individual identity is not considered during scan sampling of the whole flock, flock ranging level is underestimated as momentary scans omit time spent outdoors by different individuals (e.g. Taylor et al., 2017a). However, continuous tracking might also underestimate flock level ranging when individuals are only tracked for short periods of time because ranging increases with age and/ or experience (see below) and chickens that were staying indoors during the tracking period might still access the range later in the production cycle (Pettersson, Freire, & Nicol, 2016; Rault, 2018). Finally, it is worth mentioning that flock level ranging was often not reported in studies using continuous tracking and could not be included in Appendix Table S1.

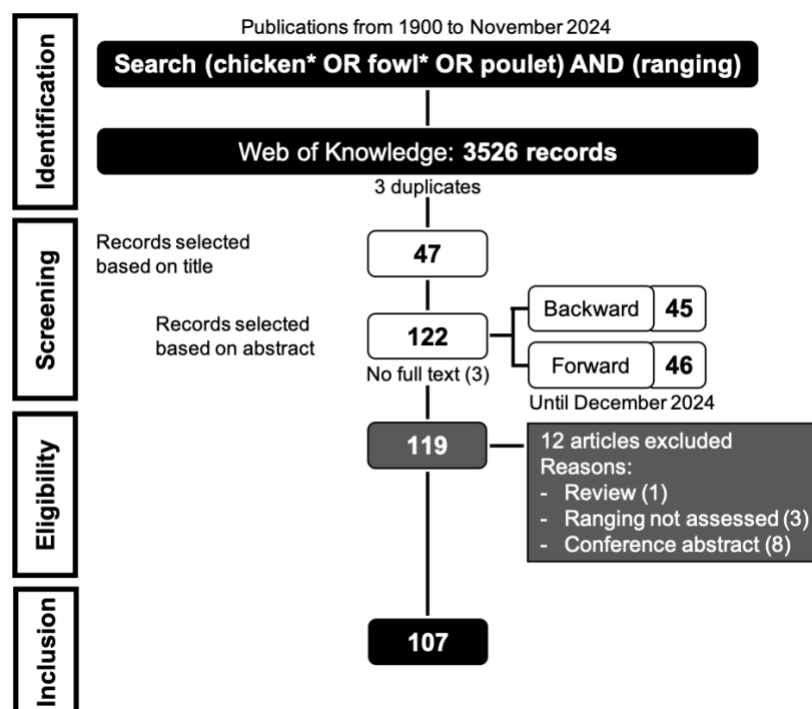


Figure 2. PRISMA diagram (Liberati et al., 2009) showing the systematic search for literature on ranging behaviour in free-range chickens. Included are the search terms, the search period and how many records were identified at each step of the selection process as well as information on the reasons for exclusion and how many records were excluded in brackets.

3 Causes of individual differences in ranging level

The causes of inter-individual differences in ranging behaviour are intriguing because we would expect large uniformity in responses from animals under strong artificial selection. Environmental conditions such as weather in combination with individual differences due to genetic background, sex, experience (e.g. Cabrera, Nilsson, & Griffen, 2021; Dougherty & Guillette, 2018) and internal states (e.g. cognition, the processes by which animals collect, store and process information from the environment; Shettleworth, 2001) can influence the decision of individual chickens to leave the barn or stay inside contributing to the observed variation. In this section, we start broadly by describing the influence of environmental factors and continuing with a stepwise decrease in the level of organisation first focusing of the effects of genetic background on ranging, then age/ experience, cognition, and then personality to emphasise that causes are complex and might interact with each other.

Table 1. Studies investigating the relationship between individual ranging behaviour and environmental factors split across studies in layers and broilers. For better comparability, studies using a similar/ the same measurement are grouped together. Consequently, references are repeated. u non-linear relationship (e.g. u-shaped relationship; u^a difference between conditions), ↓ negative relationship, ↑ positive relationship, • no statistically significant relationship found.

Chicken	Reference	Study location	Measurement
Laying hen		Time of day	
	Bubier, 1998	UK	05:00 – 19:00 ↑
	Müller et al., 2001	Germany	06:40 – 21:40 ↑

Mahboub, Müller, & Von Borell, 2004	Germany	04:00 – 21:00	u
Hegelund et al., 2005	Denmark	08:00 – 17:00	↓
Icken et al., 2008	Germany	05:00 – 20:00	u
Richards et al., 2012	UK	09:00 – 17:00	↑
Abouelezz et al., 2014	Yucatan, Mexico	08:00 – 17:00	u
Chielo, Pike, & Cooper, 2016	UK	10:00 – 14:00	↓
Rodriguez-Aurrekoetxea & Estevez, 2016	Spain	10:00 – 19:00	u
de Oliveira et al., 2022	Federal District, Brazil	08:00 – 16:00	u
Rana et al., 2022a	Tasmania, AUS	11:00 – 20:00	u
	Queensland, AUS	09:00 – 18:30	↑
	Western Australia, AUS	09:00 – 18:00	↓
Tainika, Sekeroglu, & Abaci, 2024	Turkey	09:00 – 15:00	u
Wind speed and Wind			
Hegelund et al., 2005	Denmark	Speed	↓
Richards et al., 2011	UK	Speed	↓
Richards et al., 2012	UK	Speed	↑
Hartcher et al., 2016	New South Wales, AUS	Speed	•
			↑
Gilani, Knowles, & Nicol, 2014	UK		↓
Wurtz et al., 2022	Denmark		↓
Rain			
Hegelund et al., 2005	Denmark		↓
Richards et al., 2011	UK		↓
Richards et al., 2012	UK		↓
Gilani, Knowles, & Nicol, 2014	UK		↓
Weather condition			
Tainika, Sekeroglu, & Abaci, 2024	Turkey		u ^a
Sunshine			
Richards et al., 2011	UK	Hours	↑
Temperature			
Hegelund et al., 2005	Denmark		↑
Richards et al., 2011	UK		↑
Richards et al., 2012	UK		↑
Hartcher et al., 2016	New South Wales, AUS		•
Rodriguez-Aurrekoetxea & Estevez, 2016	Spain		•
Wurtz et al., 2022	Denmark		↑
Month and season			
Hegelund et al., 2005	Denmark	Autumn to Winter	↓
Icken et al., 2008	Germany	Dec to Nov	↓
Richards et al., 2011	UK	Nov to May	↓
Rana et al., 2022a	Tasmania, AUS	Dec to Mar	↑
	Queensland, AUS	Dec to Apr	↑
	Western Australia, AUS	Jan to May	↑
Göransson et al., 2023	Sweden	May to Nov	↓

	Tainika, Sekeroglu, & Abaci, 2024	Turkey	Aug to Feb	u
Broiler	Time of day			
	Christensen et al., 2003	Denmark	06:09 – 18:11	u
	Dawkins et al., 2003	UK	08:00 – 20:00	u
	Nielsen et al., 2003	Denmark	Sunrise -set	u
	Jones et al., 2007	UK	09:30 – 17:30	↑
	Almeida et al., 2012	Denmark	08:30 – 20:00	u
	Taylor et al., 2015	Victoria, AUS	08:00 – 17:00	•
	Fanatico et al., 2016	Texas, USA	07:00 – 16:00	u
	Stadig et al., 2017a	Belgium	09:00 – 17:00	↓
	Geng et al., 2023	China	08:00 – 14:00	↓
	Hübner et al., 2024	Germany	not given	–
	Wind speed and Wind			
	Stadig et al., 2017a	Belgium	Speed	↓
	Jessen, Foldager, & Riber, 2021	Denmark	Speed	↓
	Gordon & Forbes, 2002	UK		↓
	Rain and humidity			
	Gordon & Forbes, 2002	UK		↓
	Stadig et al., 2017a	Belgium		↓
	Stadig et al., 2017b	Belgium		↓
	Jessen, Foldager, & Riber, 2021	Denmark	Humidity	↑
	Sunshine			
	Dawkins et al., 2003	UK		↓
	Stadig et al., 2017b	Belgium	Radiation	↓
	Temperature			
	Dawkins et al., 2003	UK		↑
	Rodriguez-Aurrekoetxea, Leone, & Estevez, 2014	Spain		↑
	Stadig et al., 2017a	Belgium		↑
	Stadig et al., 2017b	Belgium		↑
	Jessen, Foldager, & Riber, 2021	Denmark		↑
	Collet et al., 2024	France		↑
	Season			
	Dawkins et al., 2003	UK	Spring to Winter	↓
	Rault & Taylor, 2017	South Australia, AUS	Winter, Summer	↓

209

210 3.1 Environmental factors

211 Chickens are bred and reared globally. Depending on the geographic location, the
 212 environment chickens experience on the range can vary widely and, at least in broilers,
 213 environmental factors might explain up to 35% of the variability in range use (Sztandarski et

al., 2021b). The most consistent predictor of ranging was temperature (Table 1). Four of the six studies of layers and all six studies of broilers that considered temperature revealed increased ranging at higher temperatures (with the other two studies of layers finding no relationship; Table 1). Three studies, one in layers and two in broilers, report increased ranging during cloudy weather or in the shade on hotter days (Dawkins et al., 2003; Rana et al., 2022a; Stadig et al. 2017b) while one study reported the opposite in layers (Richards et al. 2011). Additionally, ranging was usually lower when rainfall was higher, with this pattern reported in all four studies of layers and three of the four studies of broilers that considered it (with a positive relationship reported in the other broiler study; Jessen et al. 2021). Ranging was also generally lower in higher winds, with all three studies of broilers reporting a negative relationship with wind measures. In layers this pattern was less consistent. Four of seven studies found negative relationships, but two reported a positive relationship and one found no relationship (Table 1). Therefore, the relationship between weather and ranging behaviour can be quite complex. For example, one study showed that when there was wind, more layers were found outside as the temperature rose but only if the wind speed rose simultaneously (Wurtz et al., 2022).

Patterns were less clear when considering time of day. In layers, three studies reported a decrease over the day while four reported an increase. Instead, most studies (six of broilers and seven of layers) reported a non-linear relationship with peaks either early in the morning, after sunrise, or late in the evening, around and after sunset (Table 1). When broilers were considered, two studies reported a decrease in ranging over the day, one an increase, and one no pattern (Table 1). These peaks may be related to the driest or calmest part of the day or times when the air temperature falls within chickens preferred temperature range.

Further support for the influence of local wind, rain and temperature conditions comes from studies across longer time periods and between-site studies, with a general increase in ranging from winter months to spring/summer and a general decrease from summer to winter (Table 1). However, differences might be dependent on geographic location. Rana and colleagues (2022a) studied the relationship between environmental factors and ranging

across farms in three distinct climatic regions in Australia: Tasmania, Queensland and Western Australia (increasing gradient of maximum temperature and radiation) and showed that the effects of weather on ranging behaviour differed across sites (Table 1).

Table 2. Studies investigating the relationship between individual ranging behaviour and genotype, age/ experience and sex split across studies in layers and broilers. d significant difference between groups (e.g. males and females, strain A and strain B), ↓ negative relationship, ↑ positive relationship, • no significant relationship found. * only in one strain.

Genotype			
Chicken	Reference	Measurement	
Laying hen	Müller et al., 2001	Strain	d
	Mahboub Müller & Von Borell, 2004		d
	Castellini et al., 2016		d
	Bestman et al., 2019		d
	Wurtz et al., 2022		d
	Tainika, Sekeroglu., & Abaci, 2024		d
Broiler	Christensen et al., 2003	Strain	d
	Nielsen et al., 2003		d
	Almeida et al., 2012		d
	Lindholm et al., 2016		d
	Bonnefous et al., 2023		d
	Collet et al., 2024		d
	Sztandarski et al. 2021a	Comb length	↑*
		Comb height	↑*
		Neck plumage darkness	↑*
		Beak darkness	↑*
Age, experience and sex			
Laying hen	Müller et al., 2021	Age/ experience	↑
	Zeltner & Hirt, 2003		↑
	Hegelund et al., 2005		↓
	Richards et al., 2012		●
	Gilani, Knowles, & Nicol, 2014		↑
	Cronin et al., 2016		↑
	Rodriguez-Aurrekoetxea & Estevez, 2016		●
	Campbell et al., 2017		↑
	Campbell et al., 2018a		↑
	Campbell et al., 2020		↑
	Sibanda et al., 2020b		↑
	Müller et al., 2001	Range access	↑
	Gilani, Knowles, & Nicol, 2014		●
	Bestman et al., 2019		↓

	Zeltner & Hirt, 2008	Sex	d
Broiler	Christensen et al., 2003	Age/ experience	↑
	Jones et al., 2007		↑
	Rodriguez-Aurrekoetxea, Leone, & Estevez, 2014		↑
	Taylor et al., 2015		•
	Fanatico et al., 2016		↓
	Stadig et al., 2016		↑
	Rault & Taylor, 2017		↑
	Stadig et al., 2017a		↑
	Stadig et al., 2017b		↑
	Taylor et al., 2017a		↑
	Stadig et al., 2018		↑
	Taylor et al., 2020		↑
	Jessen, Foldager, & Riber, 2021		↑
	Bonnefous et al., 2023		↑
	Collet et al., 2024		↑
	Hübner et al., 2024		↑
	Jessen, Foldager, & Riber, 2021	Range access	•
	Taylor et al., 2017b	Sex	•
	Taylor et al., 2020		•
	Collet et al., 2024		•

250

251 3.2 *Inherent individual-based factors*

252 3.2.1 Genotype, physical characteristics, age, experience and sex

253 Breeders developed strains of both layers and broilers that differ in their production
254 characteristics. Fast-growing broiler strains are usually not well suited for free-range and
255 organic systems as they are more sedentary due to their decreased ability to walk as they get
256 older (Castellini et al., 2016; Nielsen et al., 2003; Riber et al., 2018). Many slower growing
257 strains have been developed for free-range systems. Bird strain was consistently a good
258 predictor of their ranging, with six studies of layers and all six of broilers reporting a difference
259 in ranging level across strains (Table 2). For example, while 62% of Ancona individuals, a
260 slow growing strain, were seen outside at any given time, only 19% of Ross 308, a fast-
261 growing strain, were seen outside (Castellini et al., 2016; Appendix Table S1). Differences in
262 a strains' ability to adapt to different temperatures and climatic conditions (see above) could
263 also contribute to such variation (e.g. Collet et al., 2024). In one study that looked at
264 morphological characteristics, all four measured traits (comb length and height, neck plumage

and beak darkness) were positively related to ranging at least in one strain (Sztandarski et al. 2021a).

One common conclusion is that chickens change their behaviour as they age (e.g. Campbell et al., 2020; Collet et al., 2024; Hegelund et al., 2005). Our review of the literature generally confirms this conclusion. In eight studies of layers and fourteen of broilers, older and/or more experienced birds ranged more, with only one study of each reporting reduced ranging with age, and two studies of layers and one of broilers finding no effect (Table 2). The direction of change might be influenced by the duration of the study as research showed that distance ranged increased during maturation but decreased after layers reached sexual maturity (Tainika, Sekeroglu, & Abaci, 2024). Moreover, subpopulations of layers with different ranging profiles (generally indoor- or outdoor-preferring) might show different changes over time. In one study, indoor-preferring and moderate outdoor-preferring layers increased in the time they spent on the range, while it slightly decreased for outdoor-preferring birds (Sibanda et al., 2020b). However, age and experience with the range are commonly confounded in these studies. Only one study disentangled age and experience, showing that ranging was, indeed, associated with age rather than experience in layers (Zeltner & Hirt, 2008).

Birds are usually kept indoors until their plumage and condition is deemed good enough to withstand the variable outdoor environment. Four studies, three in layers and one in broilers looked at how early access to the range influenced ranging behaviour (Table 2). In layers, results are mixed with one study showing an increase in ranging, one a decrease and one no change when they got access to the range early. No relationship was found in broilers (Table 2). In addition, sex might be associated with differences in ranging behaviour but few studies have analysed differences between males and females and mostly did not find a difference (Table 2).

Table 3. Studies investigating the relationship between cognition and individual ranging level split across studies in layers and broilers. ↓ negative relationship, ↑ positive relationship, • no

292 significant relationship found. * only in birds reared under enriched conditions. P1 – before
 293 range access, P2 – after range access.

Chicken	Reference	Domain	Test applied	
Laying hen	Campbell et al., 2018b	Spatial	T-maze adult latency	↓
			T-maze adult errors	•
			T-maze juvenile latency	↓*
			T-maze adult errors	•
	Ferreira et al., 2024	Spatial	Detour social reward training	•
			Detour social reward test P1	↓
			Detour social reward test P2	•
		Attention	Attention bias	•
	Campbell et al., 2019	Attention	Attention bias	↓
	Campbell Dickson & Lee, 2019	Attention	Attention bias	•
Broiler	Ferreira et al., 2019	Spatial	Learning	↑
			Reference memory	↓
	Ferreira et al., 2020a	Spatial	Learning	•
			Local cues	•
			Distal cues	↓
	Ferreira et al., 2020b	Spatial	Learning reward: food	•
			Extinction reward: food	↑
			Learning reward: social	↑
			Extinction reward: social	•
	Ferreira et al., 2020c	Spatial	Detour social reward training	•
			Detour social reward test P2	↓

294

295 3.2.2 Cognition

296 An individual's cognition determines their behaviour (Shettleworth 2001). Consequently, their
 297 ranging behaviour might be a product of how individuals perceive, learn, and remember
 298 information and use it to make decisions (Boogert et al., 2018; Ferreira, Guesdon, &
 299 Calandreau, 2021). Two classic tests of spatial learning are the T-maze in which an animal
 300 learns to choose one rewarded arm, and the hole-board task in which animals are presented
 301 with an array of locations (e.g. holes in a board or cups in an arena) of which only one or a
 302 few provide a reward. Those individuals that learn faster and make less errors in these two
 303 tests are considered to have better spatial cognition. One study in layers and two studies in
 304 broilers using these tests found that spatial cognition was negatively associated with ranging

level, while two studies in broilers found a positive relationship (Table 3). For example, outdoor-preferring hens learned to navigate a T-maze more rapidly, and crucially, individuals that learned to navigate the maze faster before range access subsequently ranged more pointing towards inherent differences in spatial ability shaping range use. However, this might be the product of enriched early life conditions as the relationship was lost when the test was repeated with layers reared under standard conditions (Campbell et al., 2018b). For broilers, the pattern was often opposite of what might be expected. For instance, indoor-preferring individuals found the reward faster in a hole-board task and showed greater spatial cognition compared to outdoor-preferring chickens (Ferreira et al., 2019). In a subsequent study, no differences were observed when birds relied on local, less cognitively demanding cues (a white cup among black cups). However, when this salient cue was removed (all cups black), the task became more difficult for outdoor-preferring birds than for indoor-preferring birds (Ferreira et al., 2020a). These results suggest that indoor-preferring broilers may have better spatial cognition, while the two subpopulations differ in their reliance on local beacons (such as cup colour) versus spatial arrangements (Ferreira et al., 2020a). Broilers might form strong associations between locations and food, and as a consequence, they might become less interested in exploring the outdoors. Feeding practices, such as fixed feeding times (Bubier, 1998) or differences in dietary energy content (Christensen et al., 2003; Nielsen et al., 2003) have been shown to influence flock ranging patterns. In a conditioned place preference test, in which one side of the apparatus was associated with food and the other was not, indoor-preferring birds formed stronger associations and continuing to visit the previously rewarded chamber for longer. No such information is available for layers that grow slower and might have different dietary needs and motivation.

While the barn provides a predictable environment, the range is more variable and exposes birds to diverse, sometimes novel stimuli. For more sensitive individuals, this unpredictability may trigger heightened vigilance, which can be interpreted as an attention bias leading to the disproportionate allocation of attention to some stimuli (Crump, Arnott, & Bethell, 2018). For example, an animal might be disproportionately vigilant after an alarm

signal. However, only one of three studies in layers showed a negative relationship of attention bias with ranging level (Table 3). After alarm call playbacks, hens showed increased vigilance and slower feeding, and a higher proportion of indoor-preferring birds failed to resume feeding compared to outdoor birds (61% versus 93%) (Campbell et al., 2019). This points to greater sensitivity to potential threats among indoor-preferring individuals. Judgment bias also appears linked to range use. Ferreira et al. (2024) tested pullets with positive (mirror, chick photo), negative (owl photo), and ambiguous (morphed chick–owl photo) visual stimuli. Although not significant, birds that approached the ambiguous stimulus more quickly tended to be more likely to use the range in the first weeks of access (suggesting a more optimistic bias). Together, these results suggest that indoor- and outdoor-preferring birds may differ in how they evaluate environmental cues.

Heightened attention to details and environmental stimuli may itself act as a barrier when individuals decide whether to venture onto the range. Building on this idea, researchers have examined whether birds differ in motor response inhibition, that is, their ability to adapt behaviour in (novel) situations where ‘automatic’ responses are disadvantageous. For example, while walking around a transparent barrier, the visible reward behind it exerts a pull and the ease with which animals perform a detour in such situations is used as a measure of motor response inhibition. One study in layers and one in broilers found a negative relationship of ranging level with inhibition (Table 3). For example, in layers, individuals delaying their first access to the range also took longer to complete a detour before range access, but this relationship disappeared when birds were tested after range access (Ferreira et al., 2024). In broilers, indoor-preferring birds were more successful at inhibiting a direct approach towards a reward behind a transparent cylinder than outdoor-preferring birds (Ferreira et al., 2020c). These findings suggest that weaker inhibition may facilitate the initial range use of outdoor-preferring chickens by allowing them to approach and explore more readily.

Table 4. Studies investigating the relationship between individual ranging behaviour and fear/anxiety, exploration, boldness and sociability split across studies in layers and broilers. For

361 better comparability, studies testing a similar domain or using a similar/ the same test are
 362 grouped together. Consequently, references are repeated. ↓ negative relationship, ↑ positive
 363 relationship, • no significant relationship found. * only in one treatment group

Chicken	Reference	Test applied	
Laying hen	Fear/ anxiety		
	Grigor, Hughes, & Appleby, 1995b	Tonic immobility	↓
	Mahboub, Müller, & Von Borell, 2004	Tonic immobility	•
	Campbell et al., 2016	Tonic immobility	•
		Manual restraint movement	•
		Manual restraint vocalisations	↑
		Open field test vocalisations	•
	Hartcher et al., 2016	Tonic immobility	↓
	Larsen et al., 2018	Tonic immobility	↑
	Campbell et al., 2018a	Range reduction	•
	Campbell, Dickson, & Lee, 2019	Tonic immobility	•
	Bari et al., 2020a	Range reduction	↑*
	Bari et al., 2021	Tonic immobility	•
	Campbell et al., 2021	Open field test	↓*
		Novel object test	↓
	Wurtz et al., 2023	Tonic immobility	•
	Taylor et al., 2023a	Novel object test (time to first access)	↑
		Novel object test (days accessed)	↓
	Kolakshyapati et al., 2020a	Novel object test	↑
	Exploration		
	Campbell et al., 2016	Open field test (movement)	↑
	Campbell, Dickson, & Lee, 2019	Open field test (steps)	↑
	Bari et al., 2021	Open field test	↑
	Campbell et al., 2021	Novel arena test	•
	Taylor et al., 2023a	Radial arm maze	↑
		Novel arena test	↓
	Kolakshyapati et al., 2020a	Novel arena test	•
	Ferreira et al., 2024	Multivariate test	↑
	Boldness		
	Grigor, Hughes, & Appleby, 1995a	Emergence test	↓
	Bari et al., 2021	Emergence test	↓
	Sociability		
	Ferreira et al., 2024	Multivariate test	↓
Broiler	Fear/ anxiety		
	Castellini et al., 2016	Tonic immobility	↓
	Stadig et al., 2017b	Tonic immobility	•
	Taylor et al., 2020	Tonic immobility	•
	Exploration		

Ferreira et al., 2020a	Open field	•
Ferreira et al., 2022	Novel arena test	•
Bonnefous et al., 2023	Multivariate test	↑
Boldness		
Ferreira et al., 2020a	Emergence test	•
Ferreira et al., 2022	Novel arena test	•
Bonnefous et al., 2023	Multivariate test	•
Sociability		
Ferreira et al., 2020a	Social motivation test	↓
Ferreira et al., 2022	Social motivation test	•
Bonnefous et al., 2023	Social motivation test	•
Motivation		
Ferreira et al., 2021	Contrafreeloading test	↑

364

365 3.2.3 Fear, exploration, boldness, sociability and motivation

366 Keeling and colleagues (1988) proposed high levels of fear and anxiety in relation to unfamiliar
367 environments as well as the gregariousness of chickens and their tendency to flock together
368 inside the barn as explanations for the variation in ranging behaviour observed across
369 individuals. While indoor-preferring birds may be more sensitive to outdoor threats (e.g.,
370 displaying higher vigilance and reduced feeding after alarm calls, see previous section) other
371 evidence linking fear to ranging behaviour is more mixed (Table 4). Fearfulness is frequently
372 measured using responses to novel environments and objects (open field and novel object
373 test), as well as being restrained (manual restraint and tonic immobility test, i.e. death feigning;
374 Peralas et al., 2017; Rogers & Simpson, 2014; Walsh & Cummins, 1976). In these tests, longer
375 latency until movement, vocalisations or approach and avoidance indicates higher fear
376 (Greggor, Thornton, & Clayton, 2015; Walsh & Cummins, 1976). Out of 18 studies conducted
377 on layers, five studies showed a negative (high ranging level associated with lower fear), five
378 studies a positive (low ranging level associated with lower fear) and eight studies no
379 relationship of fear related behaviour and ranging level (Table 4). In broilers, we only found
380 three studies, one of which demonstrated a negative and two no relationship of fear and
381 ranging (Table 4). Some of the inconsistencies in results could be due to the timing of testing
382 in relation to range access. For example, one study found a relationship between ranging and
383 tonic-immobility only before range access, but not after (Stadig et al., 2017b).

Contrary to fear and anxiety, measures of exploration and boldness show a clearer relationship with ranging behaviour, at least in layers. Novel environment, novel object and emergence tests are used to test an individual's propensity to explore and their boldness. Higher levels of movement or number of areas visited indicated higher exploration and shorter time to enter a novel environment (or emerge) indicates higher boldness (Perals et al., 2017; Walsh & Cummins, 1976). Out of eight studies on layers, five found higher exploration in outdoor-preferring hens (positive relationship), one study found lower exploration in outdoor-preferring hens (negative relationship) and two found no relationship. While out of the three studies on broilers, only one found a positive relationship the other two found no relationship of exploration and ranging. Fewer studies considered boldness in relation to ranging level; two in layers and three in broilers. While in both studies on layers, outdoor-preferring hens were bolder (negative relationship), all three studies on broilers showed no relationship between boldness and ranging level (Table 4).

The motivation of chickens to join a group or access rewards might influence ranging level. Similar to boldness, only a few studies have considered sociability or gregariousness in relation to ranging behaviour. Sociability and motivation are tested using social motivation and contrafreeloading tests, respectively (Table 4; Ferreira et al., 2020a; Ferreira, Guesdon, & Calandreau, 2021). A total of four studies considered it; only one in layers. Outdoor-preferring layers were less sociable and spent a shorter time near conspecifics compared to indoor-preferring birds (Ferreira et al., 2024). This was also found in one study on broilers but the other two studies found no relationship (Table 4). Chickens are highly gregarious early in life but gradually become more independent as they age (Hocking et al., 2001; McBride, Parer, & Foenander, 1969; Perinot et al., 2025; Suarez & Gallup, 1983), however, based on our assessment, the inconsistent results do not seem to be related to differences in age or strain across studies.

Only one study tested how motivation to feed is linked to ranging level. As the range provides opportunities to express foraging behaviour, those individuals that are more motivated to perform such behaviours (i.e. work for their food), as compared to receiving *ad*

libitum feed in the barn, might show a higher ranging level. Indeed, outdoor-preferring broilers preferred to forage in a chamber where food was embedded in a substrate, requiring more effort to obtain it (i.e. contrafreeloading), whereas indoor-preferring birds showed no clear preference between freely accessible food and food that required effort (Ferreira et al., 2021). The involvement of motivation is further supported by a study in layers showing that they were willing to push a higher weight, and were therefore, more motivated to gain access to an outdoor range compared to access to feed (Mancinelli et al., 2025).

3.3 Summary – Causes of differences in ranging level

Crudely, chickens are more likely to range in warm, calm and dry weather that is not too sunny. These environmental factors may predictably affect ranging across the year, as the days lengthen and warm, and within a day, as the day warms. These factors appear to influence both broilers and layers in a similar way. We can also conclude that particular strains, perhaps those deliberately bred for free-range units, ranged more and ranging increased over time, with some evidence that this is more dependent on age than experience potentially because the influence of experience may plateau once the birds are accustomed to the range. In contrast to environmental factors and age/ experience, cognition is not regularly studied in the context of ranging. Despite some evidence showing better spatial cognition, heightened vigilance and higher inhibition in indoor-preferring birds (Campbell et al., 2019; Ferreira et al., 2019; 2020c), the results are mixed and often, no relationship is found which could be attributed in part to the use of a large range of tests and measurements (Table 3). Finally, no clear relationship emerges between ranging and fear despite much research effort. Exploration and boldness seem more promising as explanatory factors, but only in layers as most evidence in broilers does not show a relationship to ranging. However, results are similarly inconsistent as the results for cognition which could similarly be attributed to the wide variety of methods used (Table 4). On the other hand, investigating the influence of foraging motivation on ranging could be promising but has not been investigated in layers.

Together, while predictive power declines as analyses move from environmental to individual-level factors, integrating these perspectives offers a promising framework to understand and manage variation in free-range behaviour. Compared to environmental factors or genotype, the relationship with behaviour and cognition is less clear. As studies move from flock-level measures (environment and genotype) to individual-level assessments (cognition and behaviours), greater variability is introduced, and sample sizes decrease which reduces the power to detect effects. Across studies, many environmental factors are not well controlled introducing additional variation and decreasing the comparability with other research on the same topics. However, having a clear understanding of what causes differences in individual ranging behaviour is crucial to design targeted interventions to improve ranging level (see section further below).

Table 5. Studies investigating the relationship between ranging behaviour and welfare parameters split across studies in layers and broilers. For better comparability, studies measuring the same parameter are grouped together. Consequently, references are repeated. For plumage condition, correlation direction was adjusted based on scoring system (lower values indicate intact plumage). ↓ negative relationship, ↑ positive relationship, d difference between groups, • no significant relationship, * only in one genotype. Pre – assessment pre ranging, Post – assessment post ranging.

Chicken	Reference	Time point	Measurement
Laying hen	Plumage condition		
	Mahboub, Müller, & Von Borell, 2004	Post	↓
	Hegelund, Sørensen, & Hermansen, 2006	Post	•
	Chielo, Pike, & Cooper, 2016	Post	↑
	Hartcher et al., 2016	Post	•
	Rodriguez-Aurrekoetxea & Estevez, 2016	Post	↓
	Larsen et al., 2018	Post	•
	Bestman et al., 2019	Post	↑
	Bari et al., 2020a	Post	↓
	Bari et al., 2020b	Post	↓

Sibanda et al., 2020c	Post		↑
Wurtz et al., 2023	Post	Tail	•
		Wing	•
Feather pecking			
Gilani, Knowles, & Nicol, 2014	Post		•
Wounds			
Rodriguez-Aurrekoetxea & Estevez, 2016	Post	Comb	•
Bestman et al., 2019	Post	Comb	•
		Skin	•
Bari et al., 2020a	Post	Comb	↓
Keel bone damage			
Richards et al., 2012	Post		↓
Larsen et al., 2018	Post		•
Bestman et al., 2019	Post		↓
Bari et al., 2020a	Post		↑
Bari et al., 2020b	Post		•
Sibanda et al., 2020c	Post		•
Wurtz et al., 2023	Post		•
Bone characteristics			
Kolakshyapati et al., 2019	Post	Tibial length	•
		Tibia weight	•
		Tibia diaphyseal diameter	•
		Total tibia volume	•
		Tibia breaking strength	•
		Bone mineral composition	•
		Relative bone weight	↑
Bari et al., 2020b	Post	Bone mass	•
Sibanda et al., 2020a	Post	% blood vessel	•
		% bone marrow	•
		% cortical bone	•
		Bone volume	•
		Bone length	•
		Bone volume	•
		Bone-breaking strength	•
		Mineral density	•
		Diaphyseal diameter	•
		Trabeculae thickness	•
		Connectivity density	•
Footpad lesions			
Castellini et al., 2016	Post		↓
Rodriguez-Aurrekoetxea & Estevez, 2016	Post		•

Larsen et al., 2018	Post		•
Bestman et al., 2019	Post		•
Bari et al., 2020a	Post		↓
Bari et al., 2020b	Post		↑
Wurtz et al., 2023	Post		↓
External characteristics			
Larsen et al., 2018	Post	Comb colour	•
		Beak score	•
Bari et al., 2020a	Post	Beak score	↓
		Toenail length	↓
Internal health characteristics			
Singh et al., 2016a	Post	Gizzard weight	↑
		Gizzard pH	•
		Gut weight	↑
		Digestibility coefficient	↑
Bari et al., 2020b	Post	Gizzard weight	•
		Liver weight	•
		Adrenal weight	•
		Spleen weight	•
Kolakshyapati et al., 2020b	Post	Gizzard weight	•
		Liver weight	•
		Pancreas weight	•
Wurtz et al., 2023	Post	Gizzard weight	↑
		Gizzard fat content	↓
		Ileum length	↓
		Colon length	↑
		Caeca length	↑
		Duodenum length	•
		Crop weight	↑
		Hyperkeratosis	•
		Proventriculus weight	↑
		Proventriculus fat content	↓
Metabolism			
Kolakshyapati et al., 2020b	Post	Gross energy intake	•
		Metabolizable energy	•
		Metabolizable energy intake	↓
		Retained energy	•
		Net energy	•
		Heat production	•
		Heat increment	•
		Net energy intake	•
		Retained nitrogen	↓
Microbiome			
Bari et al., 2022	Post	Alpha diversity	•
		Beta diversity	d

Stress			
Campbell et al., 2016	Post	Corticosterone	●
Larsen et al., 2018	Post	Stress	↑
Parasite load			
Sherwin et al., 2013	Post		↑
Bari et al., 2020b	Post		●
Sibanda et al., 2020c	Post		↑
Bestman et al., 2023	Post		●
Disease and mortality			
Sibanda et al., 2020c	Post	Spotty liver	↑
		Fatty liver	↓
		Mortality	↓
Wurtz et al., 2023	Post	Bumblefoot	●
Broiler			
Plumage			
Castellin et al., 2016	Post	Condition	↓
Taylor et al., 2018	Pre	Summer breast	●
		Winter breast	↓
		Cover	●
		Cleanliness	●
	Post	Summer	●
		Winter	↓
		Cover	●
		Cleanliness	↓
Marchewka et al., 2020	Post	Condition	●
		Cleanliness	●
Vent cleanliness			
Taylor et al., 2018	Post	Summer	↑
		Winter	●
Wounds			
Castellin et al., 2016	Post	Breast	↓
Marchewka et al., 2020	Post	Comb	●
		Skin	●
		Toe	↓
Footpad lesions			
Durali et al., 2014	Post		●
Taylor et al., 2018	Pre		●
	Post		●
Marchewka et al., 2020	Post		●
Taylor et al., 2020	Pre		●
	Post		↑
Bonnefous et al., 2024	Post		●
Hock burn			
Durali et al., 2014	Post		●
Taylor et al., 2018	Pre		●

	Post		•
Marchewka et al., 2020	Post		•
Taylor et al., 2020	Pre		•
	Post		•
Bonnefous et al., 2024	Post		•
Gait			
Jones et al., 2007	Post		↓
Taylor et al., 2018	Pre		•
	Post	Summer	↓
		Winter	•
Marchewka et al., 2020	Post		•
Taylor et al., 2020	Pre		•
	Post		↓
Tibia characteristics			
Bonnefous et al., 2024	Post	Length	↓*
		Diameter	↓*
		Bone breaking strength	↑*
Internal health characteristics			
Durali et al., 2014	Post	Bursa of Fabricius	•
		Spleen weight	•
		Gizzard weight	↑
		Intestinal health	•
Stress and immunity			
Castellin et al., 2016	Post	Immunity	↑
		Stress response	↑
Taylor et al., 2020	Pre	Corticosterone	•
	Post	Corticosterone	↓
Disease and mortality			
Taylor et al., 2018	Post	Summer ascites	↓
		Winter ascites	•
		Summer pericardial fluid	↓
		Winter pericardial fluid	•
Marchewka et al., 2020	Post	Eye pathologies	•
		Respiratory infection	↓*
		Diarrhea	•
Dawkins et al., 2003	Post	Mortality	•

458

459 **4 Consequences of individual ranging behaviour**

460 It has been of great interest to evaluate the welfare outcomes of free-range access, because
461 although the free-range provides opportunities that improve welfare, it also exposes chickens
462 to risks. Furthermore, improved welfare was one of the main arguments that led to a move

towards free-range chicken production. However, free-range access does not only have consequences for welfare but also affects production. Homogeneity in the final products is a desired production trait (the size of products is expected to be uniform) and decreased homogeneity due to increased individual difference related to ranging behaviour could decrease income. Therefore, understanding both the consequences of free-range access on health as a measure of welfare and production performance are of great interest.

4.1 Consequences for welfare

A major concern in layers is feather pecking. This feather damaging behaviour is thought to be misdirected foraging behaviour, and when blood is drawn by the removal of a feather, it can lead to cannibalism and death (Cronin & Glatz, 2020). Out of 11 studies that measured feather condition in layers, four found better plumage in outdoor-preferring layers, three found better plumage in indoor-preferring birds, while four studies found no relationship (Table 5). Only one study measured feather pecking directly but found no relationship to ranging level (Gilani, Knowles, & Nicol, 2014). While plumage condition in layers is recorded as a proxy for feather pecking, in broilers it is rather used to measure cleanliness. Out of three studies, two reported better plumage condition in outdoor-preferring broilers. Although most measures were not related to ranging, in winter, broilers with better breast plumage cover before range access subsequently ranged more and retained better plumage condition (cover, cleanliness) after range access (Table 5).

The skin injuries cause by misdirected pecking might in themselves decrease welfare and affect ranging. In layers, four studies looked at skin and comb wounds but only one study found fewer wounds in outdoor-preferring layers, the other studies found no relationship (Table 5). In broilers, two studies measures wounds and found that outdoor-preferring broilers had fewer breast blisters (infected skin injuries due to increased resting) and toe wounds but skin and comb wounds were unrelated to ranging (Table 5). The lower density of individuals, higher activity and reduced resting outside (e.g. Diep, Larsen, & Rault, 2018) seems to prevent

feather pecking and the associated feather and skin damage as well as infection of skin injuries.

To get onto and utilise the range chickens need to be able and motivated to move. Pain caused by various injuries to the bones and feet might affect ranging if it reduces an individual's mobility. A frequently occurring painful injury in layers is keel bone damage and other fractures and deformities due to issues with bone mineral density (osteoporosis) and calcium utilisation during egg production as well as captive management (Leyendecker et al., 2005; Rodriguez-Navarron et al., 2018; Sibanda et al., 2020a; Giersberg & Rodenburg, 2023). Contrary to expectations, out of seven studies measuring keel bone damage, only two showed less damage in outdoor-preferring hens while one showed less damage in indoor-preferring hens and the other four revealed no relationship (Table 5). Depending on the pop hole height, movement onto the range might only be impaired due to pain by keel bone damage when hens have to jump or fly up to pass through. Richards and colleagues (2012) confirmed that hens used the pop holes less with increasing damage to the keel bone. Furthermore, the three studies that measured bone characteristics in layers also found no relationship with ranging except for one study that could show higher relative bone weight in outdoor-preferring birds (Kolakshyapati et al., 2019).

Another source of pain is damage to the feet which might impair ranging in both layers and broilers. However, due to the fast growth of broilers issues with the feet are more prevalent and analysed in more detail than in layers (Riber & Wurtz, 2024). The seven studies on layers included here measured only footpad lesions. Three studies found better foot condition in outdoor-preferring layers, one better foot condition in indoor-preferring layers but three studies found no relationship (Table 5). Wet substrate is one of the main factors leading to issues with the feet in chickens and foot condition likely changes depending on weather, which might explain the mixed results. In broilers, the six studies included in our sample not only measured footpad lesions but also hock burn and gait (Table 5). Apart from one study that revealed more footpad lesions in outdoor-preferring broilers after range access (Taylor et al., 2020), all other studies found no relationship between ranging and footpad lesions or hock burn (Table 5).

However, three out of four studies showed that outdoor-preferring broilers had better gait score post range access while ranging groups did not differ pre range access (Taylor et al., 2018; 2020). Finally, broilers that preferred to range outdoors had shorter and thinner tibia but higher bone breaking strength, but this was strain dependent (two out of four tested strains; Bonnefous et al., 2024). And in layers, one study demonstrated that outdoor-preferring individuals had improved nail and beak condition (i.e. shorter nails) while another study on external characteristics found no relationship (Table 5).

Apart from increased opportunity for movement and foraging, outdoor access provides chickens with an increased diversity of food such as plant material and insects (Glatz et al., 2005) and the opportunity to pick up grit stones (Wurtz et al., 2023) which might lead to changes in internal organs and metabolism. Four studies in layers and one study in broilers looked at organ size and health. Half of the studies in layers and the study in broilers show an increase in organ size and decrease in organ fat content in outdoor-preferring birds. These results indicate that these organs were better developed which can improve nutrient utilization, gut health and digestibility coefficients (for a detailed list see Table 5). However, the other two studies in layers found no relationship and not all organs were affected (Table 5). Furthermore, outdoor ranging was associated with decreased heat production, metabolizable energy intake (Kolakshyapati et al., 2020b) and differences in beta diversity of the cecal microbiota in layers (Bari et al., 2022).

Finally, the range does also expose chickens to parasites, diseases, predation and potentially increases stress. In layers, two studies investigated the relationship of stress and ranging, four the relationship to parasite load and two to disease and mortality. Half of the studies showed increased stress, parasite load and spotty liver disease but a lower likelihood of fatty liver syndrome and mortality in layers. However, the other half found no relationship (Table 5). In broilers, two studies looked at stress and immunity in relation to ranging and three studies at disease and mortality (Table 5). One study revealed higher immune response and stress in outdoor-preferring broilers potentially due to higher disease exposure or parasite load (Castellin et al., 2016) while corticosterone was lower in outdoor-preferring chickens post but

not pre ranging (Taylor et al., 2020). Furthermore, two studies showed that outdoor-preferring broilers had lower fluid in the abdomen in summer and lower levels of respiratory infections indicating better health in this subpopulation (Marchewka et al., 2020; Taylor et al., 2018). Contrary to layers, no relationship between ranging level and mortality was found in broilers (Dawkins et al., 2003).

4.2 Consequences for production

Higher levels of ranging produced relatively few increases in production quality, and most measures were unrelated to ranging. Only three studies linked ranging level to egg production in layers and mostly found that there was no relationship between ranging level and egg production. Only one study found a negative association between ranging level and egg number. Outdoor-preferring hens laid less eggs (Table 6). This could indicate that the desire to range might conflict with egg laying increasing the number of eggs not laid in nest boxes and the work for farmers to collect them.

In broilers, weight and weight gain are important production measure as broilers need to achieve desirable slaughter weight to be sold. Studies have looked both at the weight of broilers before and after range access and showed that those chickens with lower weight before range access ranged more and continue to have lower body weight compared to those individuals that stayed inside likely due to lower weight gain caused by reduced creatine kinase activity resulting in decreased muscle growth (Table 6; Bonnefous et al., 2024; Durali et al., 2012; Taylor et al., 2018; 2020). One study, however, found the highest body weight in high rangers, and two studies found no relationship (Table 6). All these studies demonstrate that individual ranging level increased flock heterogeneity in meat yield due to different ranging levels which could pose a challenge for farmers (Bonnefous et al., 2024). Contrary to broilers, no consistent effect of ranging level on weight was found in layers. Of the six studies measuring weight in layers, two found higher weight in outdoor-preferring birds, two lower weight in outdoor-preferring birds and two found no relationship (Table 6).

Only two studies linked individual ranging level to meat quality in broilers (Table 6). A comparison of four broiler strains showed that at least in some strains, the meat from individuals with higher ranging level was darker, paler red but more yellow (more preferred by consumers), and they yielded more meat (Table 6). Stadig and colleagues (2016) also found improved colour, but contrary to Bonnefous and colleagues (2024), they found that outdoor-preferring broilers had higher mono- and polyunsaturated fatty acid concentrations, as well as higher omega 3 and omega 6 fatty acid concentrations (they have positive effects on human heart health; Table 6), and therefore, had healthier meat. Differences in the used strain might explain the differing results in those two studies (Stadig et al., 2016: Sasso T451; Bonnefous et al., 2024: JA757, S757N, White Bresse, Dual purpose breed).

Table 6. Studies investigating the relationship between ranging behaviour and production parameters split across studies in layers and broilers. For better comparability, studies measuring the same parameter are grouped together. Consequently, references are repeated.

↓ negative relationship, ↑ positive relationship, • no significant relationship, * only in one genotype. Pre – assessment prior to ranging, Post – assessment after range access.

Chicken	Reference	Measurement
Laying hen	Weight	
	Castellini et al., 2016	↓
	Rodriguez-Aurrekoetxea & Estevez, 2016	•
	Singh et al., 2016a	↑
	Bari et al., 2020a	↓
	Sibanda et al., 2020b	↑
	Wurtz et al., 2023	•
	Meat characteristics	
	Bari et al., 2020b	Fat ↓
		Muscle ↓
	Egg characteristics	
	Icken et al., 2008	Number ↓
	Kolakshyapati et al., 2020b	Number •
		Mass •
		Laying rate •
		Number •
	Sibanda et al., 2020b	Number •

		Quality
Broiler	Weight	
Durali et al., 2014		↓
Stadig et al 2016		↓
Taylor et al., 2018	Pre summer	↓
	Pre winter	●
	Post summer gain	↓
Taylor et al., 2020	Post winter gain	●
	Pre	↓
	Post	↓
Marchewka et al., 2020		↑*
Bonnefous et al., 2024	Carcass	↓*
	Breast	↓*
	Thigh	↓*
Meat characteristics		
Bonnefous et al., 2024	Carcass yield	↓*
	Breast yield	●
	Thigh yield	↓*
	Lightness	↓*
	Redness	↓*
	Yellowness	↑*
	Drip loss	●
	Cooking loss	●
	Shear force	●
	Lipids	●
	Saturated fatty acids	●
	Monounsaturated f. a.	●
	Polyunsaturated f. a.	●
	n6/ n3	●
	Colour	↑
Stadig et al., 2016	pH	↓
	Drip loss	↓
	Cooking loss	●
	Shear force	●
	Fat	●
	Protein	●
	Moisture	●
	Ash content	●
	Unsaturated fatty acids	↑
	Polyunsaturated fatty acids	↑
	Omega 3	↑
	Omega 6	↑
	Sensory characteristics	↑
Feed conversion rate		
Dawkins et al., 2003		●

4.3 *Summary – Consequences of individual ranging behaviour*

Together, a wide range of welfare indicators are measured in both layers and broilers. In layers, studies found rather mixed results of the effect of outdoor access on plumage condition, keel bone damage and footpad lesions but wounds, bone and internal health characteristics seem largely unrelated to ranging. In broilers, results are more straightforward. Outdoor-preferring broilers sometimes show better plumage, less wounds and better gait but many studies found no relationship, especially with footpad lesions and hock burn. Although outdoor-preferring individuals might show a higher immune response and more parasites, this does not seem to translate into higher mortality, one of the biggest concerns of keeping chicken outdoors. In regard to production, only a few studies have focused on the effects of individual ranging level on production traits finding little effect on egg quality in layers and mostly negative effects on weight, but some positive effects on meat quality in broilers (Table 6).

5 Interventions to improve ranging behaviour

As shown in the previous sections, the causes and consequences of ranging behaviour are attracting increasing attention from both applied and fundamental researchers. A further strand of this work focuses on identifying the levers available to farmers to intervene and either enhance or at least homogenize ranging behaviour in their flocks. Simple changes in flock management such as changes in flock size and stocking density, barn build and enrichment (both in the barn during rearing and on the range) have potential to increase the level of ranging across the flock and improve the use of the available range area. As the free-range chicken sector is still developing, it is crucial to determine the optimal environment that encourages chickens to utilise the free-range in these systems.

5.1 *Management interventions*

A number of management actions at the shed or flock level can affect ranging behaviour. Chickens can enter or exit the barn via small openings called “pop holes”. Three of four studies

included here showed that ranging increased in both layers and broilers when there were more pop-holes allowing access to the range (Table 7) even though layers might only use certain pop holes to leave the house (Taylor et al., 2017a). This could be related to how perches are distributed inside the barn as studies have shown that roosting further from pop holes and at higher elevations decreases an individual's likelihood to be found on the range (Pettersson et al., 2018; Sibanda et al., 2020d). Furthermore, for layers, more indoor light was accompanied by more ranging in two studies although this was not the case in broilers (Table 7).

In layers, ranging level was generally lower in larger flocks (three of five studies; Appendix Table S1) and at higher stocking densities (two of three studies). However, in one study, ranging increased with stocking density. Stocking density is tightly regulated in the commercial sector (e.g. EU Directive 1999/74/EC states no more than 9 layers per m² indoors and 4m² per hen outdoors in free-range systems; EU Directive, 1999) but in a research context it can vary widely (Appendix Table S1). The orientation of the barn had no effect on ranging for either layers or broilers in four studies, however, larger ranges attracted less layers and broilers onto the range (two studies, Table 7).

Finally, although it is most common to keep layers without males, ranging increased if there were more roosters deliberately added to the flock (Bestman et al., 2019). This might be associated with the behaviour of roosters who range more and use different vocalisations to attract the attention of hens ultimately leading to more hens on the range (Harlander-Matauschek, Niebuhr, & Troxler, 2002; Ferreira et al., 2019; Nicol, 2015; Taylor et al., 2017b).

Table 7. Studies investigating how different management practices (e.g. flock size, stocking density, etc.) influence ranging behaviour split across studies in layers and broiler chickens. For better comparability, studies testing a similar type of management are grouped together. Consequently, references are repeated. Stocking density in birds per m², ↓ negative relationship, ↑ positive relationship, d difference across groups, • no significant relationship.

Chicken	Reference	Measurement
---------	-----------	-------------

Laying hen		Flock size	
	Hegelund et al., 2005	513 – 6,000	↓
	Hegelund, Sørensen, & Hermansen, 2006	1,200 – 5,000	•
	Gebhardt-Henrich, Toscano, & Fröhlich, 2014	2,000 – 18,000	•
	Gilani, Knowles, & Nicol, 2014	92 – 15,848	↓
	Bestman et al., 2019	1,854 – 23,879	↓
		Stocking density	
	Sherwin et al., 2013	Not given	↑
	Gilani, Knowles, & Nicol, 2014	4 – 12	↓
	Bestman et al., 2019	5.1 – 9	↓
		Pop holes	
	Harlander-Matauschek et al., 2006		•
	Sherwin et al., 2013		↑
	Gilani, Knowles, & Nicol, 2014		↑
		Other	
	Harlander-Matauschek et al., 2006	Barn orientation	•
	Cronin et al., 2016	Barn orientation	•
	Campbell et al., 2017	Range size	↓
	Gilani, Knowles, & Nicol, 2014	Light indoors	↑
	Bestman et al., 2019	Light indoors	↑
		Roosters in the flock	↓
Broiler			
	Dawkins et al., 2003	Barn orientation	•
	Rault & Taylor, 2017	Barn orientation	•
		Pop holes	↑
	Geng et al., 2023	Light indoors	d
	Zahid et al., 2024	Range size	↓

644

645 5.2 Early life enrichment interventions in the barn

646 Enrichment involves any improvement to the captive environment that benefits an animal and
647 increases species-specific appropriate behaviour and behavioural choice with the potential to
648 decrease abnormal behaviour (Young, 2013; Newberry, 1995). Indoor rearing enrichment has
649 been proposed to provide important experiences that could improve ranging in adulthood
650 (Campbell, De Haas & Lee, 2019; Xu et al., 2022). Enrichment can take many forms. In
651 chickens, they are often referred to as structural enrichment (large objects that break up the
652 environment such as perches), foraging enrichment (objects or insects that encourage
653 foraging), or novelty enrichment (structures and objects which are changed regularly to create

a variable environment). The most common form of enrichment are objects of varying sizes (Xu et al., 2022). In layers, one study tested the influence of early life experience with environmental choice, two the influence of unpredictability and another two the influence of novelty and structures. Out of these five studies, three found no effect regardless of the measure of ranging (Table 8). One study showed that increasing predictability early in life shortens the hours hens spend outside but increases the days they range (Campbell et al., 2018a). Structural and novelty enrichment increased ranging in the treatment groups, but this effect was only detectable when the birds became older (> 31 weeks) and was not consistent across treatments (Campbell et al., 2020). Four studies investigated early life enrichment effects in broilers and although a large variety of enrichment types were used, most increased ranging (Table 8).

Table 8. Studies investigating the effect of different early life enrichment treatments on ranging behaviour split across studies in layers and broiler chickens Difference between treatments: • no difference, ↓ lower measure in the treatment group, ↑ higher measure in the treatment group. * only in one enrichment treatment.

Chicken	Reference	Type	Measurement	
Laying hen	Skånberg et al., 2024	Environmental choice	Chickens outside	•
			Hours outside	↓
	Campbell et al., 2018a	Unpredictable environment	Visits	•
			Available days	↑
			Hours outside	•
	Campbell, Horton, & Hinch, 2018	Unpredictable environment	Visits	•
			Visit duration	•
			Hours outside < 31 weeks	•
	Campbell et al., 2020	Novelty, structures	Hours outside > 31 weeks	↑*
			Visits < 31 weeks	•
			Visits > 31 weeks	↓*
			Visit duration	↑*
			Available days < 38 weeks	•
			Available days > 38 weeks	↑*
	Taylor et al., 2023a		Hours outside	•

		Novelty, structures	Visits First access	• •
Broiler	Gordon & Forbes, 2002	Shelter provision	Chickens outside	↑
	Rodriguez-Aurrekoetxea, Leone, & Estevez, 2014	Pannels Perches	Chickens outside	• ↑
	Stadig et al., 2018	Dark brooders Trees, shelter	Chickens outside	• ↑
	Taylor et al., 2023b	Visual access, environmental complexity	Chickens outside Hours outside Days outside First access	↑* ↑* ↑* ↑*

670

671 5.3 Range enrichment interventions

672 Providing a range that is more enriched and complex and closely meets the needs of chickens
673 with regard to microclimate and predator protection offers a powerful way to improve ranging.
674 Chickens can be encouraged to increase ranging through range enrichment interventions
675 such as the provision of movable, artificial structures. Providing such cover increased ranging
676 in six of eight studies considering layers and four of seven studies of broilers (Table 9). These
677 changes in ranging behaviour were related to the attracting effect of structures on the range
678 (Rault, Van De Wouw, & Hemsworth, 2013) and birds seemed to prefer variety over number,
679 structures that provided shade and shelter (Zeltner & Hirt, 2008), tall over shorter vertical
680 structures (Larsen & Rault, 2021), and structures that were familiar (Grigor, Hughes, &
681 Appleby, 1995a).

682 Alternatively, vegetation has also been shown to attract more layers and broilers onto
683 the range (all studies, Table 9). Importantly, when comparing the effect of artificial cover with
684 natural vegetation, bushes and trees seemed most effective in drawing chickens outside and
685 away from the barn (e.g. Stadig et al., 2017a; 2017b; 2018). Compared to artificial cover,
686 plants might create more desirable microclimates and better protection from heat, wind and
687 rain, and coax chickens outside even under undesirable weather conditions (Deutsch et al.,
688 2024; Rault, Van De Wouw, & Hemsworth, 2013; Stadig et al., 2017a, b). Finally, even without
689 cover, providing access to pasture increased ranging in three of four studies of layers and in

a single broiler study (Table 9). One study of layers that involved Appendix feeding with black soldier flies had mixed effects, increasing the maximum time spent outside but not altering four other measures of ranging (Ruhnke et al., 2018). Co-grazing with other livestock such as cattle was also effective in improving ranging behaviour and simultaneously reduced predation, especially from aerial predators (Hübner et al., 2024).

Table 9. Studies investigating the effect of different range enrichments on ranging behaviour split across studies in layers and broiler chickens Difference between treatments: ↑ higher measure in the treatment group, • no significant difference.

Chicken	Reference	Type	Measurement	
Laying hen	Harlander-Matauschek et al., 2006	Tree cover	Chickens outside	↑
	Deutsch et al., 2024			↑
	Zeltner & Hirt, 2003	Artificial cover, sand	Chickens outside	•
	Hegelund et al., 2005	Artificial cover	Chickens outside	↑
	Sherwin et al., 2013			↑
	Pettersson, Weeks, & Nicol, 2017			•
	Gilani, Knowles, & Nicol, 2014	Cover	Chickens outside	↑
	Rault, Van De Wouw, & Hemsworth, 2013	Structure vertical	Chickens outside	↑
	Zeltner & Hirt, 2008	Structure number	Chickens outside	•
		Structure variety		↑
		Corridor		•
	Nagle & Glatz, 2012	Cloth cover	Chickens outside	↑
		Shelter belt		↑
		Pasture		↑
	Aygun et al., 2024	Pasture	Area covered	•
	Tainika, Sekeroglu, & Abaci, 2024			↑
	Ruhnke et al., 2018	Black soldier fly feeding	Max. hours outside	↑
			Av. hours outside	•
			Total hours outside	•
			Av. visits	•
			Total visits	•
Broiler	Dawkins et al., 2003	Tree cover	Chickens outside	↑
	Stadig et al., 2016			↑

Stadig et al., 2017a	Trees, artificial cover	Chickens outside	↑
Stadig et al., 2017b			↑
Stadig et al., 2018			↑
Dal Bosco et al., 2014	Tree cover	Hours outside	↑
Gordon & Forbes, 2002	Artificial cover	Chickens outside	↑
Taylor et al., 2015	Cover	Chickens outside	•
Rodriguez-Aurrekoetxea, Leone, & Estevez, 2014	Structures	Chickens outside	•
Fanatico et al., 2016			•
Marchewka et al., 2023	Pasture	Ranging level	↑
Hübner et al., 2024	Cattle	Area covered	↑

699

700 *Summary – Interventions to improve ranging behaviour*

701 Together, we find that there is much room for farmers to improve the conditions under which
702 chickens are reared and housed throughout their life within the free-range system that would
703 improve ranging behaviour. Such changes likely not only influence behaviour but also welfare
704 and production (see section above). Based on the data gathered in this review, decreasing
705 flock size and stocking less birds within the available space seem the most promising
706 management interventions, however, such changes come with an economic cost. Early life
707 enrichment seems less effective especially in layers with more success in broilers. Finally,
708 chickens seem to prefer areas with natural vegetation, and the largest effects are achieved
709 when dense vegetation is planted on the range although most range enrichments had a
710 positive effect on ranging behaviour (Table 9).

711

712 **6 Conclusions**

713 Increasing research effort (75% of studies published in the last 10 years) is being put into
714 understanding the causes and consequences of variation in ranging behaviour by individual
715 and flocks of chickens with the ultimate goal being to determine optimal management
716 practices and outdoor environment design to enhance welfare and productivity. Our review
717 expands previous syntheses by quantitatively integrating evidence across behavioural,
718 cognitive and environmental domains, revealing the multi-level nature of range use variation.
719 Despite much effort to isolate the contributing factors, they are often confounded within

720 studies. One example is the change in ranging behaviour over time. It is unclear if ranging
721 increase with age, experience or both? Future studies should focus on carefully designed
722 experiments that better control for potential influential factors to produce data that are easier
723 to interpret, use and compare. Such studies should be conducted for specific genotypes
724 developed for free-range systems, as we show clearly that genetic background matters. One
725 way to increase power is to use big collaborative, multi-team research networks (big team
726 science initiatives, e.g. ManyBirds, ManyPrimates, ManyManys) that have become
727 increasingly popular in recent years (Nelson, 2024). Considering the many research groups
728 across the globe that are involved in research in chickens, a similar large-scale collaboration
729 could be crucial in revealing the factors contributing to the inconsistencies in findings across
730 studies that our review has highlighted throughout. The gathered empirical evidence, if
731 available to breeders, could direct breeding decisions towards the development of genotypes
732 that are even better adapted to free-range systems. Regardless of genotype, our review
733 indicates only a small effect of ranging on production and if any, a largely positive effect on
734 welfare. However, the literature on the effect of ranging behaviour on production is small and
735 studies on welfare mostly focus on physical health not cognitive health. However, a stronger
736 focus on positive welfare measures should be taken in the future to understand if range access
737 provides chickens with the opportunity to experience positive welfare states by engaging in
738 rewarding behaviour (Mellor, 2016; Rault et al., 2025). Nevertheless, removal of negative
739 affective states due to poor physical health is a necessary first step for animals to be motivated
740 to engage in rewarding behaviours (Mellor, 2016). Consequently, more such research is
741 desirable especially as a basis to argue for improvements in chicken husbandry that include
742 changes to management practices. More information on the effects of different management
743 practices would be insightful as to the optimal husbandry conditions that could be implemented
744 in future free-range farms. Furthermore, from the information gathered in this review, the
745 easiest way to increase ranging on existing farms is to provide shelter on the range and, if
746 possible, plant vegetation, as it has the largest effect. To utilise the full potential of free-range
747 farming systems, it will be imperative to start using ranges to grow trees so as to benefit both

the chickens as well as the farmer due to increased product diversity and increasing income (e.g. production of fruit or wood and eggs/ meat). This could also help deal with the increased nutrient load on free-ranges (e.g. Dekker et al., 2012; Menzi et al., 1997; Singh et al., 2016b). Alternatively, co-grazing with other livestock is another way that seems promising to both increase ranging in chickens (Hübner et al., 2024) and add economic value to free-range chicken farming by translating into better production stability and reducing health management costs. However, further research on how to manage nutrient load on the range and cognrazing is necessary to develop best practice and determine the scale of benefits.

There are still many knowledge gaps regarding the individual, environmental and management factors that influence ranging behaviour in chickens as well as its consequences for welfare and production (Figure 1). We hope that our review will stimulate new directions of research on the topic of individual ranging in chickens and help develop effective and practical interventions that both benefit the domestic fowl as well as farmers. Ultimately, a comprehensive understanding of both the environmental and behavioural/ cognitive dimensions of range use will be key to designing sustainable, animal-oriented free-range systems.

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8 References

- Abouelezz, F. M. K., Sarmiento-Franco, L., Santos-Ricalde, R., & Segura-Correa, J. (2014). Use of the outdoor range and activities of Rhode Island Red hens grazing on natural vegetation in the tropics. *Journal of Agricultural Science and Technology* 16(7), 1555–1563.
- Ahmad, S., Mahmud, A., Hussain, J., Javed, K., Usman, M., Waqas, M., & Zaid, M. (2021). Behavioural assessment of three chicken genotypes under free-range, semi-intensive, and intensive housing systems. *Ankara Üniversitesi Veteriner Fakültesi Dergisi* 68(4), 365–372.
- Almeida, G. F. D., Hinrichsen, L. K., Horsted, K., Thamsborg, S. M., & Hermansen, J. E. (2012). Feed intake and activity level of two broiler genotypes foraging different types of vegetation in the finishing period. *Poultry Science*, 91(9), 2105-2113.
- Aygun, A., Narinc, D., Özköse, A., Arisoy, H., Acar, R., Uzal, S., & Bulut, C. (2024). Effects of outdoor plant varieties on performance, egg quality, behavior, and economic analysis of Turkey local chicken from 20 to 36 weeks of age. *Journal of the Hellenic Veterinary Medical Society* 75(1), 7007–7018.
- Bari, M. S., Allen, S. S., Mesken, J., Cohen-Barnhouse, A. M., & Campbell, D. L. M. (2021). Relationship between Range Use and Fearfulness in Free-Range Hens from Different Rearing Enrichments. *Animals* 11(2), 300.
- Bari, M. S., Downing, J. A., Dyll, T. R., Lee, C., & Campbell, D. L. M. (2020a). Relationships between rearing enrichments, range use, and an environmental stressor for free-range laying hen welfare. *Frontiers in Veterinary Science*, 7, 480.
- Bari, M. S., Kheravii, S. K., Bajagai, Y. S., Wu, S. B., Keerqin, C., & Campbell, D. L. (2022). Cecal microbiota of free-range hens varied with different rearing enrichments and ranging patterns. *Frontiers in Microbiology*, 12, 797396.
- Bari, M. S., Laurenson, Y. C., Cohen-Barnhouse, A. M., Walkden-Brown, S. W., & Campbell, D. L. (2020b). Effects of outdoor ranging on external and internal health parameters for hens from different rearing enrichments. *PeerJ* 8, e8720.

796 Bestman, M., van Niekerk, T., Göransson, L., Ferrante, V., Gunnarsson, S., Grilli, G., Arndt,
797 S. S., & Rodenburg, T. B. (2023). Free-range use and intestinal parasites in
798 organic/free-range layers. *Journal of Applied Poultry Research* 32(2), 100321.

799 Bestman, M., Verwer, C., van Niekerk, T., Leenstra, F., Reuvekamp, B., Amsler-Kepalaite,
800 Z., & Maurer, V. (2019). Factors related to free-range use in commercial layers.
801 *Applied Animal Behaviour Science* 214, 57–63.

802 Bonnefous, C., Calandreau, L., Le Bihan-Duval, E., Ferreira, V. H. B., Barbin, A., Collin, A.,
803 Reverchon, M., Germain, K., Ravon, L., Kruger, N., Mignon-Grasteau, S., &
804 Guesdon, V. (2023). Behavioural indicators of range use in four broiler strains.
805 *Applied Animal Behaviour Science* 260, 105870.

806 Bonnefous, C., Collin, A., Guilloteau, L. A., Germain, K., Ravon, L., Bordeau, T., Chartrin, P.,
807 Godet, E., Cailleau-Audouin, E., Couroussé, N., Raynaud, E., Mignon, S. V.,
808 Reverchon, M., Mattioli, S., Castellini, C., Angelucci, E., Guesdon, V., Calandreau,
809 L., Berri, C., & Le Bihan-Duval, E. (2024). Performance, meat quality and blood
810 parameters in four strains of organic broilers differ according to range use. *Scientific*
811 *Reports* 14(1), 30854.

812 Bonnefous, C., Collin, A., Guilloteau, L. A., Guesdon, V., Filliat, C., Réhault-Godbert, S., T.
813 Rodenburg, B., Tuytens, F. A. M., Warin, L., Steinfeldt, S., Baldinger, L., Re, M.,
814 Ponzio, R., Zuliani, A., Venezia, P., Vre, M., Parrott, P., Walley, K., Niemi, J. K., &
815 Leterrier, C. (2022). Welfare issues and potential solutions for layers in free-range
816 and organic production systems: A review based on literature and interviews.
817 *Frontiers in Veterinary Science*, 9, 952922.

818 Boogert, N. J., Madden, J. R., Morand-Ferron, J., & Thornton, A. (2018). Measuring and
819 understanding individual differences in cognition. *Philosophical Transactions of the*
820 *Royal Society B: Biological Sciences* 373(1756), 20170280.

821 Brantsæter, M., Nordgreen, J., Rodenburg, T. B., Tahamtani, F. M., Popova, A., & Janczak,
822 A. M. (2016). Exposure to increased environmental complexity during rearing

823 reduces fearfulness and increases use of three-dimensional space in layers (*Gallus*
824 *gallus domesticus*). *Frontiers in Veterinary Science* 3, 14.

825 Bray, H. J., & Ankeny, R. A. (2017). Happy chickens lay tastier eggs: motivations for buying
826 free-range eggs in Australia. *Anthrozoös* 30(2), 213–226.

827 Bubier, N. E. (1998). Movement of flocks of layers in and out of the hen house in four free-
828 range systems. *British Poultry Science* 39(S1), 5–6.

829 Cabrera, D., Nilsson, J. R., & Griffen, B. D. (2021). The development of animal personality
830 across ontogeny: a cross-species review. *Animal Behaviour* 173, 137–144.

831 Campbell, D. L. M., De Haas, E. N., & Lee, C. (2019). A review of environmental enrichment
832 for layers during rearing in relation to their behavioral and physiological development.
833 *Poultry Science* 98(1), 9–28.

834 Campbell, D. L. M., Dickson, E. J., & Lee, C. (2019). Application of open field, tonic
835 immobility, and attention bias tests to hens with different ranging patterns. *PeerJ* 7,
836 e8122.

837 Campbell, D. L. M., Dyall, T. R., Downing, J. A., Cohen-Barnhouse, A. M., & Lee, C. E.
838 (2020). Rearing Enrichments Affected Ranging Behavior in Free-Range Layers.
839 *Frontiers in Veterinary Science* 7.

840 Campbell, D. L., Hinch, G. N., Downing, J. A., & Lee, C. (2016). Fear and coping styles of
841 outdoor-preferring, moderate-outdoor and indoor-preferring free-range layers.
842 *Applied Animal Behaviour Science* 185, 73–77.

843 Campbell, D. L. M., Hinch, G. N., Downing, J. A., & Lee, C. (2018a). Early enrichment in
844 free-range layers: effects on ranging behaviour, welfare and response to stressors.
845 *Animal* 12(3), 575–584.

846 Campbell, D. L. M., Hinch, G. N., Dyall, T. R., Warin, L., Little, B. A., & Lee, C. (2017).
847 Outdoor stocking density in free-range layers: radio-frequency identification of
848 impacts on range use. *Animal* 11(1), 121–130.

849 Campbell, D. L. M., Horton, B. J., & Hinch, G. N. (2018). Using Radio-Frequency
850 Identification Technology to Measure Synchronised Ranging of Free-Range Layers.
851 *Animals* 8(11), 210.

852 Campbell, D. L., Talk, A. C., Loh, Z. A., Dyll, T. R., & Lee, C. (2018b). Spatial cognition and
853 range use in free-range layers. *Animals* 8(2), 26.

854 Campbell, D. L., Taylor, P. S., Hernandez, C. E., Stewart, M., Belson, S., & Lee, C. (2019).
855 An attention bias test to assess anxiety states in layers. *PeerJ* 7, e7303.

856 Campbell, D. L., Whitten, J. M., Slater, E., & Lee, C. (2021). Rearing enrichments
857 differentially modified hen personality traits and reduced prediction of range use.
858 *Animal Behaviour* 179, 97–109.

859 Castellini, C., Mugnai, C., Moscati, L., Mattioli, S., Guarino Amato, M., Cartoni Mancinelli, A.,
860 & Dal Bosco, A. (2016). Adaptation to organic rearing system of eight different
861 chicken genotypes: behaviour, welfare and performance. *Italian Journal of Animal*
862 *Science* 15(1), 37–46.

863 Christensen, J. W., Nielsen, B. L., Young, J. F., & Nøddegaard, F. (2003). Effects of calcium
864 deficiency in broilers on the use of outdoor areas, foraging activity and production
865 parameters. *Applied Animal Behaviour Science* 82(3), 229–240.

866 Chielo, L. I., Pike, T., & Cooper, J. (2016). Ranging behaviour of commercial free-range
867 layers. *Animals* 6(5), 28.

868 Collet, J. M., Bonnefous, C., Germain, K., Ravon, L., Calandreau, L., Guesdon, V., Collin, A.,
869 Le Bihan-Duval, E., & Mignon-Grasteau, S. (2024). High-throughput phenotyping to
870 characterise range use behaviour in broiler chickens. *Animal* 18(3), 101099.

871 Compassion in World Farming (CIWF) (2025). About chickens.
872 [https://web.archive.org/web/20170426063521/https://www.ciwf.org.uk/farm-](https://web.archive.org/web/20170426063521/https://www.ciwf.org.uk/farm-animals/chickens/)
873 [animals/chickens/](https://web.archive.org/web/20170426063521/https://www.ciwf.org.uk/farm-animals/chickens/)

874 Cronin, G. M., & Glatz, P. C. (2020). Causes of feather pecking and subsequent welfare
875 issues for the laying hen: a review. *Animal Production Science* 61(10), 990-1005.

876 Cronin, G. M., Tran, K. T. N., Hartcher, K. M., & Hemsworth, P. H. (2016). Free-ranging by
877 layers soon after the pop-holes open. Paper presented at the Annual Australian
878 Poultry Science Symposium.

879 Crump, A., Arnott, G., & Bethell, E. J. (2018). Affect-driven attention biases as animal
880 welfare indicators: review and methods. *Animals* 8(8), 136.

881 Dal Bosco, A., Mugnai, C., Rosati, A., Paoletti, A., Caporali, S., & Castellini, C. (2014). Effect
882 of range enrichment on performance, behavior, and forage intake of free-range
883 chickens. *Journal of Applied Poultry Research* 23(2), 137–145.

884 Dawkins, M. S., Cook, P. A., Whittingham, M. J., Mansell, K. A., & Harper, A. E. (2003).
885 What makes free-range broiler chickens range? In situ measurement of habitat
886 preference. *Animal Behaviour* 66, 151–160.

887 Dawkins, M. S., & Hardie, S. (1989). Space needs of layers. *British Poultry Science* 30(2),
888 413–416.

889 Dekker, S. E. M., Aarnink, A. J. A., De Boer, I. J. M., & Koerkamp, P. G. (2012). Total loss
890 and distribution of nitrogen and phosphorus in the outdoor run of organic layers.
891 *British Poultry Science* 53(6), 731–740.

892 de Oliveira, E. M., De Oliveira, L. Q. M., do Nascimento Mós, J. V., Teixeira, B. E.,
893 Nascimento, S. T., & Dos Santos, V. M. (2022). Solar radiation limits the use of
894 paddocks by layers raised in the free-range system. *Tropical Animal Health and*
895 *Production* 54(3), 181.

896 Deutsch, M., Dalseg, I. K., Kuchling, S., Sefc, K. M., Erregger, B., & Kalcher-Sommersguter,
897 E. (2024). Space use of free-range layers on two outdoor ranges with different
898 amounts of vegetation cover. *Applied Animal Behaviour Science* 277, 106353.

899 Diamond, A. (2013). Executive functions. *Annual Reviews in Psychology* 64, 135–168.

900 Diep, A. T., Larsen, H., & Rault, J. L. (2018). Behavioural repertoire of free-range layers
901 indoors and outdoors, and in relation to distance from the shed. *Australian Veterinary*
902 *Journal* 96(4), 127–131.

903 Dougherty, L. R., & Guillette, L. M. (2018). Linking personality and cognition: a meta-
 904 analysis. *Philosophical Transactions of the Royal Society B: Biological Sciences*
 905 373(1756), 20170282.

906 Durali, T., Groves, P., Cowieson, A., & Singh, M. (2014). Evaluating range usage of
 907 commercial free-range broilers and its effect on birds performance using radio
 908 frequency identification (RFID) technology. Paper presented at the 25th Annual
 909 Australian Poultry Science Symposium Sydney, Australia.

910 EU Directive (1999). Council Directive 99/74/EC of 19 July 1999 laying down minimum
 911 standards for the protection of layers. *Official journal of the European Communities*
 912 203, 53–57.

913 Fanatico, A. C., Cavitt, L. C., Pillai, P. B., Emmert, J. L., & Owens, C. M. (2005). Evaluation
 914 of slower-growing broiler genotypes grown with and without outdoor access: meat
 915 quality. *Poultry Science* 84(11), 1785–1790.

916 Fanatico, A. C., Mench, J. A., Archer, G. S., Liang, Y., Gunsaulis, V. B., Owens, C. M., &
 917 Donoghue, A. M. (2016). Effect of outdoor structural enrichments on the
 918 performance, use of range area, and behavior of organic meat chickens. *Poultry*
 919 *Science* 95(9), 1980–1988.

920 Ferreira, V. H. B., Barbarat, M., Lormant, F., Germain, K., Brachet, M., Lovlie, H.,
 921 Calandreau, L., & Guesdon, V. (2020a). Social motivation and the use of distal, but
 922 not local, featural cues are related to ranging behavior in free-range chickens (*Gallus*
 923 *gallus domesticus*). *Animal Cognition* 23(4), 769–780.

924 Ferreira, V. H. B., Germain, K., Calandreau, L., & Guesdon, V. (2020b). Range use is
 925 related to free-range broiler chickens' behavioral responses during food and social
 926 conditioned place preference tests. *Applied Animal Behaviour Science* 230, 105083.

927 Ferreira, V. H. B., Guesdon, V., & Calandreau, L. (2021). How can the research on chicken
 928 cognition improve chicken welfare: a perspective review. *World's Poultry Science*
 929 *Journal* 77(3), 679–698.

930 Ferreira, V. H. B., Peuteman, B., Lormant, F., Valenchon, M., Germain, K., Brachet, M.,
 931 Leterrier, C., Lansade, L., Calandreau, L., & Guesdon, V. (2019). Relationship
 932 between ranging behavior and spatial memory of free-range chickens. *Behavioural*
 933 *Processes* 166, 103888.

934 Ferreira, V. H. B., Reiter, L., Germain, K., Calandreau, L., & Guesdon, V. (2020c).
 935 Uninhibited chickens: ranging behaviour impacts motor self-regulation in free-range
 936 broiler chickens (*Gallus gallus domesticus*). *Biology Letters* 16(1), 20190721.

937 Ferreira, V. H. B., Seressia, J., Mème, N., Bernard, J., Pinard-van der Laan, M. H., Calenge,
 938 F., Lecoeur, A., Hedlund, L., Jensen, P., Guesdon, V., & Calandreau, L. (2024). Early
 939 and late cognitive and behavioral aspects associated with range use in free-range
 940 layers (*Gallus gallus domesticus*). *Poultry Science* 103(7), 103813.

941 Ferreira, V. H. B., Simoni, A., Germain, K., Leterrier, C., Lansade, L., Collin, A., Mignon-
 942 Grasteau, S., Le Bihan-Duval, E., Guettier, E., Leruste, H., Calandreau, L., &
 943 Guesdon, V. (2021). Working for food is related to range use in free-range broiler
 944 chickens. *Scientific Reports* 11(1), 6253.

945 Ferreira, V. H. B., Simoni, A., Germain, K., Leterrier, C., Lansade, L., Collin, A., Mignon-
 946 Grasteau, S., Le Bihan-Duval, E., Guettier, E., Leruste, H., Løvlie, H., Calandreau,
 947 L., & Guesdon, V. (2022). Foraging behavior shows individual-consistency over time,
 948 and predicts range use in slow-growing free-range male broiler chickens. *Frontiers in*
 949 *Veterinary Science* 9, 814054.

950 Fiorilla, E., Ozella, L., Sirri, F., Zampiga, M., Piscitelli, R., Tarantola, M., Ponzio, P., &
 951 Mugnai, C. (2024). Effects of housing systems on behaviour and welfare of
 952 autochthonous layers and a commercial hybrid. *Applied Animal Behaviour Science*
 953 274, 106247.

954 Fossum, O., Jansson, D. S., Etterlin, P. E., & Vågsholm, I. (2009). Causes of mortality in
 955 layers in different housing systems in 2001 to 2004. *Acta Veterinaria Scandinavica*
 956 51, 1–9.

957 Fraser, D., Weary, D. M., Pajor, E. A., & Milligan, B. N. (1997). A scientific conception of
 958 animal welfare that reflects ethical concerns. *Animal Welfare* 6(3), 187–205.

959 Gebhardt-Henrich, S. G., Toscano, M. J., & Fröhlich, E. K. (2014). Use of outdoor ranges by
 960 layers in different sized flocks. *Applied Animal Behaviour Science* 155, 74–81.

961 Geng, A. L., Zhang, Y., Zhang, J., Wang, H. H., Chu, Q., Yan, Z. X., & Liu, H. G. (2023).
 962 Lighting pattern and photoperiod affect the range use and feather cover of native
 963 layers under free-range condition. *Poultry Science* 102(1), 102264.

964 Giersberg, M. F., & Rodenburg, T. B. (2023). Advances in keeping layers in various cage-
 965 free systems: part I rearing phase. *World's Poultry Science Journal* 79(3), 535–549.

966 Gilani, A. M., Knowles, T. G., & Nicol, C. J. (2014). Factors affecting ranging behaviour in
 967 young and adult layers. *British Poultry Science* 55(2), 127–135.

968 Glatz, P. C., Ru, Y. J., Miao, Z. H., Wyatt, S. K., & Rodda, B. J. (2005). Integrating poultry
 969 into a crop and pasture farming system. *International Journal of Poultry Science* 4(4),
 970 187–191.

971 Göransson, L., Abeyesinghe, S., Gunnarsson, S., & Yngvesson, J. (2023). Easier said than
 972 done! Organic farmers consider free-ranging important for laying hen welfare but
 973 outdoor areas need more shelter—important gaps between research and practice.
 974 *British Poultry Science* 64(5), 544–551.

975 Göransson, L., Gunnarsson, S., Wallenbeck, A., & Yngvesson, J. (2021). Behaviour in
 976 Slower-Growing Broilers and Free-Range Access on Organic Farms in Sweden.
 977 *Animals* 11(10), 2967. doi:10.3390/ani11102967

978 Gordon, S. H., & Forbes, M. J. (2002). Management factors affecting the use of pasture by
 979 table chickens in extensive production systems. Paper presented at the UK Organic
 980 Research 2002 Conference, Organic Centre Wales, Institute of Rural Studies,
 981 University of Wales Aberystwyth.

982 Greggor, A. L., Thornton, A., & Clayton, N. S. (2015). Neophobia is not only avoidance:
 983 improving neophobia tests by combining cognition and ecology. *Current Opinion in*
 984 *Behavioral Sciences* 6, 82–89.

985 Grigor, P. N., Hughes, B. O., & Appleby, M. C. (1995a). Emergence and dispersal behaviour
986 in domestic hens: effects of social rank and novelty of an outdoor area. *Applied*
987 *Animal Behaviour Science* 45(1-2), 97–108.

988 Grigor, P. N., Hughes, B. O., & Appleby, M. C. (1995b). Effects of regular handling and
989 exposure to an outside area on subsequent fearfulness and dispersal in domestic
990 hens. *Applied Animal Behaviour Science* 44(1), 47–55.

991 Harlander-Matauschek, A., Felsenstein, K., Niebuhr, K., & Troxler, J. (2006). Influence of
992 pop hole dimensions on the number of layers outside on the range. *British Poultry*
993 *Science* 47(2), 131–134.

994 Harlander-Matauschek, A., Niebuhr, K., & Troxler, J. (2002). Untersuchungen zur Akzeptanz
995 des Auslaufes durch Hähne im Vergleich zu Hennen. *Aktuelle Arbeiten zur*
996 *artgemäßen Tierhaltung*, 45–50.

997 Hartcher, K. M., Hickey, K. A., Hemsworth, P. H., Cronin, G. M., Wilkinson, S. J., & Singh,
998 M. (2016). Relationships between range access as monitored by radio frequency
999 identification technology, fearfulness, and plumage damage in free-range layers.
1000 *Animal* 10(5), 847–853.

1001 Hartcher, K. M., & Jones, B. (2017). The welfare of layer hens in cage and cage-free
1002 housing systems. *World's Poultry Science Journal* 73(4), 767–782.

1003 Hegelund, L., Sørensen, J. T., & Hermansen, J. E. (2006). Welfare and productivity of layers
1004 in commercial organic egg production systems in Denmark. *NJAS-Wageningen*
1005 *Journal of Life Sciences* 54(2), 147–155.

1006 Hegelund, L., Sørensen, J. T., Kjaer, J. B., & Kristensen, I. S. (2005). Use of the range area
1007 in organic egg production systems: effect of climatic factors, flock size, age and
1008 artificial cover. *British Poultry Science* 46(1), 1–8.

1009 Heng, Y., Peterson, H. H., & Li, X. (2013). Consumer attitudes toward farm-animal welfare:
1010 the case of layers. *Journal of Agricultural and Resource Economics* 38(3), 418–434.

1011 Hocking, P. M., Channing, C. E., Waddington, D., & Jones, R. B. (2001). Age-related
 1012 changes in fear, sociality and pecking behaviours in two strains of laying hen. *British*
 1013 *Poultry Science* 42(4), 414–423.

1014 Hübner, S., Schanz, L., Winckler, C., & Barth, K. (2024). Mix it-cograzing with cattle reduces
 1015 broiler losses and increases broiler range use. *Poultry Science* 103(8), 103906.

1016 Icken, W., Cavero, D., Schmutz, M., Thurner, S., Wendl, G., & Preisinger, R. (2008).
 1017 Analysis of the free-range behaviour of layers and the genetic and phenotypic
 1018 relationships with laying performance. *British Poultry Science* 49(5), 533–541.

1019 Jessen, C. T., Foldager, L., & Riber, A. B. (2021). Effects of hatching on-farm on behaviour,
 1020 first week performance, fear level and range use of organic broilers. *Applied Animal*
 1021 *Behaviour Science* 238, 105319.

1022 Jones, R. B., & Waddington, D. (1992). Modification of fear in domestic chicks, *Gallus gallus*
 1023 *domesticus*, via regular handling and early environmental enrichment. *Animal*
 1024 *Behaviour* 43(6), 1021–1033.

1025 Jones, T., Feber, R., Hemery, G., Cook, P., James, K., Lamberth, C., & Dawkins, M. (2007).
 1026 Welfare and environmental benefits of integrating commercially viable free-range
 1027 broiler chickens into newly planted woodland: A UK case study. *Agricultural Systems*
 1028 94(2), 177–188.

1029 Kanginakudru, S., Metta, M., Jakati, R. D., & Nagaraju, J. (2008). Genetic evidence from
 1030 Indian red jungle fowl corroborates multiple domestication of modern day chicken.
 1031 *BMC Evolutionary Biology* 8, 1–14.

1032 Keeling, L. (1995). Spacing behaviour and an ethological approach to assessing optimum
 1033 space allocations for groups of layers. *Applied Animal Behaviour Science* 44(2-4),
 1034 171–186.

1035 Keeling, L. J., Hughes, B. O., & Dun, P. (1988). Performance of free-range layers in a
 1036 polythene house and their behaviour on range. *Farm Building Progress* 94, 21–28.

1037 Knierim, U. (2006). Animal welfare aspects of outdoor runs for layers: a review. *NJAS:*
 1038 *Wageningen Journal of Life Sciences* 54(2), 133–145.

1039 Kolakshyapati, M., Flavel, R. J., Sibanda, T. Z., Schneider, D., Welch, M. C., & Ruhnke, I.
 1040 (2019). Various bone parameters are positively correlated with hen body weight while
 1041 range access has no beneficial effect on tibia health of free-range layers. *Poultry*
 1042 *Science* 98(12), 6241–6250.

1043 Kolakshyapati, M., Taylor, P. S., Hamlin, A., Sibanda, T. Z., Vilela, J. D. S., & Ruhnke, I.
 1044 (2020a). Frequent visits to an outdoor range and lower areas of an aviary system is
 1045 related to curiosity in commercial free-range layers. *Animals* 10(9), 1706.

1046 Kolakshyapati, M., Wu, S. B., Sibanda, T. Z., Ramirez-Cuevas, S., & Ruhnke, I. (2020b).
 1047 Body weight and range usage affect net energy utilisation in commercial free-range
 1048 layers when evaluated in net energy chambers. *Animal Nutrition* 6(2), 192–197.

1049 Larsen, H., Hemsworth, P. H., Cronin, G. M., Gebhardt-Henrich, S. G., Smith, C. L., & Rault,
 1050 J. L. (2018). Relationship between welfare and individual ranging behaviour in
 1051 commercial free-range layers. *Animal* 12(11), 2356–2364.

1052 Larsen, H., & Rault, J. L. (2021). Preference for artificial range enrichment design features in
 1053 free-range commercial layers. *British Poultry Science* 62(3), 311–319.

1054 Lay Jr, D. C., Fulton, R. M., Hester, P. Y., Karcher, D. M., Kjaer, J. B., Mench, J. A., Mullens,
 1055 B. A., Newberry, R. C., Nicol, C. J., Sullivan, N. P., & Porter, R. E. (2011). Hen
 1056 welfare in different housing systems. *Poultry Science* 90(1), 278–294.

1057 Leyendecker, M., Hamann, H., Hartung, J., Kamphues, J., Neumann, U., Sürrie, C., & Distl,
 1058 O. (2005). Keeping layers in furnished cages and an aviary housing system
 1059 enhances their bone stability. *British Poultry Science* 46(5), 536–544.

1060 Lindholm, C., Karlsson, L., Johansson, A., & Altimiras, J. (2016). Higher fear of predators
 1061 does not decrease outdoor range use in free-range Rowan Ranger broiler chickens.
 1062 *Acta Agriculturae Scandinavica, Section A – Animal Science* 66(4), 231–238.

1063 Mahboub, H. D. H., Müller, J., & Von Borell, E. (2004). Outdoor use, tonic immobility,
 1064 heterophil/lymphocyte ratio and feather condition in free-range layers of different
 1065 genotype. *British Poultry Science* 45(6), 738–744.

1066 Mancinelli, A. C., Chiattelli, D., Menchetti, L., Mariotti, S., Castellini, C., & Birolo, M. (2025).
 1067 Assessing the motivation of layers to outdoor space access. *Applied Animal*
 1068 *Behaviour Science* 285, 106581.

1069 Marchewka, J., Solka, M., Sztandarski, P., Jaszczyk, A., Zdanowska-Sasiadek, Z.,
 1070 Mastalerczuk, G., Borawska-Jarmulowicz, B., Komorowska, D., & Horbanczuk, J. O.
 1071 (2023). Free-range characteristics and use by chickens from two genetic lines.
 1072 *Animal Science Papers and Reports* 41(2), 139–152.

1073 Marchewka, J., Sztandarski, P., Zdanowska-Sasiadek, Z., Damaziak, K., Wojciechowski, F.,
 1074 Riber, A. B., & Gunnarsson, S. (2020). Associations between welfare and ranging
 1075 profile in free-range commercial and heritage meat-purpose chickens (*Gallus gallus*
 1076 *domesticus*). *Poultry Science* 99(9), 4141–4152.

1077 McBride, G., Parer, I. P., & Foenander, F. (1969). The social organization and behaviour of
 1078 the feral domestic fowl. *Animal Behavior Monographs* 2, 125–181.

1079 Mellor, D. J. (2016). Updating animal welfare thinking: Moving beyond the “Five Freedoms”
 1080 towards “a Life Worth Living”. *Animals* 6(3), 21.

1081 Menzi, H., Shariatmadari, H., Meierhans, D., & Wiedmer, H. (1997). Nähr- und
 1082 Schadstoffbelastung von Geflügelausläufen. *Agrarforschung* 4, 361–364.

1083 Miao, Z. H., Glatz, P. C., & Ru, Y. J. (2005). Free-range poultry production-A review. *Asian-*
 1084 *Australasian Journal of Animal Sciences* 18(1), 113–132.

1085 Müller, J., Hillig, J., von Borell, E., & Thies, N. (2001). Untersuchungen zur Akzeptanz des
 1086 Auslaufs durch Legehennen in einem Haltungssystem mit Wintergarten und
 1087 Grünauslauf. *Lohmann Information* 4(2001), 3–7.

1088 Nagle, T. A. D., & Glatz, P. C. (2012). Free-range hens use the range more when the
 1089 outdoor environment is enriched. *Asian-Australasian Journal of Animal Sciences*
 1090 25(4), 584.

1091 Nelson, E. L. (2024). The Future of Comparative Cognition: Answering Developmental
 1092 Questions with Big Team Science. *Comparative Cognition & Behavior Reviews* 19,
 1093 79 – 83.

1094 Newberry, R. C. (1995). Environmental enrichment: Increasing the biological relevance of
 1095 captive environments. *Applied Animal Behaviour Science* 44(2-4), 229–243.

1096 Nicol, C. J. (2015). *The behavioural biology of chickens*. Cabi.

1097 Nielsen, B. L., Thomsen, M. G., Sørensen, P., & Young, J. F. (2003). Feed and strain effects
 1098 on the use of outdoor areas by broilers. *British Poultry Science* 44(2), 161–169.

1099 Perals, D., Griffin, A. S., Bartomeus, I., & Sol, D. (2017). Revisiting the open-field test: what
 1100 does it really tell us about animal personality? *Animal Behaviour* 123, 69–79.

1101 Perinot, E., Petelle, M. B., Gómez, Y., & Toscano, M. J. (2025). Temporal-spatial
 1102 associations of large groups of layers in a quasi-commercial barn. *Applied Animal
 1103 Behaviour Science* 283, 106516.

1104 Pettersson, I. C., Freire, R., & Nicol, C. J. (2016). Factors affecting ranging behaviour in
 1105 commercial free-range hens. *World's Poultry Science Journal* 72(1), 137–150.

1106 Pettersson, I. C., Weeks, C. A., & Nicol, C. J. (2017). Provision of a resource package
 1107 reduces feather pecking and improves ranging distribution on free-range layer farms.
 1108 *Applied Animal Behaviour Science* 195, 60–66.

1109 Pettersson, I. C., Weeks, C. A., Norman, K. I., Knowles, T. G., & Nicol, C. J. (2018). Internal
 1110 roosting location is associated with differential use of the outdoor range by free-range
 1111 layers. *British Poultry Science* 59(2), 135–140.

1112 Pettersson, I. C., Weeks, C. A., Wilson, L. R. M., & Nicol, C. J. (2016). Consumer
 1113 perceptions of free-range laying hen welfare. *British Food Journal* 118(8), 1999–
 1114 2013.

1115 Rana, M. S., Lee, C., Lea, J. M., & Campbell, D. L. M. (2022a). Relationship between
 1116 sunlight and range use of commercial free-range hens in Australia. *PLoS One* 17(5),
 1117 e0268854.

1118 Rault, J. L. (2018). Ranging in free-range layers: animal welfare and other considerations.
 1119 Paper presented at the Professionals in food chains.

1120 Rault, J. L., Bateson, M., Boissy, A., Forkman, B., Grinde, B., Gygax, L., Harfeld, J. L.,
 1121 Hintze, S., Keeling, L. J., Kostal, L., Lawrence, A. B., Mendl, M. T., Miele, M.,

1122 Newberry, R. C., Sandøe, P., Špinka, M., Taylor, A. H., Webb, L. E., Whalin, L., &
 1123 Jensen, M. B. (2025). A consensus on the definition of positive animal welfare.
 1124 *Biology Letters*, 21(1), 20240382.

1125 Rault, J. L., & Taylor, P. S. (2017). Indoor side fidelity and outdoor ranging in commercial
 1126 free-range chickens in single- or double-sided sheds. *Applied Animal Behaviour*
 1127 *Science* 194, 48–53.

1128 Rault, J. L., Van De Wouw, A., & Hemsworth, P. (2013). Fly the coop! Vertical structures
 1129 influence the distribution and behaviour of layers in an outdoor range. *Australian*
 1130 *Veterinary Journal*, 91(10), 423–426.

1131 Riber, A. B., Van De Weerd, H. A., De Jong, I. C., & Steinfeldt, S. (2018). Review of
 1132 environmental enrichment for broiler chickens. *Poultry Science* 97(2), 378–396.

1133 Riber, A. B., & Wurtz, K. E. (2024). Impact of growth rate on the welfare of broilers. *Animals*,
 1134 14(22), 3330.

1135 Richards, G. J., Wilkins, L. J., Knowles, T. G., Booth, F., Toscano, M. J., Nicol, C. J., &
 1136 Brown, S. N. (2011). Continuous monitoring of pop hole usage by commercially
 1137 housed free-range hens throughout the production cycle. *Veterinary Record* 169(13),
 1138 338–338.

1139 Richards, G. J., Wilkins, L. J., Knowles, T. G., Booth, F., Toscano, M. J., Nicol, C. J., &
 1140 Brown, S. N. (2012). Pop hole use by hens with different keel fracture status
 1141 monitored throughout the laying period. *Veterinary Record* 170(19), 494–494.

1142 Rodriguez-Aurrekoetxea, A., & Estevez, I. (2016). Use of space and its impact on the
 1143 welfare of layers in a commercial free-range system. *Poultry Science* 95(11), 2503–
 1144 2513.

1145 Rodriguez-Aurrekoetxea, A., Leone, E. H., & Estevez, I. (2014). Environmental complexity
 1146 and use of space in slow growing free-range chickens. *Applied Animal Behaviour*
 1147 *Science* 161, 86–94.

1148 Rodriguez-Navarro, A. B., McCormack, H. M., Fleming, R. H., Alvarez-Lloret, P., Romero-
 1149 Pastor, J., Dominguez-Gasca, N., Prozorov, T., & Dunn, I. C. (2018). Influence of

1150 physical activity on tibial bone material properties in layers. *Journal of Structural*
1151 *Biology* 201(1), 36–45.

1152 Rogers, S. M., & Simpson, S. J. (2014). Thanatosis. *Current Biology*, 24(21), R1031-R1033.

1153 Ruhnke, I., Normant, C., Campbell, D. L. M., Iqbal, Z., Lee, C., Hinch, G. N., & Roberts, J.
1154 (2018). Impact of on-range choice feeding with black soldier fly larvae (*Hermetia*
1155 *illucens*) on flock performance, egg quality, and range use of free-range layers.
1156 *Animal Nutrition* 4(4), 452–460.

1157 Sherwin, C. M., Nasr, M. A., Gale, E., Petek, M. E. T. İ. N., Stafford, K., Turp, M., & Coles,
1158 G. C. (2013). Prevalence of nematode infection and faecal egg counts in free-range
1159 layers: relations to housing and husbandry. *British Poultry Science* 54(1), 12–23.

1160 Sibanda, T. Z., Flavel, R., Kolakshyapati, M., Welch, M., Schneider, D., & Ruhnke, I.
1161 (2020a). The association between range usage and tibial quality in commercial free-
1162 range layers. *BRITISH POULTRY SCIENCE*, 61(5), 493-501.

1163 Sibanda, T. Z., Kolakshyapati, M., Welch, M., Schneider, D., Boshoff, J., & Ruhnke, I.
1164 (2020b). Managing free-range layers - Part A: Frequent and non-frequent range
1165 users differ in laying performance but not egg quality. *Animals* 10(6), 991.

1166 Sibanda, T. Z., O'Shea, C. J., de Souza Vilela, J., Kolakshyapati, M., Welch, M., Schneider,
1167 D., Courtice, J., & Ruhnke, I. (2020c). Managing free-range layers—part B: early
1168 range users have more pathology findings at the end of lay but have a significantly
1169 higher chance of survival—an indicative study. *Animals*, 10(10), 1911.

1170 Sibanda, T. Z., Walkden-Brown, S. W., Kolakshyapati, M., Dawson, B., Schneider, D.,
1171 Welch, M., Iqbal, Z., Cohen-Barnhouse, A. M., Morgan, N. K., Boshoff, & J. Ruhnke,
1172 I. (2020d). Flock use of the range is associated with the use of different components
1173 of a multi-tier aviary system in commercial free-range layers. *British Poultry Science*
1174 61(2), 97–106.

1175 Singh, M., Hernandez, C., Lee, C., Hinch, G., & Cowieson, A. J. (2016a). Wanderers versus
1176 stay-at-home: Who has the better guts? Paper presented at the Australian Poultry
1177 Science Symposium.

1178 Singh, M., Ruhnke, I., De Koning, C., Drake, K., Hinch, G., & Skerman, A. (2016b). Nutrient
 1179 loading on free-range layer farms. In 27th Annual Australian Poultry Science
 1180 Symposium.

1181 Sherwin, C. M., Nasr, M. A. F., Gale, E., Petek, M., Stafford, K., Turp, M., & Coles, G. C.
 1182 (2013). Prevalence of nematode infection and faecal egg counts in free-range layers:
 1183 relations to housing and husbandry. *British Poultry Science* 54, 12–23.

1184 Shettleworth, S. J. (2001). Animal cognition and animal behaviour. *Animal Behaviour* 61(2),
 1185 277–286.

1186 Skånberg, L., Holt, R. V., Newberry, R. C., Estevez, I., McCrea, K., & Keeling, L. J. (2024).
 1187 Making the most of life: environmental choice during rearing enhances the ability of
 1188 layers to take opportunities. *Frontiers in Veterinary Science* 11, 1425851.

1189 Skånberg, L., Newberry, R. C., Estevez, I., & Keeling, L. J. (2023). Environmental change or
 1190 choice during early rearing improves behavioural adaptability in laying hen chicks.
 1191 *Scientific Reports* 13(1), 6178.

1192 Stadig, L. M., Rodenburg, T. B., Ampe, B., Reubens, B., & Tuytens, F. A. M. (2017a).
 1193 Effects of shelter type, early environmental enrichment and weather conditions on
 1194 free-range behaviour of slow-growing broiler chickens. *Animal* 11(6), 1046–1053.

1195 Stadig, L. M., Rodenburg, T. B., Ampe, B., Reubens, B., & Tuytens, F. A. (2017b). Effect of
 1196 free-range access, shelter type and weather conditions on free-range use and
 1197 welfare of slow-growing broiler chickens. *Applied Animal Behaviour Science* 192, 15–
 1198 23.

1199 Stadig, L. M., Rodenburg, T. B., Reubens, B., Aerts, J., Duquenne, B., & Tuytens, F. A.
 1200 (2016). Effects of free-range access on production parameters and meat quality,
 1201 composition and taste in slow-growing broiler chickens. *Poultry Science* 95(12),
 1202 2971–2978.

1203 Stadig, L. M., Rodenburg, T. B., Reubens, B., Ampe, B., & Tuytens, F. A. M. (2018). Effects
 1204 of dark brooders and overhangs on free-range use and behaviour of slow-growing
 1205 broilers. *Animal* 12(8), 1621–1630.

1206 Suarez, S. D., & Gallup, G. G. (1983). Social reinstatement and open-field testing in
 1207 chickens. *Animal Learning and Behavior* 11, 119–126.

1208 Sztandarski, P., Marchewka, J., Wojciechowski, F., Riber, A. B., Gunnarsson, S., &
 1209 Horbanczuk, J. O. (2021a). Associations between neck plumage and beak darkness,
 1210 as well as comb size measurements and scores with ranging frequency of Sasso and
 1211 Green-legged Partridge chickens. *Poultry Science* 100(9), 101340.

1212 Sztandarski, P., Marchewka, J., Wojciechowski, F., Riber, A. B., Gunnarsson, S., &
 1213 Horbanczuk, J. O. (2021b). Associations between weather conditions and individual
 1214 range use by commercial and heritage chickens. *Poultry Science* 100(8), 101265.

1215 Tainika, B., Sekeroglu, A., & Abaci, S. H. (2024). Factors influencing ranging behavior of
 1216 different strains of hens. *Agricultural Research* 13, 832–840.

1217 Taylor, P. S., Campbell, D. L., Jurecky, E., Devine, N., Lee, C., & Hemsworth, P. H. (2023a).
 1218 Novelty during rearing increased inquisitive exploration but was not related to early
 1219 ranging behavior of layers. *Frontiers in Animal Science* 4, 1128792.

1220 Taylor, P. S., Fanning, L., Dawson, B., Schneider, D., Dekoning, C., McCarthy, C., & Rault,
 1221 J. L. (2023b). Visual access to an outdoor range early in life, but not environmental
 1222 complexity, increases meat chicken ranging behavior. *Poultry Science*, 102(12),
 1223 103079.

1224 Taylor, P., Hemsworth, P., Dawkins, M., Groves, P., & Rault, J. (2015). Free-range broiler
 1225 chicken behavioural time budgets: Inside and outside of the shed. Paper presented
 1226 at the 26th Annual Australian Poultry Science Symposium.

1227 Taylor, P. S., Hemsworth, P. H., Groves, P. J., Gebhardt-Henrich, S. G., & Rault, J. L.
 1228 (2017a). Ranging Behaviour of Commercial Free-Range Broiler Chickens 1: Factors
 1229 Related to Flock Variability. *Animals* 7(7), 54.

1230 Taylor, P. S., Hemsworth, P. H., Groves, P. J., Gebhardt-Henrich, S. G., & Rault, J. L.
 1231 (2017b). Ranging Behaviour of Commercial Free-Range Broiler Chickens 2:
 1232 Individual Variation. *Animals* 7(7), 55.

1233 Taylor, P. S., Hemsworth, P. H., Groves, P. J., Gebhardt-Henrich, S. G., & Rault, J. L.
 1234 (2018). Ranging behavior relates to welfare indicators pre- and post-range access in
 1235 commercial free-range broilers. *Poultry Science* 97(6), 1861–1871.

1236 Taylor, P. S., Hemsworth, P. H., Groves, P. J., Gebhardt-Henrich, S. G., & Rault, J. L.
 1237 (2020). Frequent range visits further from the shed relate positively to free-range
 1238 broiler chicken welfare. *Animal* 14(1), 138–149.

1239 Thuy Diep, A., Larsen, H., & Rault, J. L. (2018). Behavioural repertoire of free-range layers
 1240 indoors and outdoors, and in relation to distance from the shed. *Australian Veterinary*
 1241 *Journal* 96(4), 127–131.

1242 Walsh, R. N., & Cummins, R. A. (1976). The open-field test: a critical review. *Psychological*
 1243 *Bulletin* 83(3), 482–504.

1244 West, B., & Zhou, B. X. (1988). Did chickens go north? New evidence for domestication.
 1245 *Journal of Archaeological Science* 15(5), 515–533.

1246 Wurtz, K. E., Tahamtani, F. M., Foldager, L., Thodberg, K., & Riber, A. B. (2023).
 1247 Associations of range use with individual behaviour, clinical welfare indicators, fear
 1248 response and gastrointestinal characteristics of two laying hen hybrids. *Applied*
 1249 *Animal Behaviour Science* 265, 105978.

1250 Wurtz, K. E., Thodberg, K., Berenjian, A., Foldager, L., Tahamtani, F. M., & Riber, A. B.
 1251 (2022). Commercial layer hybrids kept under organic conditions: a comparison of
 1252 range use, welfare, and egg production in two layer strains. *Poultry Science* 101(9),
 1253 102005.

1254 Xu, D., Shu, G., Liu, Y., Qin, P., Zheng, Y., Tian, Y., Zhao, X., & Du, X. (2022). Farm
 1255 Environmental Enrichments Improve the Welfare of Layer Chicks and Pullets: A
 1256 Comprehensive Review. *Animals*, 12(19), 2610.

1257 Young, R. J. (2013). *Environmental enrichment for captive animals*. John Wiley & Sons.

1258 Zahid, S., Usman, M., Ishaq, H. M., Haider, M. F., Saleem, M. M., Elahi, U., Hussain, M.,
 1259 Latif, H. R. A., Saleem, K., Ahmad, S., & Ebeid, T. A. (2024). Impact of different

- 1260 range areas on behavior, welfare, and performance of Naked Neck chickens.
- 1261 Tropical Animal Health and Production 56(7), 227.
- 1262 Zeltner, E., & Hirt, H. (2003). Effect of artificial structuring on the use of laying hen runs in a
- 1263 free-range system. British Poultry Science 44(4), 533–537.
- 1264 Zeltner, E., & Hirt, H. (2008). Factors involved in the improvement of the use of hen runs.
- 1265 Applied Animal Behaviour Science 114(3-4), 395–408.

1266 **Appendix**

1267 **Table S1.** Details of studies (selected based on reporting frequency) reporting the maximum percent of birds on the range (as given in the
1268 reference text or figures: numbers per flock or tagged birds, average + SD across flocks – for studies using individual tracking, percent
1269 corresponds to the birds that entered the range at least once during the study period). Genotype (strain, as stated in the reference), colour (as
1270 per google search), age of testing in days (average across the study period), age in days at which chickens received first access to the range,
1271 indoor stocking density as birds per m² (as given in the reference or calculated based on flock size and enclosure measurements), flock size
1272 (birds housed together in the same enclosure, not total number of chickens use in the study), country the study was conducted in, time of day
1273 observations of ranging behaviour were done (for simplicity, single observation points are grouped into ranges – for studies using individual
1274 tracking, bird movement was continuously tracked when pop holes were open), and reference from which the numbers were taken. – no data
1275 available, * numbers obtained from other references.

Studies using flock level counts										
Chicken	%	Genotype	Colour	Age at testing	Age 1 st range access	Indoor stocking density	Flock size	Location	Obs. time	Reference
Laying hen	41.6	ATAK-S	Brown	182	-	7	20	Turkey	-	Aygun et al., 2024
	30.9	ISA Brown	Brown	190	182	-	50	Australia, NSW	09:00 to 16:00	Cronin et al., 2016
	47.9			311.5	140	9	6000	Spain	10:00 to 19:00	Rodriguez-Aurrekoetxea & Estevez, 2016
	42			227.5	-	5	256	Germany	07:00 to 20:00	Harlander-Matauschek et al., 2006

32			294	-	8	466	Switzerland	10:30 20:30	to Zeltner & Hirt, 2003
26			-	-	-	-	-	-	Kjær & Isaksen, 1998
38	ISA Brown Lohman Brown	Brown	-	-	-	513- 6000	Denmark	08:42 15:35	to Hegelund et al., 2005
37	Bovans Robust	-	84.5	189	1.7	21-23	Sweden	All day	Skånberg et al., 2024
56	Bovans White Bovans Brown LSL	White Brown White	518	133- 280	-	5372- 8825	Sweden	09:00 17:00	to Göransson et al. 2023
8.98	Lohmann Brown Bovan Brown	Brown	308	-	-	4000	UK	10:00 13:00	to Pettersson et al., 2018
4.6 8.8 3	Lohmann Brown	Brown	343 257 364	-	-	15470 15797 23548	UK	10:00 14:00	to Chielo, Pike, & Cooper, 2016
46.26 44.25	LSL Classic Lohmann Sandy	White	196	84	3.58	10	Turkey	09:00 15:00	to Tainika, Sekeroglu, & Abaci, 2024
56.5 67.8 26.6 28	Lohmann Tradition	Brown	147 147 329 -	-	5.5 5.5 8 -	20-22 20-22 250 500	Switzerland	All day	Zeltner & Hirt, 2008
45 43 54	Hy-Line® Brown	Brown	196 266 448	-	-	20	Australia, QLD	Morning, Evening	Nagle & Glatz, 2012
35.1 20.1 6.3			385 336 189	-	-	3900 7300 15573	UK	10:00 14:00	to Chielo, Pike, & Cooper, 2016
46.1	Rhode Island Red	Brown	231	189	0.75	4	Mexico	08:00 17:00	Abouelezz et al., 2014
42.1	Comet J Links Browns Warrens	Brown	329	-	5.4-9.1	490- 2450	UK	05:00 20:00	to Bubier, 1998

Hi Sex										
	99	GLK Bankiva GLN Bankiva	Brown	248.5	-	1	150	Brazil	08:00 17:00	to de Oliveira et al., 2022
	15	New Hampshire	Brown	-	-	-	-	-	-	Kjær & Isaksen, 1998
	38	ISA Brown ISA Babcock Hyline Brown Lohmann Brown Hellevad White	Brown Brown Brown Brown White	308	-	-	1200- 5000	Denmark	Morning Evening	Hegelund, Sørensen, & Hermansen, 2006
	58	Col. Lohmann Brown Hy-Line Goldline other	Brown	150.5	-	4-12	92- 15848	UK	11:00 15:00	to Gilani, Knowles, & Nicol, 2014
	57 48 52	-	-	388.5	-	5.1 7 5.9 9	1854 3504 8562 23879	Netherlands	-	Bestman et al., 2019
		-	-	-	-	-	750	Germany	-	Fürmetz et al., 2005
Broiler	14.3	Sherwood White	White	49	28	11.3	10000	UK	08:00 20:00	to Dawkins et al., 2003
	50	Sherwood White Ross 308	White	42	28	11.8	1340 670	UK	9:30 17:30	to Jones et al., 2007
	37	Ross 308	White	29.5	12-18	13	39740	Australia, SA	06:32 19:01	to Rault & Taylor, 2017
	21.5	Rowan Ranger Hubbard JA57/JA87	Brown	55	23-30	6.0-7.4	4217 ± 1290	Sweden	15.00 15.30	to Göransson et al., 2021
	14.2	Hubbard JA57 Color Yield	Brown	30.5	35	9.8	600	Denmark	09:00 to 15:00	Jessen, Foldager, & Riber, 2021

[illegible]

65.7	-	-	-	-	-	-	-	-	-	Mirabito, Joly, & Lubac, 2001
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Studies using individual tracking

Chicken	%	Genotype	Colour	Age	1 st range access	Stocking density	Flock size	Location	Obs. time	Reference
Laying hen	18	Hy-Line® Brown	Brown	203	147	3	46-50	Australia, NSW	Continuous	Campbell et al., 2018a
	72.7			161	175	8.9	154	Australia, NSW		Taylor et al., 2023a
	97.1			364	-	12.1	18000	Australia, VIC		Larsen et al., 2018
	95 84 78	ISA Brown	Brown	192.5 455 353.5	140 - 147	8.4 - 9	50 200 900	Australia, NSW	Continuous	Hartcher et al., 2016
										Singh et al., 2016
										Campbell et al., 2017
	92.3 85	Lohmann Brown	Brown	360.5 322	112 168	8.3 -	1500 5000	UK Switzerland	Continuous	Richards et al., 2012
										Gebhardt-Henrich, Toscano, & Fröhlich, 2014
	99.7 92.3	Lohmann Cl.	Brown	315 360.5	112 112	9 8.3	625 1500	Australia, NSW UK	Continuous	Kolakshyapati et al., 2020a
										Richards et al., 2011
	90 72 78 70 70 56 59	LSL	White	- 322	- 168	- -	50 2000 6000 9000 9000 12000 18000	Germany Switzerland	Continuous	Müller et al., 2001
										Gebhardt-Henrich, Toscano, & Fröhlich, 2014
	66 90 63	HN White	White	322	168	-	246 2000 2000	Switzerland	Continuous	Gebhardt-Henrich, Toscano, & Fröhlich, 2014

	47					6000				
	90	HN Brown	Brown	322	168	-	5600	Switzerland	Continuous	Gebhardt-Henrich, Toscana, & Fröhlich, 2014
	65	Lohmann Silver	Silver	308	140	5	272	Germany	Continuous	Icken et al., 2008
	58	Lohmann Tradition	Brown	-	91	-	50	Germany	Continuous	Müller et al., 2001
Broiler	87.9	Cobb 500	White	21.5	21	2.5	25	Australia, VIC	Continuous	Taylor et al., 2023b
	95			30.5	21	-	265	Australia, NSW		Durali et al., 2014
	97	Rowan ranger	Brown	56.5	28	6	1500	Sweden	Continuous	Lindholm et al., 2016
	94.5	Ross 308	White	24.5	15	16.5	305	Australia, VIC	Continuous	Taylor et al., 2020
	88			56.5	28	6	1500	Sweden		Lindholm et al., 2016
	87.3			33	21	16	8000	Australia, VIC		Taylor et al., 2017
	82.1			33	21	15	8000			Taylor et al., 2018

1276

1277 Appendix references

1278 Kjær, J. B., & Isaksen, P. K. (1998). Individual use of the free range area by laying hens and effect of genetic strain. Paper presented at the
1279 32nd Congress of the International Society for Applied Ethology.

1280 Mirabito, L., Joly, T., & Lubac, S. (2001). Impact of the presence of peach tree orchards in the outdoor hen runs on the occupation of the space
1281 by 'Red Label' type chickens. *British Poultry Science* **42**, S18–S19.

1282 Mirabito, L., & Lubac, S. (2001). Descriptive study of outdoor run occupation by 'Red Label' type chickens. *British Poultry Science* **42**, S16–S17.