Pettersson, I., Freire, R., & Nicol, C. J. (2016). Factors affecting ranging behaviour in commercial free-range hens. World's Poultry Science Journal, 72(1), 137-150. DOI: 10.1017/S0043933915002664

Peer reviewed version

Link to published version (if available):
10.1017/S0043933915002664

Link to publication record in Explore Bristol Research
PDF-document

FACTORS AFFECTING RANGING BEHAVIOUR IN COMMERCIAL FREE-RANGE HENS

I.C. PETTERSSON[1]*, R. FREIRE[2] and C.J. NICOL[1]

[1] Animal Behaviour & Welfare Group, School of Veterinary Sciences, Bristol University, Langford House, Langford, Bristol, BS40 5DU, United Kingdom.

[2] School of Animal and Veterinary Sciences, Charles Sturt University, LMB 588, Wagga Wagga, NSW 2678, Australia.

Corresponding author: i.pettersson@bristol.ac.uk

Abbreviated title: Ranging in free-range hens

Summary:

Many studies have assessed use of the outdoor 'range' area on free-range laying farms. Collated data reveal that percentage range use at any one time rarely exceeds 50% and is sometimes below 10%. What constitutes 'good' range use is difficult to determine without better knowledge of ranging bout lengths under ideal conditions. Well documented factors that affect percentage range use include prevailing weather, flock size and shelter on the range. Other factors such as pophole design, internal and external stocking density and system design appear to play a role although their effects are not as clear and more research would be valuable to truly understand their relevance. Factors affecting bird distribution on the range are also reviewed.

Key words: laying hen, free-range, range use, ranging behaviour, shelter, flock size, spatial distribution

Introduction:

The range has great potential to improve welfare, as a well-designed range provides opportunities to fulfil behavioural needs such as foraging and dustbathing (Weeks and Nicol, 2006; Lay *et al*., 2011) and provides additional space. Range use has been shown to have positive effects on feather pecking behaviour - a 9-fold reduction in risk of feather pecking was found in flocks that used the range more on sunny days (Nicol *et al*., 2003), and poor range use was found to be a risk factor for feather pecking (Green *et al*., 2000; Lambton *et al*., 2010). Fraser (2003) explains that people conceptualise welfare in three ways: physical health, mental health and naturalness. Consumers often believe that animals should be kept in as close to natural conditions as possible, preferring a free-range system (Harper and Henson, 2001). EU egg marketing regulations state that eggs can be sold as free-range if hens have "continuous daytime access to open-air runs" (Commission Regulation EC/589/2008). Consumer expectation is that most birds will use and be seen to use this outside area, as consumers appear to be influenced by an idyllic image of the countryside (Vanhonacker *et al*., 2010). If a low percentage (e.g. under 50%) of birds is seen out at a given time, there may therefore be a breach in consumer confidence. Indeed, range use is often lower than this consumer expectation (table 1). This review aims to investigate the factors that affect ranging behaviour in hens.

Measuring range use:

There are a number of ways in which range use can be measured on a commercial farm and the method used depends on access, resources and the question being addressed.

Perhaps the most popular method employed is to count or estimate the number of birds on the range (or a subsection of it) at a point in time (either once or repeated and an average taken).

To account for factors such as age and climate counts may be repeated throughout the flock cycle and various weather conditions. This method of assessing range use is usually presented as a percentage of all birds in the flock so for clarification will be referred to as 'percentage range use' throughout this review. Farmers themselves may sometimes make these estimates instead of researchers.

Estimated percentage range use does not give information on the time spent outside by individual birds. A given overall percentage range use could reflect occasional usage by all or most birds, or frequent usage by a small minority. This information is important in establishing how many birds receive the direct benefits associated with ranging and whether birds inside the house benefit indirectly through reduced internal stocking densities. To obtain this information individual birds must be tracked. This is technologically difficult and expensive although some work has been done using radio frequency identification (RFID) tags to assess pophole use by a subset of birds (Richards *et al*., 2011; Gebhardt-Henrich *et al*., 2014). Development of more readily accessible and improved methods is needed in this area as the current technology can produce skewed data if birds sit in the popholes causing repeated counts on the RFID recording system (Richards *et al*. 2011). Evidence using RFID tags suggests that although the percentage range use is often below 40%, a higher proportion of birds use the range at least once during the day.

Consumers may assume that most birds will use the outdoor area each day, and for a significant proportion of time. However, to provide consumers with reassurance we must first understand how long individual birds spend on the range under 'ideal' baseline conditions i.e. when both the internal house environment and external range are managed according to current best practice. Knowing whether individual hens choose to range for 1h/day or 6h/day under these ideal conditions, would permit a better interpretation of scan samples of percentage range use.

Another valuable measure is the distribution of birds in relation to the house. For example, Hegelund *et al*. (2005) counted birds at close, middle and remote distances from the house.

Prevalence of Range Use

Range use has been measured in multiple studies, with varying scope, flock sizes and consequent results. See table 1 for an overview of these studies, presented in order of recency.

Table 1 indicates that often fewer than half of the birds in commercial flocks use the range at any one time, sometimes less than 10%. Taken together with the figures for individually tagged birds it appears that a higher percentage access the open range at least once a day. There is a need for future research studying ranging bout lengths to test this.

Factors Influencing Range Use

The likelihood of hens ranging on a given farm will be influenced by both motivation and physical ability. The motivation of hens to use the range will be influenced by both internal and external causal factors (for a discussion of the concept of motivational causation see Jensen and Toates, 1993). For example, the tendency to use the range might be increased by an increased desire to forage, provoked by a combination of falling glucose levels (internal factor) and the sight of dry, friable dirt on the range (external factor). However, even highly motivated hens may be physically blocked from accessing the range if house design is inappropriate or if birds are in poor health. The high prevalence of keel bone fractures in laying hens (including those in free-range systems) (Wilkins *et al*., 2004; 2011) is relevant in this regard.

Birds with keel fractures have reduced mobility, finding it more difficult to jump down levels (Nasr *et al*., 2012) and a study using RFID tagged birds in a commercial unit found that birds with badly damaged keels used the popholes less (Richards *et al*., 2012). Keel fracture prevalence, severity and the factors that contribute to this may therefore affect ability to range.

Motivation to range has a diurnal pattern with peaks in the morning and early evening (Bubier and Bradshaw, 1998; Mahboub *et al*., 2004; Hegelund *et al*., 2005; Richards *et al*., 2011; Nagle and Glatz, 2012). By opening the popholes late or closing them early (due to bad weather or the early training period before 21 weeks) producers may restrict ranging by preventing access during prime ranging periods.

Most studies of ranging behaviour have used brown hybrids (table 1). Mahboub *et al.* (2004) looked at differences in the use of an outdoor area between white and brown hybrids, finding that brown hybrids spent more time outside but white hybrids moved more frequently to this area. This suggests that there may be differences in ranging behaviour between genetic strains although this work was on small groups of 50 birds so cannot be easily generalised to commercial conditions.

Internal stocking density, flock size and house size on % range use:

There is some evidence that internal house stocking density affects range use in commercial free-range hens. Gilani *et al*. (2014) conducted a study on the effect of various factors on percentage range use in 33 flocks and produced predictive models of ranging behaviour. Percentage range use was significantly higher with reduced flock size and stocking density (lay period only).

Stocking density is a function of both flock size and the area available. As these three factors are closely linked it can be difficult to differentiate which is causing any effects on percentage range use. Houses with different stocking densities must also differ in either flock size or house size, making it hard to test the effect of stocking density alone. Each of these three factors should be considered when discussing the effect of one. It should also be noted that as birds range, the stocking density in the house will decrease.

Stocking density will not necessarily have the same effect at different flock sizes. Small flocks kept in small houses may achieve relatively even distributions of hens due to the confining effects of walls although some clustering around resources may occur (Collins *et al*., 2011; Lentfer *et al*., 2013). However, in larger houses with larger flocks (at the same stocking density) birds can move greater distances from each other and resulting in increased clustering and uneven stocking densities around the house. This effect of increased clustering in larger pens (as discussed in Appleby, 2004) results in reduced freedom of movement for hens in certain areas of the house compared with others.

The effect of stocking density on hen movement was investigated by Carmichael *et al*. (1999) in an early multi-tier system. Birds spent less time moving and more time standing at 19.0 birds/m^2 compared with 9.9 birds/m^2, suggesting that movement becomes more difficult with increased crowding. Appleby *et al*. (1989) also found that locomotion decreased linearly with increased stocking density from 3.4 to 10.7 birds/m^2. High stocking densities could therefore limit the ability of birds to move to the popholes and get onto the range area. Whether this effect was caused by physical blocking or social factors is not so clear. Grigor *et al*. (1995c) found that hens were slower to enter a test pen when passing an unfamiliar bird and the latency to enter the test pen increased with the number of unfamiliar birds. High stocking densities may force more unfamiliar birds into close proximity, limiting movement. However, in commercial sized flocks hens are unable to discriminate between individuals and do not form a traditional hierarchy (Pagel and Dawkins, 1997; D'Eath and Keeling, 2003). Instead hens respond to physical attributes of conspecifics to detect potential aggressors (D'Eath and Keeling, 2003). Perhaps the movement of commercial hens could therefore be limited by being forced into close proximity with such "aggressor hens" although this is speculation and work is yet to be done in this area.

Internal stocking density is usually relatively tightly specified by law (e.g. max 9 birds/m^2 in the EU (Council Directive 1999/74/EC)), making commercial studies of its effects difficult. Flock size however, is more variable and much evidence suggests that flock size affects ranging behaviour. Bestman and Wagenaar (2003) studied 63 Dutch organic flocks finding that flock size was a highly significant factor with smaller flocks seeing higher percentage range use (all under optimal ranging conditions). Hegelund *et al*. (2005) also reported a tendency for lower percentage range use with increasing flock size. The lack of statistical significance may be because few flocks over 3000 birds were included in the study. Whay *et al*. (2007) looked at larger free-range flocks (3000-16000) and found that bigger flocks had lower percentage range use. Appleby and Hughes (1991) also reported unpublished observations of reduced percentage range use in flocks exceeding 1000 birds. Conversely, in a study using individually tagged birds to assess ranging, no association was found between the percentages of birds registered outside and flock size (Gebhardt-Henrich *et al*., 2014). Despite this, hens from small (2000-2500 birds) and medium (5000-6000) sized flocks visited the outside area more frequently and for longer than hens in large flocks (9000+). Additionally, foraging behaviour on the range was more frequent and extensive in small and medium flocks. This suggests that flock size may affect behaviour on the range as well as whether hens leave the house. Currently, no legal maximum flock size for free-range units exists in most parts of the world although the Lion Code (BEIC, 2013) and RSPCA Assured (RSPCA, 2013) standard in the UK both set a limit of 16,000 birds (in colonies of max 4000).

House area, shape and size may also affect range use by increasing the distance needed to travel to reach a pophole. The interior contents of the house will further affect this and will be discussed in detail later in this review.

Pophole number, size and design on % range use:

Popholes usually provide the sole access point to the range so ensuring suitable design and management of these openings is important to encourage good range use. Minimum pophole availability in the EU as set by council directive 1999/74/EC (1999) is 2m per 1000 hens (35cm high x 40cm wide).

Gilani *et al*. (2014) measured pophole availability (cm/bird) for 33 commercial flocks finding that percentage range use significantly increased with increased availability (average of 0.5cm/bird, range of 0.1-1.9cm/bird). Sherwin *et al*. (2013) found that that percentage range use increased with the number of popholes available per bird although actual figures were not provided. Hens have been seen to perch for periods of time in the popholes (Richards *et al*., 2011) consequently reducing the available pophole space, and potentially range access.

Conversely, a study looking at the effect of pophole dimensions on range use (Harlander-Matauschek *et al.*, 2006) found no effect of pophole width (range of 0.2-1.2cm/bird). This study looked at relatively small groups of hens (256 birds) compared with commercial flocks. Range use is often greater in smaller flocks and this may have overridden the importance of pophole dimensions. Additionally, as the experiment began when birds were 32 weeks, previous range experience may have affected the results. The importance of pophole availability may be greater in commercial flocks where more factors work to limit pophole access and this may explain the significant effect seen in the Gilani *et al.* (2014) study.

Many commercial houses have popholes on one side of the building only. This effectively increases the distance needed to travel to reach a pophole on average. Evidence suggests that hens do not access all areas of the house but instead remain in certain horizontal or vertical localities (Freire *et al*., 2003; Nakarmi *et al*., 2014). If popholes are only available in one area of the house, access to the range may be limited to a relatively small proportion of the flock that happen to stay in that area.

The height of a pophole from the ground is important because elevated popholes may prove physically difficult for hens to negotiate. Studies on the ability of hens to jump between and up to perches suggest that vertical jumps over 50cm start to present difficulties (Scott *et al*., 1997). Pophole elevation is not typically regulated by law although RSPCA Assured (2013) regulations suggest ramps if the pophole is above ground level. As yet, no studies have looked at the specific effect of pophole elevation on range use. The height of the opening itself is also relevant as hens show some aversion to entering spaces with vertical heights below 46cm (Dawkins, 1985).

General system design on % range use:

Free-range housing design varies greatly. As previously mentioned, hens tend to restrict themselves to certain areas within the house potentially resulting in limited pophole access for some individuals. This effect will be emphasised if the interior contents of the shed are arranged in such a way that birds are physically blocked from accessing certain areas of the shed (e.g. by tiers of nestboxes or multi-tier rows with the litter underneath fenced off).

It is important to encourage birds to use the areas of the house that adjoin the popholes. Popholes are often accessed from litter areas and so anything that discourages litter usage will also discourage range use. Poor litter quality may reduce litter attractiveness for performing behaviours (Odén *et al*., 2002), as will the use of electric wires crossing the litter area (used in some countries to reduce floor eggs) or along the walls of the litter area (commonly used in the UK during early lay). The ‘relative attractiveness’ of the house may also play a role. If the house is much more attractive to hens than the range (e.g. through readily available resources, a quality foraging/dustbathing substrate and security) they may be less likely to go outside (Keeling *et al*., 1988). This should be addressed by improving the range rather than reducing the attractiveness of the house.

Feeders and drinkers are usually placed on the slatted area or the first two tiers of a multi-tier system. Hens feed with great frequency during daylight hours (Nicol *et al*., 2009) so do not stray far from these important resources. If food and water is only provided indoors hens will be less likely to range or range any distance. Hens will run to the feeders prior to feeding (Bubier and Bradshaw, 1998). Very regular feeds may therefore prevent birds staying on the range for very long or ranging far from the house as they would be disadvantaged for feeding (Bubier and Bradshaw, 1998). Indeed, in a small study of 4 farms the farm with *ad libitum* feeding had the highest proportion of flock outdoors (Bubier and Bradshaw, 1998). This result was likely affected by the smaller size of this flock.

Climatic conditions on % range use:

Percentage range use is largely influenced by weather conditions (Keeling *et al*., 1988; Nicol *et al*., 2003; Hegelund *et al*., 2005; Richards *et al*., 2011). Nicol *et al*. (2003) collected both farmer reported figures and researcher observations of percentage range use, finding a higher percentage ranged when the weather was ‘calm and dull’ than when it was ‘wet’, ‘cold’ or ‘sunny’. Hegelund *et al*. (2005) studied 37 organic flocks over a 4 year period and found a significant effect of temperature, wind, precipitation and season on percentage range use. Percentage range use decreased in higher winds and precipitation and increased up to 17°C.

Richards *et al*. (2011) tracked individual pophole usage and found reductions in pophole use during high winds and rainfall. An increase in pophole use was found with both temperature and hours of sunshine, although the effect of sunshine was more noticeable at lower temperatures and the authors hypothesise that this was due to the warming effect of sun.

The effect of weather and the management practices best suited to dealing with it are different depending on the country and its climate. Provision of shade, shelter, wind breaks, outdoor water provision and ground drainage are all management practices that can reduce the effect of adverse weather on ranging behaviour.

Hens from different climates will be affected differently by weather. Hens that have acclimatised to higher temperatures have improved heat tolerance compared with non-acclimatised birds (Hutchinson and Sykes, 1953). In the case of range use, it would be reasonable to assume that particularly hot days will discourage hens in warm climates from ranging less than those in colder climates.

Range design on % range use:

High outdoor stocking densities may affect bird health by increasing the risk of worm infection (Sherwin *et al*. 2013). Sick birds may have a reduced ability to use the range. A higher outdoor stocking density (actual figures not provided) has actually been shown to increase percentage range use (Sherwin *et al*., 2013), perhaps because the increased presence and proximity of other birds on the range increases their sense of security. Hens on the range may therefore act as a form of enrichment, further encouraging more birds out. Keeling *et al*. (1988) found increased numbers of birds further out on the range with increased percentage range use, suggesting that the presence of ranging birds also affects distribution. Intended stocking densities on the range will not necessarily reflect the actual stocking densities experienced by the birds. For example, 2500 birds/ hectare on the range assumes that the birds are evenly spread and all ranging together. Instead, as discussed with regards to indoor stocking densities, we see uneven distributions resulting in higher stocking densities in certain areas (near the popholes/house is common). This is particularly apparent on the range as birds using the range area at a given time can be so variable. Spacing behaviour in small groups is influenced by forces that bring individuals closer such as protection from predators and forces that keep them apart such as reducing competition for food (Keeling, 1995). However, the spatial needs of commercial hens kept in large groups has not been assessed on the range and remains unclear.

Various studies have provided resources on the range to try and encourage good ranging. Resources that provide opportunities to forage or dustbath may encourage birds out as they are highly motivated to perform these behaviours (Weeks and Nicol, 2006). Poorly maintained ranges, with wet mud or compacted earth will prevent hens from using the ground to perform these behaviours.

Nicol *et al*. (2003) found that outdoor use was positively correlated with the presence of trees and hedges on the range. Shelter, whether natural or artificial, provides protection from the elements and can reduce bird fearfulness by increasing their perception of safety from predators (Collias, 1987). Experimental work has demonstrated that hens are more likely to emerge into an open area if familiar objects are present (Grigor *et al*., 1995b). As chickens are prey animals provision of shelter may increase the range use if they feel safer. In both experimental and on-farm trials carried out in Australia the provision of shelterbelts and artificial shelter increased percentage range use. In fact, 17 times more hens used the shelterbelt areas than control areas (Nagle and Glatz, 2012). This effect may have been exacerbated in the latter study by the hot climate and need for shade. Zeltner and Hirt (2008) found that flocks with structures installed on the range had significantly greater percentage range use than controls. Similarly the presence of artificial cover has been found to increase percentage range use (Hegelund *et al*., 2005). A study using small flocks of 256 birds found that percentage range use averaged 31% for ranges with negligible cover but increased to 38% for ranges with vegetation cover (Harlander-Matauschek *et al*., 2006).

Rearing and experience on % range use:

Hens are initially fearful of novel environments such as the outdoor range, becoming more confident with repeated exposure and increased familiarity (Jones, 1977; Grigor *et al*., 1995b). Early life experience of the range increases readiness to emerge into an outdoor environment experimentally (Grigor *et al*., 1995a). However, Gilani *et al*. (2014) found no effect of rearing with or without range access on subsequent percentage range use commercially at 35 weeks. It is possible that rearing did lead to an effect, but that any rearing effects may have been overcome by subsequent experience by this age.

Pullets reared without access to perches or similar raised structures will be less physically able than birds reared with perches, with effects on both their spatial and navigational abilities (Gunnarsson *et al*., 2000). This will affect their ability to navigate the house and exit through popholes if doing so presents a physical challenge.

It is a reasonably common practice on laying hen farms to keep birds enclosed on the slatted area for a period of time when they are first housed. This experience will make the litter less familiar, potentially increasing fear responses, and reducing likelihood to access litter-based popholes. Conversely, new research on the effect of this practice indicated that welfare was not adversely affected, and some parameters even suggested improved welfare in those held off the litter for two weeks (Alm *et al*., 2015). As this study looked at hens in a non-free-range system the effect of this practice on subsequent ranging remains unclear.

Factors influencing bird distribution on the range:

Overall range-use is not the only issue where commercial norms fail to meet consumer expectation. The distribution of birds on the range is rarely even, with the majority of hens staying close to the house (Hirt *et al*., 2000; Zeltner and Hirt, 2003; Hegelund *et al*., 2005; Rault *et al*., 2013, Steenfeldt and Nielsen, 2015). This leads to overuse of pasture near the house (Maurer *et al*., 2013), reducing potential foraging opportunities and potentially increasing concentrations of parasites in certain areas. This is an area of concern for producers. Additionally, accumulation of phosphorus and nitrogen in the soil occurs (Maurer *et al*., 2013), posing a hazard to the environment. Very high stocking densities near the popholes may limit the movement of birds in the area, reducing ability to exit the shed.

When a simple roofed box with sand was placed in the furthest quarter of the range, a higher percentage of birds were found in this area (Zeltner and Hirt, 2003). Flocks with structures on the range had a significantly greater percentage of birds using the middle area of the range compared with controls (Zeltner and Hirt, 2008). Similarly, the addition of vertical structures encouraged hens to range further (Rault *et al*., 2013). Gilani *et al*. (2014) found a strongly significant effect of cover on the range in increasing the proportion of birds ranging away from the house. These studies show that structuring the range can affect the distribution.

Although distribution on the range is skewed to areas near the house, hens have been observed ranging over 50m from the house (Zeltner and Hirt, 2003). Small ranges, or those of a shape so that birds cannot move outwards further than a few metres may therefore restrict freedom of movement on the range for some hens (Zeltner and Hirt, 2008). Cooper and Hodges (2010) reported that trees have positive effects on ranging up to 50m but no further, likely due to other limiting effects such as the desire to stay close to the resources provided in the house.

When different structures were provided outside, hens were mostly found near those that provided shelter and shade (Zeltner and Hirt, 2008). The literature indicates that by providing shelter, either natural or artificial, we can both encourage more birds out onto the range and encourage them to travel further.

Conclusions:

There are many studies that have reported figures for percentage range use in free-range hens although these figures are often lower than consumer expectation, rarely exceeding 40%. Less information is available on range use by individual hens, particularly in large commercial systems. There is therefore a lack of knowledge on ranging bout lengths, although existing research suggests that hens do not range for long. Research looking at how long a hen chooses to range under a variety of conditions would be valuable as this would allow targets for scan samples of percentage range use to be developed. As ranging is affected by age and potentially hybrid, this work would ideally be repeated on different strains and ages.

Many factors affecting percentage range use have been identified, often through observational studies of commercial flocks, particularly the effects of climate, shelter and flock size. However, certain factors are somewhat underrepresented in the literature. The effect of pophole size and elevation has not been studied much, likely because of the difficulty in manipulating this factor. Similarly, very little research has looked at the effect of external stocking density or space requirements on the range. The effect of hybrid, specifically brown vs white birds, has not been well researched with regards to range use and this would be an interesting aspect to investigate further.

References:

ALM, M., WALL, H., HOLM, L., WICHMAN, A., PALME, R. and TAUSON, R. (2015) Welfare and performance in layers following temporary exclusion from the litter area on introduction to the layer facility. *Poultry Science* **94**: 565-573.

APPLEBY, M.C. (2004) What causes crowding? Effects of space, facilities and group size on behaviour, with particular reference to furnished cages for hens. *Animal Welfare* **13**: 313-320.

APPLEBY, M.C. and HUGHES, B.O. (1991) Welfare of laying hens in cages and alternative systems - environmental, physical and behavioral-aspects. *Worlds Poultry Science Journal* **47**: 109-128.

APPLEBY, M.C., HUGHES, B.O. and HOGARTH, G.S. (1989) Behaviour of laying hens in a deep litter house. *British Poultry Science* **30**: 545-553.

BEIC (2013) Code of Practice for Lion Eggs, Version 7. British Egg Industry Council, London, UK.

BESTMAN, M.W.P. and WAGENAAR, J.P. (2003) Farm level factors associated with feather pecking in organic laying hens. *Livestock Production Science* **80**: 133-140.

BUBIER, N.E. and BRADSHAW, R.H. (1998) Movement of flocks of laying hens in and out of the hen house in four free range systems. *British Poultry Science* **39**: S5-S6.

CARMICHAEL, N.L., WALKER, A.W. and HUGHES, B.O. (1999) Laying hens in large necks in a perchery system: influence of stocking density on location, use of resources and behaviour. *British Poultry Science* **40**: 165-176.

COLLIAS, N.E. (1987) The vocal repertoire of the red junglefowl: a spectrographic classification and the code of communication. *The Condor* **89:** 510-524.

COLLINS, L.M., ASHER, L., PFEIFFER, D.U., BROWNE, W.J. and NICOL, C.J. (2011) Clustering and synchrony in laying hens: The effect of environmental resources on social dynamics. *Applied Animal Behaviour Science* **129**: 43-53.

COMMISSION REGULATION EC/589/2008 (2008) laying down detailed rules for implementing Council Regulation (EC) No 1234/2007 as regards marketing standards for eggs. Official Journal of the European Union No. L163, 0006-0023.

COOPER, J. and HODGES, H. (2010) Effect of tree cover on ranging behaviour of free-range hens. *Proceedings of the 44th Congress of the International Society for Applied Ethology*, Uppsala, p. 75.

COUNCIL DIRECTIVE 1999/74/EC (1999) laying down minimum standards for the protection of laying hens. Official journal of the European Communities No. L203, 0053-0057.

D'EATH, R.B. and KEELING, L.J. (2003) Social discrimination and aggression by laying hens in large groups: from peck orders to social tolerance. *Applied Animal Behaviour Science* **84**: 197-212.

DAWKINS, M. (1985) Cage height preference and use in battery-kept hens. *Veterinary Record* **116**: 345-347.

FRASER, D. (2003) Assessing animal welfare at the farm and group level: The interplay of science and values. *Animal Welfare* **12**: 433-443.

FREIRE, R., WILKINS, L.J., SHORT, F. and NICOL, C.J. (2003) Behaviour and welfare of individual laying hens in a non-cage system. *British Poultry Science* **44**: 22-29.

GEBHARDT-HENRICH, S.G., TOSCANO, M.J. and FROEHLICH, E.K.F. (2014) Use of outdoor ranges by laying hens in different sized flocks. *Applied Animal Behaviour Science* **155**: 74-81.

GILANI, A.M., KNOWLES, T.G. and NICOL, C.J. (2014) Factors affecting ranging behaviour in young and adult laying hens. *British Poultry Science* **55**: 127-135.

GREEN, L.E., LEWIS, K., KIMPTON, A. and NICOL, C.J. (2000) Cross-sectional study of the prevalence of feather pecking in laying hens in alternative systems and its associations with management and disease. *Veterinary Record* **147**: 233-238.

GRIGOR, P.N., HUGHES, B.O. and APPLEBY, M.C. (1995a) Effects of regular handling and exposure to an outside area on subsequent fearfulness and dispersal in domestic hens. *Applied Animal Behaviour Science* **44**: 47-55.

GRIGOR, P.N., HUGHES, B.O. and APPLEBY, M.C. (1995b) Emergence and dispersal behaviour in domestic hens: effects of social rank and novelty of an outdoor area. *Applied Animal Behaviour Science* **45**: 97-108.

GRIGOR, P.N., HUGHES, B.O. and APPLEBY, M.C. (1995c) Social inhibition of movement in domestic hens. *Animal Behaviour* **49**: 1381-1388.

GUNNARSSON, S., YNGVESSON, J., KEELING, L.J. and FORKMAN, B. (2000) Rearing without early access to perches impairs the spatial skills of laying hens. *Applied Animal Behaviour Science* **67**: 217-228.

HARLANDER-MATAUSCHEK, A., FELSENSTEIN, K., NIEBUHR, K. and TROXLER, J. (2006) Influence of pop hole dimensions on the number of laying hens outside on the range. *British Poultry Science* **47**: 131-134.

HARPER, G. and HENSON, S. (2001) Consumer Concerns about Animal Welfare and the Impact on Food Choice. *EU FAIR CT98-3678 Final Report*. http://www.londonpressservice.org.uk/haeu/20131031020146/http://ec.europa.eu/food/animal/welfare/research/fair_project.pdf. Accessed 22/09/15.

HEGELUND, L., SORENSEN, J.T., KJAER, J.B. and KRISTENSEN, I.S. (2005) Use of the range area in organic egg production systems: effect of climatic factors, flock size, age and artificial cover. *British Poultry Science* **46**: 1-8.

HIRT, H., HÖRDEGEN, P. and ZELTNER, E. (2000) Laying hen husbandry: group size and use of hen-runs. *Proceedings of the 13th International IFOAM Scientific Conference,* Basel, p. 363.

HUTCHINSON, J.C.D. and SYKES, A.H. (1953) Physiological acclimatization of fowls to a hot humid environment. *Journal of Agricultural Science* **43**: 294-322.

JENSEN, P. and TOATES, F. (1993) Who needs 'behavioural needs'? Motivational aspects of the needs of animals. *Applied Animal Behaviour Science* **37**: 161-181.

JONES, R. (1977) Repeated exposure of the domestic chick to a novel environment: effects on behavioural responses. *Behavioural Processes* **2**: 163-173.

KEELING, L.J. (1995) Spacing behaviour and an ethological approach to assessing optimum space allocations for groups of laying hens. *Applied Animal Behaviour Science* **44**: 171-186.

KEELING, L.J., HUGHES, B.O. and DUN, P. (1988) Performance of free-range laying hens in a polythene house and their behavior on range. *Farm Building Progress* **94**: 21-28.

LAMBTON, S.L., KNOWLES, T.G., YORKE, C. and NICOL, C.J. (2010) The risk factors affecting the development of gentle and severe feather pecking in loose housed laying hens. *Applied Animal Behaviour Science* **123**: 32-42.

LAY, D.C., FULTON, R.M., HESTER, P.Y., KARCHER, D.M., KJAER, J.B., MENCH, J.A., MULLENS, B.A., NEWBERRY, R.C., NICOL, C.J., O'SULLIVAN, N.P. and PORTER, R.E. (2011) Hen welfare in different housing systems. *Poultry Science* **90**: 278-294.

LENTFER, T.L., GEBHARDT-HENRICH, S.G., FRÖHLICH, E.K.F. and VON BORELL, E. (2013) Nest use is influenced by the positions of nests and drinkers in aviaries. *Poultry Science* **92**: 1433-1442.

MAHBOUB, H.D.H., MÜLLER, J. and VON BORELL, E. (2004) Outdoor use, tonic immobility, heterophil/lymphocyte ratio and feather condition in free-range laying hens of different genotype. *British Poultry Science* **45**: 738-744.

MAURER, V., HERTZBERG, H., HECKENDORN, F., HÖRDEGEN, P. and KOLLER, M. (2013) Effects of paddock management on vegetation, nutrient accumulation, and internal parasites in laying hens. *The Journal of Applied Poultry Research* **22**: 334-343.

NAGLE, T.A.D. & GLATZ, P.C. (2012) Free Range Hens Use the Range More When the Outdoor Environment Is Enriched. *Asian-Australasian Journal of Animal Sciences* **25**: 584-591.

NAKARMI, A.D., TANG, L., and XIN, H. (2014) Automated Tracking and Behavior Quantification of Laying Hens Using 3D Computer Vision and Radio Frequency Identification Technologies. *Transactions of the ASABE* **57**: 1455.

NASR, M.A.F., MURRELL, J., WILKINS, L.J. and NICOL, C.J. (2012) The effect of keel fractures on egg-production parameters, mobility and behaviour in individual laying hens. *Animal Welfare* **21**: 127-135.

NICOL, C.J., POTZSCH, C., LEWIS, K. and GREEN, L.E. (2003) Matched concurrent case-control study of risk factors for feather pecking in hens on free-range commercial farms in the UK. *British Poultry Science* **44**: 515-523.

NICOL, C.J., CAPLEN, G., EDGAR, J. and BROWNE, W.J. (2009) Associations between welfare indicators and environmental choice in laying hens. *Animal Behaviour* **78**: 413-424.

ODÉN, K., KEELING, L.J. and ALGERS, B. (2002) Behaviour of laying hens in two types of aviary systems on 25 commercial farms in Sweden. *British Poultry Science* **43**: 169-181.

PAGEL, M. and DAWKINS, M.S. (1997) Peck orders and group size in laying hens:futures contracts' for non-aggression. *Behavioural Processes* **40**: 13-25.

RAULT, J.L., VAN DE WOUW, A. and HEMSWORTH, P. (2013) Fly the coop! Vertical structures influence the distribution and behaviour of laying hens in an outdoor range. *Australian Veterinary Journal* **91**: 423-426.

RICHARDS, G.J., WILKINS, L.J., KNOWLES, T.G., BOOTH, F., TOSCANO, M.J., NICOL, C.J. and BROWN, S.N. (2011) Continuous monitoring of pop hole usage by commercially housed free-range hens throughout the production cycle. *Veterinary Record* **169**: 338.

RICHARDS, G.J., WILKINS, L.J., KNOWLES, T.G., BOOTH, F., TOSCANO, M.J., NICOL, C.J. and BROWN, S.N (2012) Pop hole use by hens with different keel fracture status monitored throughout the laying period. *Veterinary Record* **170**: 494-494.

RSPCA (2013) RSPCA welfare standards for laying hens. http://science.rspca.org.uk/sciencegroup/farmanimals/standards/layinghens. Accessed 31/07/15.

SCOTT, G.B., LAMBE, N.R. and HITCHCOCK, D. (1997) Ability of laying hens to negotiate horizontal perches at different heights, separated by different angles. *British Poultry Science* **38**: 48-54.

SHERWIN, C.M., NASR, M.A.F., GALE, E., PETEK, M., STAFFORD, K., TURP, M. and COLES, G.C. (2013) Prevalence of nematode infection and faecal egg counts in free-range laying hens: relations to housing and husbandry. *British Poultry Science* **54**: 12-23.

STEENFELDT, S. and NIELSEN, B.L. (2015) Welfare of organic laying hens kept at different indoor stocking densities in a multi-tier aviary system. I: egg laying, and use of veranda and outdoor area. *Animal*: doi:10.1017/S1751731115000713.

VANHONACKER, F., VAN POUCKE, E., TUYTTENS, F. and VERBEKE, W. (2010) Citizens' Views on Farm Animal Welfare and Related Information Provision: Exploratory Insights from Flanders, Belgium. *Journal of Agricultural & Environmental Ethics* **23**: 551-569.

WEEKS, C.A. and NICOL, C.J. (2006) Behavioural needs, priorities and preferences of laying hens. *World's Poultry Science Journal* **62**: 296-307.

WHAY, H.R., MAIN, D.C.J., GREEN, L.E., HEAVEN, G., HOWELL, H., MORGAN, M., PEARSON, A. and WEBSTER, A.J.F. (2007) Assessment of the behaviour and welfare of laying hens on free-range units. *Veterinary Record* **161**: 119-128.

WILKINS, L.J., BROWN, S.N., ZIMMERMAN, P.H., LEEB, C. and NICOL, C.J. (2004) Investigation of palpation as a method for determining the prevalence of keel and furculum damage in laying hens. *Veterinary Record* **155**: 547-549.

WILKINS, L.J., MCKINSTRY, J.L., AVERY, N.C., KNOWLES, T.G., BROWN, S.N., TARLTON, J. and NICOL, C.J. (2011) Influence of housing system and design on bone strength and keel bone fractures in laying hens. *Veterinary Record* **169**: 414.

ZELTNER, E. and HIRT, H. (2003) Effect of artificial structuring on the use of laying hen runs in a free-range system. *British Poultry Science* **44**: 533-537.

ZELTNER, E. and HIRT, H. (2008) Factors involved in the improvement of the use of hen runs. *Applied Animal Behaviour Science* **114**: 395-408.

Table 1: Summary of the literature where figures for range use have been reported.

AUTHORS	STUDY SCOPE	HYBRID	COUNTRY	FLOCK SIZES	METHOD USED	% RANGE USE
Gebhardt-Henrich *et al*., 2014	12 flocks on 8 farms	10 white, 2 brown	Switzerland	2000-18000	Counts via photographs	15.7% (6.9-63.4%)
					10% of each flock RFID tagged for 18-21 days	70.5% of tagged birds registered on the range at least once
Gilani *et al*., 2014	33 flocks on 28 farms	29 brown, 4 unknown	UK	92-15848	Counts (3-4 per visit)	13% (1-58%)
Sherwin *et al*., 2013	19 flocks	Unknown	UK	1000-16000	Counts (several per visit)	26% of flocks <11% out 32% of flocks 11-25% out 37% of flocks >25% out
Richards *et al*., 2011	4 groups in a commercial unit	Brown	UK	1500	10% of each flock RFID tagged	80% of tagged birds used the popholes frequently
Zeltner and Hirt, 2008	8 flocks	Brown	Switzerland	19-21	Counts (18 per day)	57%
	8 groups in a commercial unit	Brown		500	Counts (9 per day)	26%
	16 flocks on 8 farms	Unknown		500	Counts (10-15 per day)	28% (with structures on range)

						21.4% (without structures)
Whay *et al*., 2007	25 flocks	24 brown, 1 silver	UK	3000-16000	Counts (Once per visit, 4 visits)	38%
					Farmer estimates in calm, dull weather	15-80%
Harlander-Matauschek *et al*., 2006	8 flocks in an experimental unit	Brown	Austria	256	Counts (every hour for 14 hours during the day)	30-40%
Hegelund *et al*., 2005	37 flocks on 5 farms	Brown	Denmark	513-6000	Counts	9% (2-24%)
Bestman and Wagenaar, 2003	63 flocks on 26 farms (brown or black)	31 brown, 20 black, 11 unknown	Netherlands	31% ≤1000 27% 1001-2000 42% ≥2001	Farmer estimates under optimum conditions	20% of flocks <25% out 38% of flocks 26-50% out 7% of flocks 51-75% out 38% of flocks >75% out
Nicol *et al*., 2003	50 feather pecking (FP) flocks on 36 farms	Brown	UK	Average of 4999	Counts if <100 out, estimating to nearest 25 if >100 out	13.9%
	50 flocks where no FP was observed on 34 farms					22.1%
	50 FP flocks on 36 farms				Farmer estimates	8.1% (when wet) 34% (when dry and still)
	50 flocks where no FP was observed on 34 farms					13.7% (when wet)

						46% (when dry and still)
Zeltner and Hirt, 2003	8 flocks on 1 farm	Brown	Switzerland	420-511	Counts (8 per day)	22%
Hirt *et al*., 2000	12 flocks	Unknown	Switzerland	50-3000	Counts (12 per flock)	30%
Bubier and Bradshaw, 1998	4 flocks	3 brown, 1 unknown	UK	490-2450	Counts (hourly for 16 hours over 2 days)	5.1%-42.1%
Keeling *et al*., 1988	1 flock	Brown	UK	600	Counts (1 per day)	14-22%