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Laying hen welfare I. Social environment and space

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Confinement housing appears to be at the forefront of concern about farm animal welfare. Although many factors may affect the welfare of commercial laying hens housed in cage and non-cage systems, welfare issues in confinement systems often involve behavioural restrictions, while many welfare issues in more extensive systems involve health and hygiene. Hens require an absolute amount of three-dimensional space in order to be able to perform basic body movements. They may prefer to distance themselves from other birds, but their strength of motivation to do so has not been thoroughly investigated, and preferred inter-individual distances may vary with activity. The relationships between the effects of space and group size on behaviour are not well understood, particularly in large groups where birds may cluster together around resources and at different times of day. There are common risks to hen welfare posed by both cage and non-cage systems such as overcrowding. However, some welfare issues present a greater risk in one system compared to another. When considering space and social environment, the comparison of cage and non-cage systems must take into account the threats to welfare that are specific to each system. Furthermore, this review highlights the importance of the design of the housing system rather than just the housing system *per se*.

Keywords: cage; confinement; group size; housing system; movement; space; stocking density

Introduction

There is widespread interest in the treatment of animals (Fraser, 2008). From the perspective of the public, captive environments that inhibit or prevent behaviours that are considered to be part of the normal behavioural repertoire are generally contentious. Confinement housing of farm animals, such as those used in modern poultry and pig farming systems, appear to be at the forefront of these concerns. Many factors may affect the welfare of commercial laying hens housed in cage and non-cage systems. The key

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welfare issues relate to space allowance and group size, and behaviour patterns constrained by conventional cages (nesting, dust bathing and foraging; covered in the companion paper, and perching; Hester, 2014). In addition to issues that relate to behaviour, there are welfare issues that relate to health, such as osteoporosis and broken bones, feather pecking and cannibalism, and health and hygiene (*e.g.* air quality, infectious disease, parasitic infections and foot health), which may be more prominent in non-cage systems (Rodenburg *et al.*, 2013).

Although there is wide acceptance of scientific problem solving, its ability to contribute to the welfare debate has been limited by a lack of consensus on the approach to studying animal welfare and in particular methods used to assess the effects of behavioural constraints. For many scientists, animal welfare is defined and measured on the basis of how well the animal is performing from a biological functioning perspective (Broom, 1986). For others, welfare is determined by affective state, such as suffering, pain, and other feelings or emotions. Thus animal welfare can be studied by measuring animal preferences and strength of preferences on the basis that these are influenced by emotions, which have evolved to motivate behaviour to avoid harm and facilitate survival, growth, and reproduction (Duncan, 2005). Another concept is that welfare of animals is improved in environments or situations in which the animals display normal or 'natural' behaviour (Spinka, 2006). These different concepts have led to different methodologies to assess welfare (Fraser, 2008).

Comparisons of the effects of different housing systems on welfare are difficult due to of the wide variation across systems, and because specific design features within systems often have greater effects on welfare than differences between systems. In addition, it is important to recognise that scientists may differ in the degree of importance they place on measures of biological functioning, affective state and natural behaviour as well as how they interpret research findings from varying methodologies. Although the biological functioning, affective state and natural living frameworks were initially seen as competing, Fraser *et al.* (1997) suggested that ethical concerns for quality of life for animals were more fully addressed when all three viewpoints were considered. Hemsworth *et al.* (2015) recently suggested a more unified orientation where biological functioning is taken to include affective experiences. Therefore, a comprehensive assessment of welfare should include available evidence from each of the different viewpoints and identify areas where different types of scientific evidence concur, where they conflict and where evidence is lacking.

These different viewpoints have been articulated in some working definitions of animal welfare used in policy, *e.g.* the Five Freedoms developed by the Farm Animal Welfare Council in 1979 in response to concepts originally proposed by the Brambell Report have shaped animal welfare policy in the UK for decades (FAWC, 2009). More recently the World Organization for Animal Health stated in its Terrestrial Animal Health Code (OIE, 2010) that 'an animal is in a good state of welfare if (as indicated by scientific evidence) it is healthy, comfortable, well nourished, safe, able to express innate behaviour, and not suffering from unpleasant states such as pain, fear and distress'. In Canada, the Scientific Committees for the National Farm Animal Care Council were specifically tasked with reviewing scientific literature that encompassed all three aspects of welfare when producing reports used to inform the development of codes of practice for the care of farm animals (Widowski *et al.*, 2013).

In the following and its companion paper the scientific literature specific to behavioural constraints imposed by different housing systems for laying hens from each of the different approaches to studying animal welfare is reviewed. The current paper focuses on space allowance, group size and the interactions between these two factors, *i.e.* stocking density. In order to avoid misunderstanding, the same

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terminology is used as defined by Keeling (1995), *i.e.* space allowance is the amount of space per individual hen, group size is the number of hens in the group, and stocking density is the number of hens in a given area or in other words the combination of space allowance and group size.

Space allowance

The minimum spatial need of an animal allows sufficient room to accommodate physical size and basic movement and to enable the animal to effectively change posture (*e.g.* lie down) or turn around without injuring itself (Fraser and Broom, 1997). Dawkins and Hardie (1989) showed that the minimum space used by brown laying hens to accommodate their size and basic movements is greater than provided in conventional cages. For example, using one to four birds per cage to modify floor space over the range of 450-6724 cm^2/hen, video records showed that birds used 540-1006 cm^2 when turning, 653-1118 cm^2/hen when stretching wings and 540-1005 cm^2/bird when ground scratching. Using three-dimensional kinematics, Mench and Blatchford (2014) showed that individually-housed light hybrids used, on average, 563 cm^2 for standing, 1315 cm^2 for turning and 1378 cm^2 for wing flapping.

In addition to physical space, there may be a need for personal space, *i.e.* to maintain separation between individuals and their conspecifics (Fraser and Broom, 1997). The latter space is particularly important for group housing, but its relative importance in small and large groups is not known. Mench and Keeling (2001) suggested that there is little evidence that birds have a personal space, although hens in groups do increasingly maximise distance to their nearest neighbour as floor space allowance increases (Keeling, 1994). Savory *et al.* (2006) found that average nearest neighbour distances in groups of six hens were around 20, 37, 44, 49, 51 and 53 cm at space allowances of 600, 2400, 4800, 7200, 9600 and 12,000 cm^2/hen, respectively, with the rate of change levelling off at around 5000 cm^2/hen. This suggested that hens have a requirement for physical space to stretch and exercise muscles and may prefer to distance themselves from other birds. Domestication does not appear to have influenced inter-individual distances in the fowl, although it may have reduced behavioural synchronisation (Eklund and Jensen, 2011). Furthermore, many species are motivated to separate several important functions, for example nesting away from the feeding area.

Space may be needed for body care or grooming and assisting in thermoregulation *i.e.* when hot (Guo *et al.*, 2012). Hence, when considering spatial requirements for individual animals, it should also be recognised that the animal may have further spatial requirements other than those necessary for physical size and basic movement - they also have requirements for space to perform a range of behaviours that are likely to affect their welfare.

Space allowance and behaviour

While behaviour changes as a consequence of different housing systems, and presumably space and group size are integral to this, comfort behaviours, such as preening, body shaking, scratching, stretching and beak cleaning were found to be similar in conventional cages (stocked at 720 cm^2/hen) and aviary systems (stocked at 2953 cm^2/hen) (Hansen, 1994). However, wing stretching, leg stretching and tail wagging all increased in frequency when birds housed with less space were released into larger cages or enclosures (Baxter, 1994; Nicol, 1987) and in furnished cages as stocking

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density was decreased (*i.e.* two and eight hens in the same-sized cage that changed space allowance from 750 to 3000 cm^2/ hen; Albentosa and Cooper, 2004). Keeling (1994) found that walking and ground pecking decreased, but preening was unaffected as space allowance was varied from 5630 to 600 cm^2/hen in groups of three White Leghorns. Engel (2015) found a 64% reduction in locomotion, a 36% reduction in floor and object pecking and a 17% reduction in preening when brown hens were stocked at 542 versus 1648 cm^2/hen in 6-bird cages. Similarly, Guo *et al.* (2012) observed birds in furnished cages in groups of 21 at 586 cm^2 and 48 at 583 cm^2 to sit less and walk more than hens in conventional cages comprised of four hens at 398 cm^2/hen. The amount of vertical space provided may be important, although few differences in behaviour were found between cage heights of 38 and 45 cm (Cooper and Albentosa, 2004; Albentosa *et al.,* 2007).

Interestingly, Al-Rawi and Craig (1975) showed a curvilinear relationship between space allowance from 412-2884 cm^2/hen in four-hen cages and agonistic interactions, with fewer interactions at the lowest and highest space allowances and more interactions at intermediate space allowances of 824 and 1442 cm^2/hen. These results do provide evidence for a need for minimal personal space, but that at the lowest space allowance the birds did not have enough physical space to engage in normal agonistic behaviour.

Preference for space

A few studies have investigated hens' preferences and motivation for environmental space (Cooper and Albentosa, 2003). When given free choice among different sized cages, individual hens reared in floor pens spent more time in larger enclosures than in smaller ones, although the hens regularly visited and spent short periods of time in the small cages (Nicol, 1986). Using an operant method, Lagadic and Faure (1987) showed that groups of four hens would work to increase space above 400 cm^2 /hen, but only for 25% of the time, suggesting that there may be an intermittent preference for a larger cage that is context dependent (Cooper and Albentosa, 2003).

Faure (1991) found that when hens were trained to peck at a key in order to increase their cage size, rearing conditions had a significant effect. Hens reared in cages worked less to enlarge their cages than those from floor pens. However, Engel (2015) found no effect of either rearing space allowance (315 versus 945 cm^2/hen) or adult space allowance of 542 versus 1648 cm^2/hen on hens' choice of an enlarged cage over feed offered in a small cage in a Y-maze; only 7% of hens housed with reduced space chose the side offering additional space.

Space and biological function

Published data on the effects of space allowance in conventional layer cages shows that in general as floor space decreases, within a range of 300 to 650 cm^2/hen, biological function generally decreases, based on either higher mortality, lower egg production and body weight or poorer feed conversion (Hill, 1977; Hughes, 1983; Adams and Craig, 1985; Sohail *et al.,* 2004). An explanation, as suggested by Hughes (1983), is the reduced feeding space and in turn its effects on feed intake associated with a floor area reduction in cages of generally constant depth. Another explanation is that crowding may lead to elevated corticosterone concentrations, which in turn may adversely affect both production efficiency and health. Mench *et al.* (1986) reported that reducing space allowance in 2-bird cages from 1394 to 697 cm^2/bird increased plasma corticosterone

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concentrations. Koelkebeck *et al.* (1987) reported an 11% increase in plasma corticosterone concentrations in caged hens when space allowance was decreased from 460 to 350 cm^2/bird, although the increase was not statistically significant. However, Engel (2015) found no effect of space allowances on body weight, measures of egg production, blood or egg corticosteroids or heterophil:lymphocyte ratio when hens were stocked at 542 *versus* 1648 cm^2/hen in 8-bird cages, although feather condition was significantly better at the higher space allowance. Elson (2004) found better plumage condition as space allowance increased in furnished cages from 600 to 870 cm^2/hen.

Group size

For caged hens, while there are studies that show detrimental effects of increasing group size in conventional cages from four to 28 hens per cage on agonistic pecking (Al-Rawi and Craig, 1975); from four to 14 hens (space allowance in both studies of 412 cm^2/hen) on agonistic pecking and mortality (Al-Rawi *et al.*, 1976) and in furnished cages from four or five to eight hens per cage on feather pecking and mortality (Appleby *et al.*, 2002). However, similar effects were not apparent in another study on groups of five to eight hens in furnished cages (Abrahamsson and Tauson, 1997). Nevertheless, a review by Mench and Keeling (2001) reported that increasing group size was associated with increased mortality, feather and skin damage and decreased egg production. Appleby (2004) recommended that groups of 10 to 12 birds were best for hen welfare in furnished cages as there was a larger total cage size, yet a lower risk of aggression among birds. Wall *et al.* (2004) acknowledged that the risk of aggression increased with group size and undertook a study to determine the effects of an 'escape area'. They compared hens in standard 16-bird furnished-cages with the same cage divided into two compartments by a partition with pop-holes. They found no benefits based on heterophil:lymphocyte ratios as a measure of stress or feather condition as a measure of aggression. Barnett *et al.* (2009) found evidence of increased stress in hens in furnished cages kept in groups of 16 compared to groups of eight hens, based on egg albumen corticosterone concentrations, a lower ACTH-induced corticosterone response at mid-lay, and immunosuppression based on proliferation test to determine the lymphocyte response, controlling for space allowance.

Although the group sizes in furnished cages is restricted to less than 20 birds in some countries (Elson and Tauson, 2012), many newer models of furnished cages house around 60 hens. Reports on different models of large furnished cages stocked at the EU standard of 750 cm^2/hen indicated no effects of group size ranging from ten to 60 hens on mortality (Weitzenbürger *et al.,* 2005), eight to 40 hens (Wall, 2011) or 20 to 60 hens (Huneau-Salaun *et al.*, 2011) on either production parameters or mortality.

In non-cage systems, aggression appears to be reduced in both small (0 to 20) and large (>100) bird groups (Rodenburg *et al.*, 2005). A comparison of housing birds on the floor in groups of 15, 30 and 60 hens, found production problems with the intermediate group size of 30 hens (Keeling *et al.*, 2003) . Results of several studies on laying hens suggest that as group sizes increase and hens are no longer able to discriminate between all individuals in the group, they switch from a social strategy of maintaining pecking order to a strategy of social tolerance (D'Eath and Keeling, 2003) where group distribution immediately around resources, such as feeders, has a greater effect on aggression than the overall group size (Estevez *et al.,* 2002).

In a review of group life in animals, Lindberg (2001) makes some salient points on optimum group size. Groups of optimal size may vary in the wild because if there were

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such a group size, it would pay for other individuals to join the group and increase it (Sibly, 1983). This may result in unstable groups. Hence in nature, while groups may be stable, they may be larger than optimum (Pulliam and Caraco, 1984). Dawkins (1982) refers to the elusive concept of preferred group size as a range of factors that will affect what is optimum for different individuals in a flock. Thus, the stability of groups, stocking density and features of the physical environment may be more important than group size *per se*.

Stocking density

At any given space allowance, increasing group size alters the dynamics of space use resulting in changes in the amount of space provided to individual hens. While the total amount of space available for locomotion and other behavioural patterns increases, birds tend to cluster around resources resulting in high density in some areas and leaving other areas largely unoccupied (Channing *et al.*, 2001; Collins *et al.*, 2011).

Few studies have focused on the effects of stocking density in large furnished cages, where the larger group sizes afford more total and free space per individual bird. Based on their determination of the space envelope required for wing-flapping, Mench and Blatchford (2014) calculated that the individual space allowance per hen required to perform wing-flapping decreased as group size increased. They estimated that the floor space required per hen to perform this behaviour essentially levelled off at around 599 cm^2/hen at group sizes of 60 or more. Recently, Widowski *et al.* (2014) and Karcher *et al.* (2014) examined the effects of stocking density on productivity and welfare measures in large furnished (enriched colony) cages. When comparing performance of light hybrid hens housed in two sizes of furnished cage stocked at either 520 cm^2 or 748 cm^2 total floor space (group sizes of 40 or 28 hens in the smaller and 80 or 55 in the larger cages), Widowski *et al.* (2014) found no effects on egg production, egg quality, body weight or mortality. However, stocking birds at higher densities resulted in poorer feather condition, cleanliness and foot health in both cage sizes. Karcher *et al.* (2014) found similar results when comparing light hybrid hens stocked at 464, 581, 652, 748, 800 and 929 cm^2/hen. There were no effects of stocking density on hen day egg production, but keel deformities were greater and feather condition poorer in the more crowded cages. The authors suggested that space allowance at or above 581 cm^2/hen was appropriate for maintaining the production and welfare of hens in enriched colony cages. The effects of stocking density in non-cage systems are poorly understood. Surprisingly, in studies that had a relatively large space allowance, there was a consistent trend for egg production to increase as space decreased from 2980 to 1580 cm^2/hen and from 1050 to 940 cm^2/hen (Appleby *et al.*, 1988). Nicol *et al.* (2006) reported that mortality was lower but feather loss was worse in small commercial flocks (2450-3150 birds/flock) stocked at 12 birds/m^2 (833 cm^2/bird) compared to those stocked at either 7 birds/m^2 (1428 cm^2/bird) or 9 birds/m^2 (1111 cm^2/bird) in single-tiered aviaries. Egg production, faecal corticosterone and heterophil:lymphocyte ratios were not affected by stocking rate, but stress measures at the end of lay were substantially elevated compared to the end of the rearing period, and the authors considered them to be at levels indicative of poor welfare at all of the stocking densities. Behavioural observations reported for those same flocks showed a density by age interaction with feather pecking and aggression being the highest in the low stocking density initially (at 30 weeks) but it increased with age so that there were no differences by 60 weeks of age (Zimmerman *et al.,* 2006). When Nicol *et al.* (1999) compared flocks varying from 72 to 368 birds, at stocking densities of 6, 14, 22 or 30 birds/m^2 (1666 to 333 cm^2/bird), from 14 to 30 weeks of age, six birds /m^2 had higher

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egg production at 23 weeks and better plumage at 30 weeks compared to birds at all other densities. Channing *et al.* (2001) found that the spatial distribution of birds in group sizes ranging from 323 to 912 birds at a constant density of 18.5 birds/m^2, varied considerably over time, with specific areas of densities ranging from 9 to 41 birds/m^2 and the flux of birds from one part of the pen to another being greater in larger group sizes. Therefore system design, as it affects distribution of birds, may have a greater effect on bird welfare than group size and space.

Conclusions

Within cage systems, there appear to be different thresholds for the effects of space allowance on different measures of hen welfare. In conventional cages or small group furnished cages (two to 30 birds), there is evidence of higher mortality, lower egg production and body weight or poorer feed conversion below 542-650 cm^2/hen. However, there are conflicting reports regarding stress (corticosterone concentrations) in hens kept in increasing larger spaces above 542-697 cm^2/hen, and evidence of behavioural restriction in terms of wing stretching, leg stretching, tail wagging, locomotion, floor and object pecking and preening at 542-750 cm^2/hen. These results suggest biological disruption, in terms of behaviour, stress physiology, mortality and productivity, at the lower end of the space range of 300 to 650 cm^2/caged laying hens in conventional or small group furnished cages. The more recent literature on furnished cages suggests that these effects do not necessarily hold true with larger group sizes due to economy of scale and social dynamics.

Hens may prefer to distance themselves from other birds, but their strength of motivation to do so has not been thoroughly investigated and appears to depend on the activities that hens are engaged in. Furthermore, there is still limited knowledge on the effects of group size, in cages or non-cage systems. The effect of stocking density, and particularly through the effects of larger group size on individual space allowance, social dynamics of space use and behaviour, are poorly understood in large cages systems and non-cage systems.

Future work is needed to determine the space requirements of hens for particular resources (*e.g.* feeders, litter or scratch areas, nests) rather than space allowance *per se*, in these more complex housing systems. Additionally, differences in social distancing, behavioural synchrony and the time-of-day around specific resources need to be identified in order to design systems that minimise crowding or competition.

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